



MATRIX OLYMPIAD

The Most Innovative Talent Recognition Exam

PHYSICS

Class - X



MATRIX

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Few words for the Readers

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The above thought has been our guiding principle while designing and collating the study material for **Matrix Olympiad** . And hence, we hope that this particular material will be helpful towards your preparation for **Matrix Olympiad**.

Our team at **MATRIX** has put in their best efforts for making this particular module interesting and relevant for you. Additional efforts have been made to ensure that the content is easy to understand and error free to the extent possible. However, there might remain some inadvertent errors in answer keys and theoretical portion and we would welcome your valuable feedback regarding the same.

If there are any suggestions for corrections, please write to us at smd@matrixacademy.co.in and we would be highly grateful.

Finally, we would like to end this message by a famous quote by Ernest Hemingway - *"There is no friend as loyal as a book."* So, please give your study material the time and attention it deserves, and it will surely help you reach newer heights in your fight with competition examinations.

With love and best wishes !

Team MATRIX

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ELECTRICITY

1

Concepts

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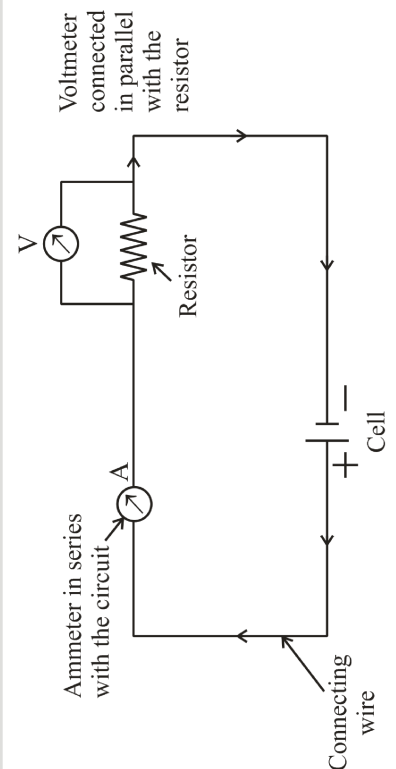
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INTRODUCTION

Electricity is indispensable to us. From the humble torch to the powerful computer, thousands of things we use every day need electricity to work. The source of all electricity is charge. As charge is the basis of all electrical phenomena, we often need to know the amount of charge on a body.

1. CHARGE ON A MACROBODY

From the study of atomic structure, we know that an atom consists of a central part called nucleus and around the nucleus there are a number of electrons revolving in different paths or orbits. The nucleus contains protons and neutrons. A proton is a positively charged particle while a neutron has no charge. Therefore, the nucleus of an atom bears a positive charge. An electron is a negatively charged particle having negative charge equal to the positive charge on a proton. Normally, the number of electrons is equal to the number of protons in an atom. Therefore, an atom is neutral as a whole; the negative charge on electrons cancelling the positive charge on protons. This leads to the conclusion that under ordinary conditions, a body is neutral i.e. it exhibits no charge.

When this equality or balance is disturbed by removing or supplying electrons, the body acquires a net charge. The body will acquire a positive or negative charge depending upon whether electrons are removed from it or added to it.

1.1 TYPES OF ELECTRIC CHARGE

There are two types of charge. They are :

- (i) Positive charge – A body having deficiency of electrons.
- (ii) Negative charge – A body having excess of electrons.

1.2 CHARGING OF A BODY

There are a number of methods to charge a body as :

- (i) Charging by friction
- (ii) Charging by conduction
- (iii) Charging by induction etc.

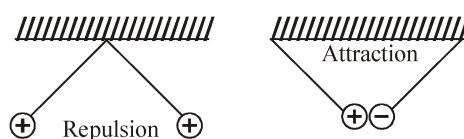
We will discuss charging by friction :

Whenever two bodies (at least one non conductor) are rubbed against each other, heat is produced due to friction present between them. Due to this heat produced, electrons in both the bodies are excited. The body having more electron affinity attracts some of the electrons from other body. Both the bodies develop equal and opposite charges by this method.

POSITIVE CHARGE	NEGATIVE CHARGE
1. Glass Rod	1. Silk cloth
2. Fur or woolen cloth	2. Ebonite, Amber, Rubber rod
3. Woolen coat	3. Plastic seat
4. Woolen carpet	4. Rubber shoes
5. Nylon or Acetate	5. Cloth
6. Dry hair	6. Comb

1.3 PROPERTIES OF ELECTRIC CHARGE

(i) Like charges repel each other and unlike charge attract each other.



(ii) Charge is a scalar quantity.

(iii) Charge is always quantized : The amount of charge on a charged body is always in integral multiple of the elementary charge the fractional multiple is not possible. If system have n electrons then charge of the system is given by $Q = ne$, where e is the charge on an electron, and $e = 1.6 \times 10^{-19}$ C.

(iv) Charge is conserved.

(v) Charge is always associated with mass.

(vi) Total charge of system remains conserved.

1.4 UNIT OF ELECTRIC CHARGE

S.I. unit of charge is coulomb abbreviated as C.

One coulomb of charge is equal to the charge on 625×10^{16} electrons.

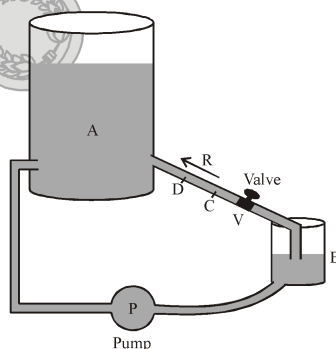
$$1 \text{ coulomb} = \text{charge on } 625 \times 10^{16} \text{ electrons}$$

$$\text{or } 6.25 \times 10^{18} \text{ electrons}$$

Thus, when we say that a body has a positive charge of one coulomb (i.e. + 1C) it means that the body has a deficit of 625×10^{16} electrons from the normal due to share.

2. ELECTRIC FIELD AND ELECTRIC POTENTIAL

The flow of electricity in a circuit can be regarded very much similar to the flow of water in a pipe. The water pipe is analogous to the electric conductor, while the amount of water flowing through a given point per second corresponds to electric current. Figure below shows how the pump (P) builds up and maintains pressure by lifting water from a tank (B) to the reservoir (A) through the pipe (R). Note that along the pipe, different points are at different pressure. Water in the pipe flow from, say, a point C to D only when the pressure at C is greater than that at D. Thus, when the valve (v) is open, water would start flowing into the reservoir.



In the same manner electrons will move along a wire only if there is a difference of electric pressure called potential difference along the conductor. This difference of potential is produced by the cell or a battery, which acts like a water pump in the circuit.

The chemical action within the cell generates the difference in potential between the electrodes, which sets the electrons in motion and produces the current.

2.1 ELECTRIC FIELD

(i) Definition : Electric field due to a given charge is defined as the space around the charge in which electrostatic force of attraction or repulsion due to charge can be experienced by any other charge. If a test charge experiences no force at a point, the electric field at that point must be zero.

(ii) Electric field intensity at any point is the strength of electric field at that point. It is defined as the force experienced by unit positive charge placed at that point.

(iii) Formula : If F is the force acting on a test charge $+q_0$ at any point then electric field intensity at this point is given by

$$V = \frac{F}{q_0}$$

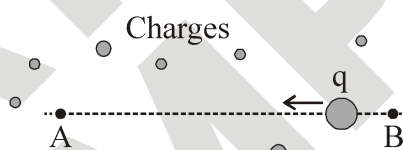
(iv) Electric field is a vector quantity.

(v) S.I. unit is Newton per coulomb (N/C).

2.2 ELECTRIC POTENTIAL

An electrical potential difference arises out of charges. Consider a group of stationary charges (figure). A separate charge q is placed at B. It experiences a force exerted by the group of charges. This affects the force required, and hence, the work done (W) in moving q to the point A. The quantity W/q is called the potential difference between A and B. In other words, the potential difference between two points A and B is the work done per unit charge in taking a charge from B to A. We express this mathematically as

$$\Delta V = V_A - V_B = \frac{W}{q} \dots\dots(i)$$



Here, ΔV is the potential difference between the points A and B, and V_A and V_B are the potentials at these points.

While defining coordinates of a point in mathematics, you choose a point, call it the origin, and say that its coordinates are (0,0). The coordinates of all other points are found by measuring the distances from this point. Similarly, you can choose a reference point and say that the potential there is zero. The potentials of other points are found with respect to this point. Quite often, the potential at infinity is chosen as zero.

If B be the reference point, the potential at B is $V_B = 0$. From equation (i), the potential at A is $V_A = W/q$. So, the potential at a point is the work done per unit charge in taking a charge to that point from a chosen reference point. Equation (i) may also be written as

$$W = qV \dots\dots(ii)$$

The work done on the charge q is stored as the electric potential energy (U) of the group of charges. So, $U = qV \dots\dots(iii)$

Unit of potential difference

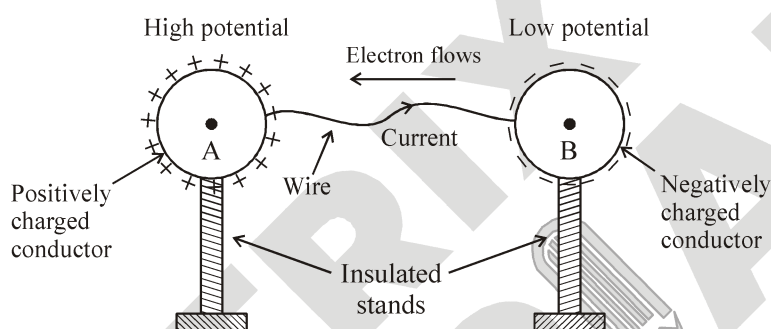
The unit of potential difference (and potential) is the volt, whose symbol is V. The volt is named in honour of the Italian physicist Alessandro Volta (1745-1827). If 1 joule of work is done in taking 1 coulomb of charge from one point to another, the potential difference between the points is 1 volt.

$$V = \frac{W}{q} = \frac{1 \text{ joule}}{1 \text{ coulomb}} = 1 \text{ volt}$$

The potential difference between two points is sometimes also called the voltage.

2.3 FLOW OF CHARGE

When two charged bodies at different potentials are connected by a conducting wire, electrons flow from the body at lower potential to the one at higher potential till the potentials of both the bodies become equal i.e., potential difference between the two bodies becomes zero. Figure shows the two oppositely charged conductors A and B which are held on stands. The positively charged conductor A is said to be at higher potential and the negatively charged conductor B is said to be at lower potential.

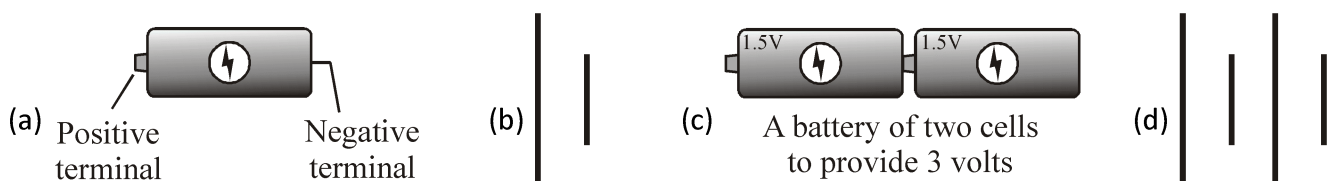


It means that there exists a potential difference between the conductors A and B. Therefore, on joining positively charged conductor A to negatively charged conductor B, negative charge starts flowing from conductor B to conductor A. Flow of charge will stop when both the conductors A and B acquire the same potential.

2.4 A CELL PROVIDE A CONSTANT POTENTIAL DIFFERENCE

The potential difference provided by things like charged spheres reduces to zero quickly once charges start to flow. So, we have to use cells to provide constant potential difference for a long time. Cells have chemical inside. Reactions in the cell cause positive and negative charges to gather separately. This creates a potential difference between the terminals of the cell. The terminal at a higher potential is called the positive terminal and the one at a lower potential is called the negative terminal.

The cells that we commonly use are called dry cells (figure (a)). In a common dry cell, the small metallic cap at one end is the positive terminal, while the flat metallic plate at the other end is the negative terminal. It provides a potential difference of 1.5 V. A cell is represented by the symbol shown in (figure(b)). The larger line represents the positive terminal, while the shorter line represents the negative terminal. A combination of cells is called a battery. Quite often, multiple cells are combined to get a potential difference that is higher than that of a single cell. For example, we connect two 1.5-V cells to get a potential difference of 3V (figure(c)). This is using symbols in (figure(d)).



3. ELECTRIC CURRENT

Consider a metallic wire ACB connected across a cell of potential difference V . Since the end A is connected to the positive terminal, it is at a higher potential than the end B. In metals, some electrons are loosely bound to the atoms, and can move with in it. These are called free electrons. In the metallic wire, these electrons (negative charges) move from the low-potential side B to the high-potential side A. After reaching A, they enter the cell. The chemical reactions in the cell drive these electrons to the negative terminal. From there, they re-enter the wire at the end B. Thus, there is a continuous flow of electrons in the wire from B to C to A. We say that there is an electric current in the wire.

In a metal, the flow of negative charges constitutes the current. An electric current can also be a flow of positive charges. So, a flow of charge is called an electric current.

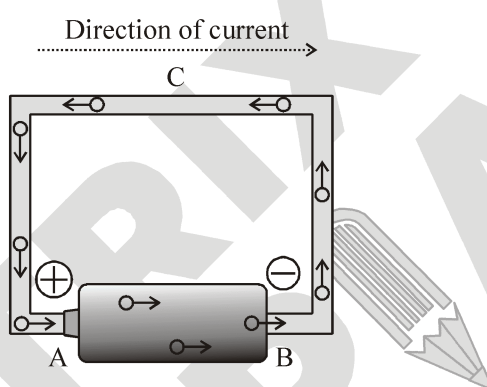


Figure : Current in a wire connected to a cell

(i) Definition :

The rate of flow of electric charge from one body to another through a conductor such as metal wire is called electric current

OR

The quantity of charge passing through a given point of the conductor in one second is called electric current.

Formula :

If Q is the charge which flows through a conductor in time t , then the electric current is given by :

$$\text{Current (I)} = \frac{\text{Charge (Q)}}{\text{Time (t)}}$$

$$\text{or } I = \frac{Q}{t}$$

$$\text{or } Q = It$$

- The electric current is a scalar quantity.
- S.I. unit of current is ampere, which is denoted by letter A.
- Definition of 1 ampere : Current is said to be one ampere if one coulomb of charge flows through any cross section of a conductor in one second, i.e.

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}$$

$$\text{or } 1A = 1Cs^{-1}$$

(ii) Direction of electric current :

By convention, the direction of current is taken as the direction of flow of positive charges. Thus, the direction of current is opposite to the direction of flow of negative charges. So, when a wire is connected to a cell, the current in the wire is from the positive-terminal end to the negative-terminal end.

Example 1

6×10^{17} electrons cross through an area per minute. What is the electric current ?

Solution :

The charge carried by an electron = 1.6×10^{-19} C.

Total charge carried by 6×10^{17} electrons is $Q = 6 \times 10^{17} \times 1.6 \times 10^{-19}$ C.

$$\text{So, the current } i = \frac{Q}{t} = \frac{6 \times 10^{17} \times 1.6 \times 10^{-19} \text{ C}}{60 \text{ s}} = 1.6 \times 10^{-3} \text{ A} = 1.6 \text{ mA}$$

4. CONDUCTOR AND INSULATORS

Materials that conduct electricity easily are called good conductors or simply, conductors. And, materials that do not conduct electricity easily are called insulators.

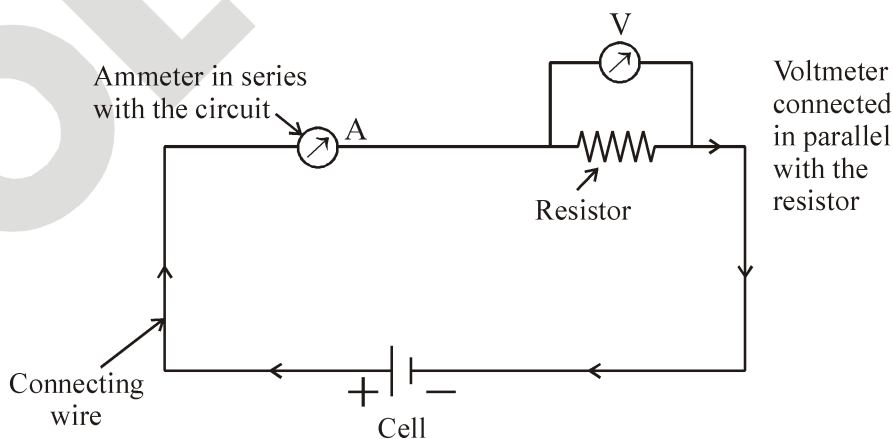
All metals conduct electricity because they have some loosely bound free electrons, which flow when a potential difference is applied. However, some metals conduct electricity better than others. Silver is the best conductor. But because of the high cost of silver, electric wires are made of copper, or in some cases aluminium.

Most nonmetallic solids do not conduct electricity. Although diamond and graphite are both forms of carbon (a nonmetal), graphite is a conductor while diamond is an insulator. Insulators do not conduct electricity because their electrons are tightly bound to the atoms. Rubber, plastics, wood, glass and procelain are some examples of insulators. Insulators have many uses. For example, they are used as protective covers on electric wires and electrician’s tools.

5. ELECTRIC CIRCUITS AND MEASURING INSTRUMENT

(A) Electric Circuit :

A continuous path consisting of conducting wires and other electric elements (like lamps, bulbs etc.) between the terminals of a battery, along which an electric current flows, is called a circuit.



(B) Types of Electric Circuit :

(i) Open Circuit : An electric circuit through which no electric current flows is known as open electric circuit. The electric circuit will be open circuit if the plug of the key is taken out or if the connecting wires break from any point.

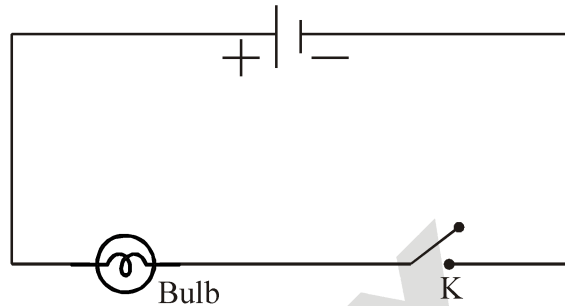


Figure : Open circuit

(ii) Closed Circuit : An electric circuit through which electric current flows continuously is known as closed circuit.

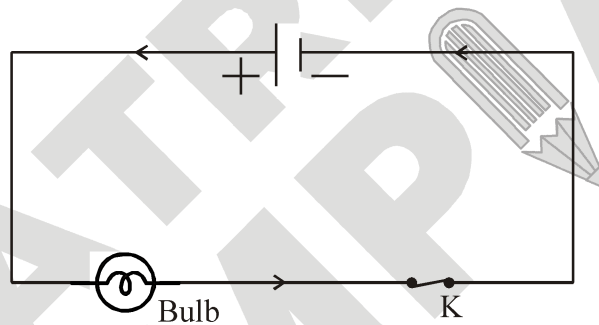


Figure : Closed circuit

(C) Electric Symbol :

The various electrical symbols used in electric circuits are given below :

(i) Cell



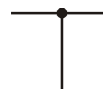
(ii) Battery



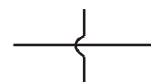
(iii) Connecting wire



(iv) A wire joint



(v) Wire crossing without contact



(vi) Fixed resistance (or Resistor)



(vii) Variable resistance (or Rheostat)



(viii) Ammeter



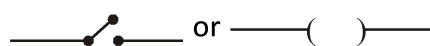
(ix) Voltmeter



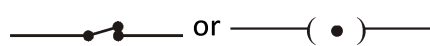
(x) Galvanometer



(xi) An open switch (An open plug key)



(xii) A closed switch (A closed plug key)



(xiii) Electric bulb



(D) Common Measuring Instrument :

(i) Galvanometer : A galvanometer is an instrument that can detect the presence of a current in a circuit. The pointer remains at zero (the centre of the scale) for zero current flowing through it. It can deflect either to the left or to the right of the zero mark depending on the direction of current.

Galvanometers are **two types**

(a) Moving coil galvanometer

(b) Moving magnet galvanometer

(ii) Ammeter : Ammeter is an electrical instrument which measures the strength of current in ‘ampere’ in a circuit which is always connected in series in circuit so that total current (to be measured) may pass through it. The resistance of an ideal ammeter is zero (practically it should be minimum).

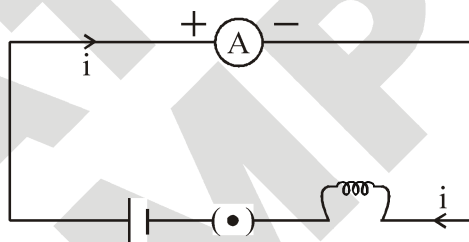


Figure : Ammeter in a circuit

(iii) Voltmeter : It is an electrical instrument which measures the potential difference in ‘volt’ between two points of electric circuit. Voltmeter has very high resistance and the resistance of an ideal voltmeter is infinite. A voltmeter is always connected in parallel.

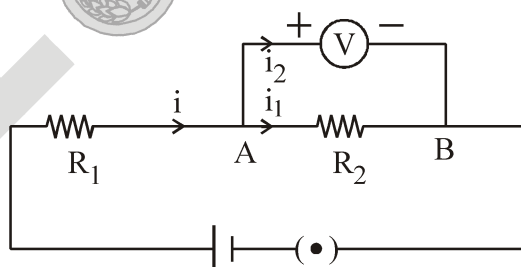


Figure : Voltmeter in a circuit

Here, the current flowing through the voltmeter is different from those flowing through the other elements of the circuit. Also, even if the voltmeter is removed, the current continues to flow in the circuit.

Note that the potential difference across R_2 and the voltmeter is the same.



Focus Point

The only difference between ammeter and voltmeter is that ammeter has its negligible (approximately zero) resistance so that it may measure current of circuit passing through it more accurately giving the deflection accordingly, while the voltmeter passes negligible current through itself so that potential difference developed due to maximum current passing through circuit may be measured.

6. OHM'S LAW

(i) Statement : It states that the current passing through a conductor is directly proportional to the potential difference across its ends, provided the temperature and other physical conditions (mechanical strain, temperature etc.), remain unchanged i.e., $I \propto V$ or $V \propto I$ or $V = RI \Rightarrow R = V/I$
Where R is a constant called resistance of the conductor.

The relation $V = IR$ is referred to as Ohm's law, after the German physicist George Simon Ohm (1789-1854), who discovered it.

(ii) Experimental varification of Ohm's law : Set up a circuit as shown in the figure below consisting of a wire AB, a current measuring instrument called ammeter, an instrument measuring the potential difference called voltmeter and a number of cells, each of which provides some constant potential difference across the two points of a conductor. First, use one cell and note the current in the circuit and the potential difference across the wire AB. Suppose the cell produce a current I in the circuit and a potential difference (V) across the wire AB. Repeat this experiment with two cells, three cells and four cells.

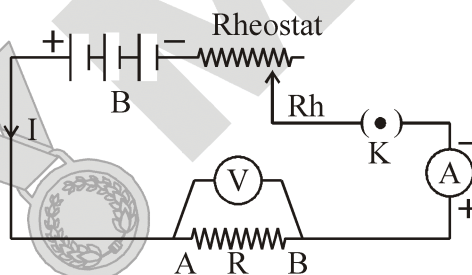


Figure : Ohm's law

Note the successive readings in the ammeter and the voltmeter. We will find that with two cells in the circuit, the current would be 2I and the potential difference 2V. Similarly, with three cells the current is 3I and potential difference 3V and so on. [The important precaution to observe here is not to allow the current to flow in the wire continuously. This can be done by taking off the plug key and closing it only when the current is to be drawn]

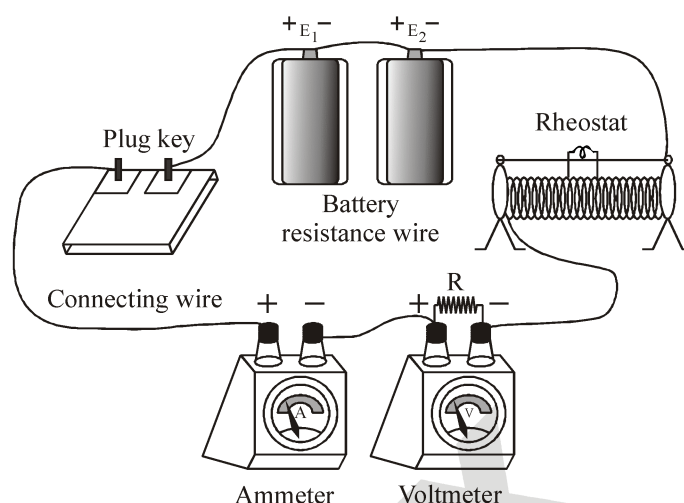
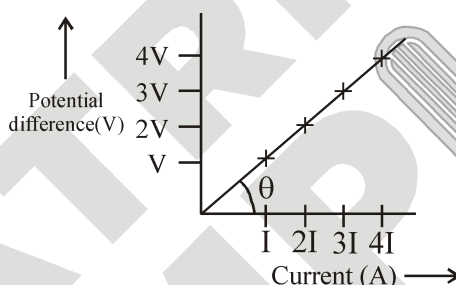


Figure : Experimental setup for verification of Ohms law

Now, plot a graph between the current and the potential difference, we will get a straight line graph and the slope of this graph represent resistance of conductor



(iii) Resistance :

When the electrons move from one part of the conductor to the other part, they collide with other electrons and with the atoms and ions present in the body of the conductor. Due to these collisions, there is some obstruction or opposition to the flow of electrons through the conductor.

The property of a conductor due to which it opposes the flow of current through it, is called resistance. The resistance of a conductor is numerically equal to the ratio of potential difference across its ends to the current flowing through it.

$$\Rightarrow \text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

$$\text{or } R = \frac{V}{I}$$

$$\text{Slope of graph, } \tan \theta = \frac{V}{I} = R$$

Unit of resistance :

The S.I. unit of resistance is ohm, which is denoted by the symbol Ω .

When a potential difference of 1 volt is applied to the ends of the conductor and a current of 1 ampere flows through it, then resistance of the conductor will be 1 ohm.

$$\therefore R = \frac{1V}{1A} = 1\Omega$$

6.1 FACTOR AFFECTING THE RESISTANCE OF CONDUCTOR

(i) Resistance depends on the material :

On the basis of their electrical resistance, all the substances can be divided into three groups : Conductors, resistors and insulators.

(a) Conductors : Those substances which have very low electrical resistance are called conductors. A conductor allows the electricity to flow through it easily. Silver metal is the best conductor of electricity. Copper and aluminium metals are also good conductors. Electric wires are made of copper or aluminium because they have very low electrical resistance and less economic.

(b) Resistors : Those substances which have comparatively high electrical resistance, are called resistors. The alloys like nichrome, manganin and constantan (or ureka), all have quite high resistances, so they are used to make those electrical devices where high resistance is required. A resistor reduces the current in the circuit.

(c) Insulators : Those substances which have infinitely high electrical resistance are called insulators. An insulator does not allow electricity to flow through it Rubber is an excellent insulator. Electricians wear rubber hand gloves while working with electricity because rubber is an insulator and protects them from electric shocks. Wood is also a good insulator.

(ii) Resistance depends on length :

The resistance of a given conductor is directly proportional to its length i.e.

$$R \propto L$$

(iii) Resistance depends on area of cross section :

The resistance of a given conductor is inversely proportional to its area of cross-section i.e.

$$R \propto \frac{1}{A}$$

(iv) Resistance depends on temperature :

The resistivity of most of the metals (conductor) increases with temperature. But it reduces for semiconductors on increase in temperature.

6.2 RESISTIVITY

We found that for a given material, resistance is

- (i) inversely proportional to the area of cross section, and
- (ii) directly proportional to length.

Combining (i) and (ii),

$$R \propto \frac{L}{A} \Rightarrow R = \frac{\rho \times L}{A} \dots\dots\dots(iii)$$

Where ρ (rho) is a constant known as resistivity of the material of the conductor. Resistivity is also known as specific resistance. It shows the nature of material of the conductor.

Resistivity, $\rho = \frac{R \times A}{L} \dots\dots\dots(iv)$

By using this formula, we will now obtain definition of resistivity. Let us take a conductor having a unit area of cross-section of 1 m^2 and a unit length of 1 m . So, putting $A = 1 \text{ m}^2$ and $L = 1 \text{ m}$ in equation (iv), we get :

Resistivity, $\rho = R \Omega\text{-m}$

(i) Definition of resistivity : The resistivity of a substance is numerically equal to the resistance of a rod of that substance which is 1 metre long and 1 metre square in cross-section.

(ii) Unit of resistivity :

$$\rho = \frac{\text{ohm} \times (\text{metre})^2}{\text{metre}} = \text{ohm} - \text{metre}$$

The S.I. unit of resistivity is ohm-metre which is written in symbols as $\Omega\text{-m}$.

Note :

(i) Resistivity of a substance does not depend on its length or thickness. It depends only on the nature of the substance. The resistivity of a substance is its characteristic property. So, we can use the resistivity to compare the resistance of two or more substances.

(ii) Importance of resistivity : A good conductor of electricity should have a low resistivity and a poor conductor of electricity should have high resistivity. The resistivity of alloy are much more higher than those of the pure metals. It is due to their high resistivity that maganin and constantan alloys are used to make resistance wires used in electronic appliances to reduce the current in an electrical circuit.

Nichrome alloy is used for making the heating elements of electrical appliances like electric irons, room-heaters, water-heaters and toasters etc. because it has very high resistivity and it does not undergo oxidation (or burn) even when red-hot.

7. COMBINATION OF RESISTOR

A conducting material (e.g., a wire) of a particular resistance meant for use in a circuit is called a resistor. The resistances can be combined in two ways :

- (i) Series combination
- (ii) Parallel combination

7.1 SERIES COMBINATION OF RESISTOR

(i) Definition : When one end of a resistor is connected to one end of second resistor and other end of second resistor is connected to third resistor one end this type of combination is called series combination of resistors.

(ii) Equivalent resistance of series combination : Consider three resistors of resistances R_1 , R_2 and R_3 connected in series to cell of potential difference V as shown in figure. Since the three resistors are connected in series therefore the current I through each of them is same.

By ohm's law the potential drop across each resistor is given by $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$.

Since V is the total potential in the circuit, therefore by conservation of energy we have

$$V = V_1 + V_2 + V_3$$

Substituting for V_1 , V_2 and V_3 in above equation we have,

$$V = IR_1 + IR_2 + IR_3 \dots\dots(i)$$

If R_s is the equivalent resistance of the series combination, then by Ohm's law we have

$$V = IR_s \dots\dots(ii)$$

Therefore from equations (i) and (ii)

$$IR_s = IR_1 + IR_2 + IR_3$$

$$\text{Hence } R_s = R_1 + R_2 + R_3$$

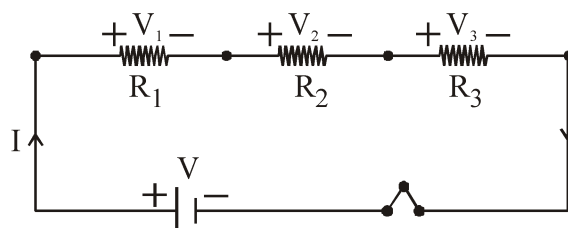


Figure : Series combination circuit

Thus in series combination the equivalent resistance is the sum of the individual resistances. For more resistors, the above expression would have been :

$$R_s = R_1 + R_2 + R_3 + \dots$$

(iii) Features of series combination :

In a circuit, if the resistors are connected in series :

- (a) The current is same in each resistor of the circuit
- (b) The resistance of the combination of resistors is equal to sum of the individual resistors.
- (c) The total voltage across the combination is equal to the sum of the voltage drop across the individual resistors.
- (d) The equivalent resistance is greater than that of any individual resistance in the series combination.

7.2 PARALLEL COMBINATION OF RESISTOR

(i) Definition :

If one end of each resistor are connected to one point and other end of each resistor are connected to other end then such type of resistor is known as parallel combination.

In parallel combination voltage drop across each resistor are same but current through each resistor are different.

(ii) Equivalent resistance of parallel combination :

Consider two resistors R_1 and R_2 connected in parallel as shown in figure. When the current I reaches point 'a', it splits into two parts I_1 going through R_1 and I_2 going through R_2 . If R_1 is greater than R_2 , then I_1 will be less than I_2 i.e. the current will tend to take the path of least resistance.

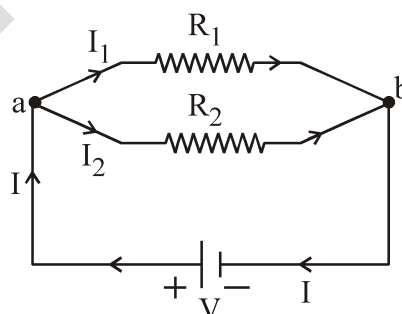


Figure : Parallel combination circuit

Since charge must be conserved, therefore the current I that enters at point 'a' must be equal to the current that leaves the point 'b'. Therefore we have

$$I = I_1 + I_2 \quad \dots\dots(i)$$

Since the resistors are connected in parallel therefore the potential across each resistor must be same, hence by Ohm’s law we have

$$I_1 = \frac{V}{R_1} \text{ and } I_2 = \frac{V}{R_2}$$

substituting in equation (i) we have

$$I = \frac{V}{R_1} + \frac{V}{R_2} \quad \dots\dots(ii)$$

Let R_p be the equivalent resistance of the parallel combination, then by Ohm’s law we have,

$$I = \frac{V}{R_p} \quad \dots\dots(iii)$$

Hence from equations (ii) and (iii) we have,

$$\frac{V}{R_p} = \frac{V}{R_1} + \frac{V}{R_2} \text{ or } \frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$$

An extension of this analysis to three or more resistors in parallel gives the following general expression

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

(iii) Features of parallel combination :

- (a) The sum of the reciprocals of the individual resistance is equal to the reciprocal of equivalent resistance (R_p).
- (b) The currents in various resistors are inversely proportional to the resistances, higher the resistance of a branch, the lower will be the current through it. The total current is the sum of the currents flowing in the different branches.
- (c) The voltage across each resistor of a parallel combination is the same and is also equal to the voltage across the whole group considered as a unit.
- (d) The equivalent resistance is smaller than that of any individual resistance in parallel combination.

Example 2

Two resistances of 3Ω and 6Ω are connected in parallel. Calculate their equivalent resistance.

Solution :

The equivalent resistance is

$$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{(3\Omega) \times (6\Omega)}{(3\Omega) + (6\Omega)} = \frac{10\Omega^2}{9\Omega} = 2\Omega$$

Example 3

A $1\text{-}\Omega$ resistor is connected in parallel to a $100\text{-}\Omega$ resistor. Calculate the equivalent resistance.

Solution :

The equivalent resistance is

$$R = \frac{R_1 R_2}{R_1 + R_2} = \frac{(1\Omega) \times (100\Omega)}{(1\Omega) + (100\Omega)} = \frac{100\Omega^2}{101\Omega} = 0.99\Omega$$

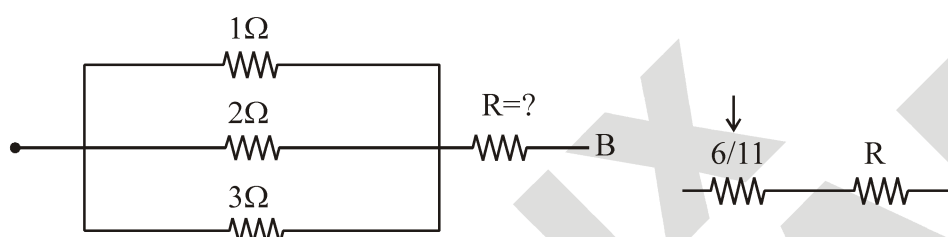
We find that when a resistance is joined parallel to a comparatively smaller resistance, the equivalent resistance is very close to the value of the smaller resistance.

Example 4

Three resistance of value 1Ω , 2Ω and 3Ω are connected in parallel. If the effective resistance of the circuit has to be 1Ω , then find the value of the resistance to be connected in series to this circuit.

Solution :

Equivalent resistance is one ohm.



As per question $\frac{6}{11} + R = 1$

$\therefore R = 1 - \frac{6}{11} \quad R = \frac{11-6}{11} \Rightarrow R = \frac{5}{11}\Omega$

7.3 DISTRIBUTION OF CURRENT IN TWO RESISTOR IN PARALLEL

Consider the circuit in figure. The resistors R_1 and R_2 are connected in parallel. The current i gets distributed in the two resistors.

We have $i = i_1 + i_2$ (i)

Applying Ohm's law to the resistor R_1 ,

$V_A - V_B = R_1 i_1$ (ii)

And applying Ohm/s law to the resistor R_2 ,

$V_A - V_B = R_2 i_2$ (iii)

From (ii) and (iii), $R_1 i_1 = R_2 i_2$ or $i_2 = \frac{R_1}{R_2} i_1$

Substituting for i_2 in (i) we have

$$i = i_1 + \frac{R_1}{R_2} i_1 = i_1 \left(1 + \frac{R_1}{R_2} \right) = i_1 \frac{R_1 + R_2}{R_2}$$

or $i_1 = \frac{R_2}{R_1 + R_2} i$

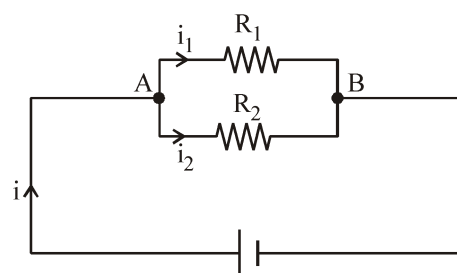


Figure : Current distribution in parallel

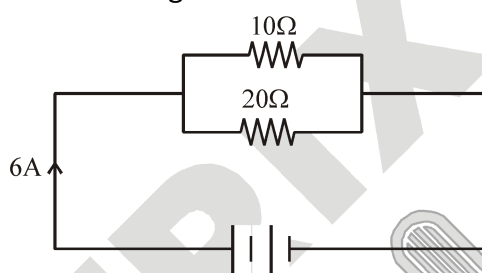
Similarly, $i_2 = \frac{R_1}{R_1 + R_2} i$

Thus, $\frac{i_1}{i_2} = \frac{R_2}{R_1}$

So the current through each branch in a parallel combination of resistors is inversely proportional to its resistance.

Example 5

Two resistors of resistances 10Ω and 20Ω are connected in parallel. A battery supplies $6A$ of current to the combination, as shown in figure. Calculate the current in each resistor.



Figure

Solution :

The current in the 10Ω resistor is $i_1 = \frac{R_2}{R_1 + R_2} i = \frac{(20\Omega) \times (6A)}{(10\Omega) + (20\Omega)} = 4A$

The current in the 20Ω resistor is $i_2 = \frac{R_1}{R_1 + R_2} i = \frac{(10\Omega) \times (6A)}{(10\Omega) + (20\Omega)} = 2A$

8. HEATING EFFECT OF ELECTRIC CURRENT

(i) Definition : The effect of electric current due to which heat is produced in a wire when current is passed through it is called heating effect of current or Joule heating.

(ii) Explanation : When the ends of a conductor are connected to a battery, then free electrons move with drift velocity and electric current flows through the wire. These electrons collide continuously with the positive ions of the wire and thus the energy taken from the battery. This energy is transferred to the ions of the wire rises. The effect of electric current due to which heat is produced in a wire when current is passed through it is called heating effect of current or Joule heating.

(iii) Joule’s law of heating effect of electric current : In 1841 Joule found that when current is passed through a conductor the heat produced across it is :

- (a) Directly proportional to the square of the current through the conductor i.e. $H \propto I^2$.
- (b) Directly proportional to the resistance of the conductor i.e. $H \propto R$
- (c) Directly proportional to the time for which the current is passed i.e. $H \propto t$

Combining the above three equations we have

$H = I^2Rt$ (in joule)

$$H = \frac{i^2 R t}{J} \text{ (in calorie)}$$

Where J is called Joule's mechanical equivalent of heat and has a value of $J = 4.18 \text{ J cal}^{-1}$. The above equation is called Joule's law of heating

8.1 ELECTRIC POWER

(i) Definition : The rate at which energy is dissipated or consumed or rate of doing work is termed as electric power.

(ii) Formula of electric power :

The power P is given by, $P = \frac{E}{t} = \frac{\text{Energy}}{\text{Time}}$

We know, $P = \frac{i^2 R t}{t} = i^2 R$

So Electric Power $P = i^2 R$

Using $V = iR$,

$$P = Vi \text{ and } P = \frac{V^2}{R}$$

(c) S.I and commercial unit of electric power :

- The S.I. unit of electric power is 'watt' which is denoted by the letter W .
- Definition of 1 watt : If one joule electric energy consume by the appliance in one second then electric power of the appliance is 1 watt.
- Power of an agent is also expressed in horse power (hp).

$$1 \text{ hp} = 746 \text{ watt}$$

8.2 ELECTRIC ENERGY

The work done by the source to maintain the value of electric current in the circuit is known as electric energy.

S.I. and commercial unit of electric energy :

- S.I. unit of electrical energy : The S.I. unit of electrical energy is joule.
- Commercial unit of electric energy : Commercial purposes we use a bigger unit of electrical energy which is called "kilowatt - hour". One kilowatt - hour is the amount of electrical energy consumed when an electrical appliance having a power rating of 1 kilowatt and is used for 1 hour.
- Relation between kilowatt hour and joule :

Kilowatt-hour is the energy supplied by a rate of working of 1000 watt for 1 hour.

$$1 \text{ kilowatt-hour} = 3600000 \text{ joules}$$

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

Note :

(i) The electrical energy used in houses, factories, etc., is measured in kilowatt hours. The cost of electricity is fixed per kilowatt hour. One kilowatt hour of electrical energy is often called one unit.

$$1 \text{ kWh} = 1 \text{ unit}$$

(ii) Calculation of Electric bill

Energy consumed by electric appliance is given by the formula

$$\text{Electricity energy (in kWh)} = \frac{\text{no.of appliance} \times \text{power of appliance (in watt)} \times \text{Time (in hour)}}{1000}$$

Example 6

The rate of electricity in a town is Rs. 3.00 per unit. Calculate the cost of running an 80-watt fan for ten hours a day for the whole month of June.

Solution :

Total time for which the fan is used is (10 hours) × 30 = 300 hours.

The power consumed is (80 W) × (300 hours) = 24000 watt hours = 24 kilowatt hours, or 24 units.

The cost of this power = (Rs. 3.00/unit) × (24 units) = Rs. 72

9. APPLICATION OF HEATING EFFECT OF ELECTRIC CURRENT

(i) Domestic electrical appliance : Domestic electrical appliances such as electric bulb, electric iron, geyser, room heater etc work on heating effect of current and are rated in terms of voltage and wattage. The coils of these devices are made of a material of a very high resistance, (for instance, nichrome or tungsten) such that when a current passes through the coil, heat is generated. Generally the potential difference applied to the electrical appliance is the same as that of the mains i.e. 220-230 V in India and 110 V in U.S.A., Canada etc.

(ii) Electric fuse : An electric fuse is an easily fusible wire of short length put into an electrical circuit for protection purpose. It is arranged to melt (“blow”) at a definite current.

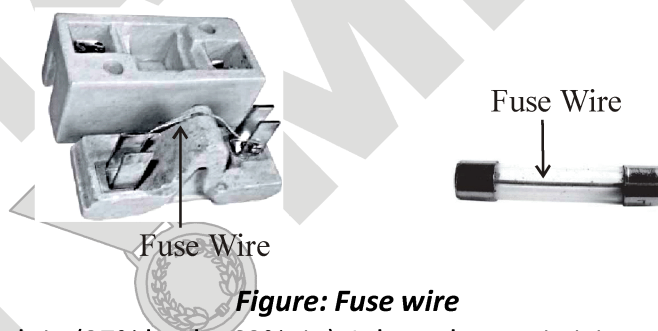


Figure: Fuse wire

It is an alloy of lead and tin (37% lead + 63% tin). It has a low resistivity and low melting point. As soon as the safe limit of current exceeds, the fuse “blows” and the electric circuit is cut off.

10. DISADVANTAGE OF THE HEATING EFFECT OF CURRENT

A current always produces some heat, whether we use the heat or not. If the heat produced cannot be utilized, it represents a wastage of energy. A considerable amount of energy is thus wasted in the transmission of electricity from the generating station to our homes. Sometimes, the heat produced in a device is so much that it can damage the device, unless proper cooling arrangements are made. To dissipate the heat produced in TV sets, monitors, etc., their cabinets have grills for air to pass. Certain components of a computer get so hot that they have fans to cool them.

11. RATING OF ELECTRIC APPLIANCE

Take an electric bulb and see what is written on it. Apart from the name and the symbol of the company, you will find values of power and potential difference. For example, it could be 60 W, 220 V. It means that 220 V should be applied across this bulb, and when 220V is applied, the power consumed will be 60 W. You will find similar markings on all electric appliances. For an electric appliance, the values of power and voltage taken together form what is called the rating of the appliance.

From the rating of an appliance, you can easily calculate its resistance by using the equation $P = V^2/R$. Note that higher the power rating, smaller the resistance. So, a 1000-W heater has less resistance than a 100-W bulb. You can also calculate the current drawn by an appliance by using the relation $i = P/V$.

Example 7

An electric kettle is rated 500 W, 220 V. It is used to heat water for 30 seconds. Assuming the voltage to be 220 V, calculate the heat produced.

Solution :

Since the voltage is 220V, the power consumed is $P = 500\text{W}$. The heat produced in 30 seconds is $W = Pt = (500 \text{ W}) \times (30 \text{ s}) = 15,000 \text{ J}$.

SOLVED EXAMPLES

SE. 1

A conductor carries a current of 0.2 A. Find the amount of charge that will pass through the cross-section of the conductor in 30s. How many electrons will flow in this time interval if the charge on one electron is 1.6×10^{-19} C ?

Ans. Here, $I = 0.2$ A, $t = 30$ s

Using, $I = \frac{Q}{t}$, we get

$$Q = I \times t = 0.2 \times 30 = 6 \text{ C}$$

If n electrons flow and e is the charge on an electron, then

$$Q = ne \text{ or } n = \frac{Q}{e} = \frac{6}{1.6 \times 10^{-19}} = 3.75 \times 10^{19}$$

SE. 2

A battery of emf 10V and internal resistance 3Ω is connected to a resistor. if the current in the circuit is 0.5A, what is the resistance of the resistor ? What is the terminal voltage of the battery when the circuit is closed ?

Ans. $I = \frac{\epsilon}{R+r}$

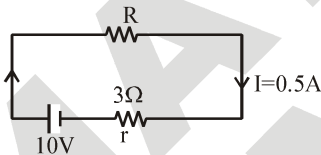
$$0.5 = \frac{10}{R+3}$$

$$R + 3 = 20$$

$$R = 17 \Omega$$

Terminal voltage of the battery

$$V = \epsilon - Ir = 10 - 0.5 \times 3 = 8.5 \text{ V}$$



SE. 3

Two heater wires of the same dimensions are first connected in series and then in parallel to a source of supply. What will be the ratio of heat produced in the two cases ?

Ans. As heater wires are of the same dimensions, their resistance are equal, say R each. In series, their resultant resistance $R_s = 2R$. Now, if connected to supply source of voltage V for time t , the heat produced,

$$H_s = \frac{V^2 t}{R_s} = \frac{V^2 t}{2R}$$

In parallel, the resultant resistance, $R_p = \frac{R}{2}$

and for same supply source voltage V and for same time t , the heat produced

$$H_p = \frac{V^2 t}{R_p} = \frac{V^2 t}{\frac{R}{2}} = V^2 t \times \frac{2}{R} = \frac{2V^2 t}{R}$$

$$(\because R_p = R/2)$$

$$\text{Now, } \frac{H_s}{H_p} = \frac{\frac{V^2 t}{2R}}{\frac{2V^2 t}{R}} = \frac{V^2 t}{2R} \times \frac{R}{2V^2 t} = \frac{1}{4}$$

$$\therefore \frac{H_s}{H_p} = \frac{1}{4}$$

SE. 4

In a particular television tube, a beam of electrons is emitted. The beam current is $80 \mu\text{A}$. How many electrons strike the screen of TV every second ? Also find the total charge striking the screen in 2 minutes.

Ans. Here, $I = 80 \mu\text{A} = 80 \times 10^{-6} \text{ A} = 8 \times 10^{-5} \text{ A}$

(i) $t = 1$ second

Using, $I = \frac{q}{t} = \frac{ne}{t}$, we get

$$n = \frac{It}{e} = \frac{8 \times 10^{-5} \text{ A} \times 1 \text{ s}}{1.6 \times 10^{-19} \text{ C}} = 5 \times 10^{14}$$

$$(\because e = 1.6 \times 10^{-19} \text{ C})$$

So, 5×10^{14} electrons strike the screen every second.

(ii) $I = \frac{q}{t}$

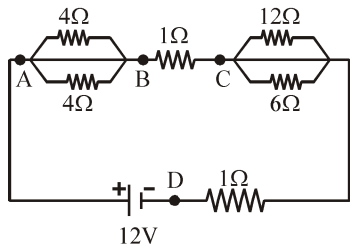
$$q = It = 8 \times 10^{-5} \text{ A} \times 2 \text{ minutes}$$

$$= 8 \times 10^{-5} \text{ A} \times 2 \times 60 \text{ seconds}$$

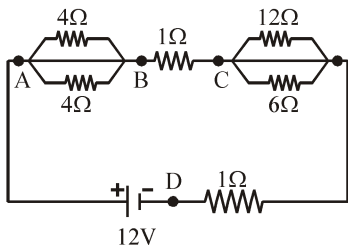
$$= 960 \times 10^{-5} \text{ C} = 9600 \times 10^{-6} \text{ C} = 9600 \mu\text{C}$$

SE. 5

A network of resistor is connected with a 12V battery as shown in figure.



Find the potential difference V_{AB} , V_{BC} and V_{CD} .



Ans.

Total resistance of circuit = resistance of two of 4Ω resistance in parallel + resistance of 1Ω + resistance of 12Ω and 6Ω in parallel + 1Ω resistance

$$= 2 + 1 + \frac{12 \times 6}{12 + 6} + 1 = 8$$

So, current through cell, $I = \frac{V}{R} = \frac{12}{8} = \frac{3}{2} \text{ A}$

Now, $V_{AB} = I \times R_{AB} = \frac{3}{2} \times 2 = 3\text{V}$

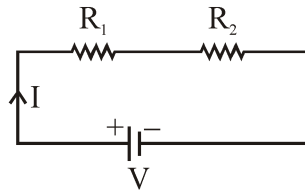
$V_{BC} = I \times R_{BC} = \frac{3}{2} \times 1 = \frac{3}{2} \text{ V}$

$V_{CD} = I \times R_{CD} = \frac{3 \times 5}{2} = \frac{15}{2} = 7.5 \text{ V}$

SE. 6

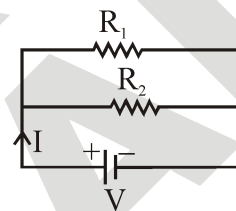
The resistance of two conductor in series is 40Ω and their resistance becomes 6.4Ω , when connected in parallel. Find the resistance of individual conductors.

Ans. Let R_1 and R_2 be the resistances of two conductors. Then, when R_1 and R_2 are connected in series



$$R_s = R_1 + R_2 = 40 \quad \dots(i)$$

when R_1 and R_2 are connected in parallel



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

$$\Rightarrow R_p = \frac{R_1 R_2}{R_1 + R_2}$$

Now, $R_p = \frac{R_1 R_2}{R_1 + R_2} = 6.4$ (given)

or $R_1 R_2 = 6.4(R_1 + R_2) = 6.4 \times 40 = 256$

$$\therefore R_1 R_2 = 256 \quad \dots(ii)$$

Now, from eq.(i), $R_1 = (40 - R_2)$

putting this value in (ii) we get, $(40 - R_2) R_2 = 256$

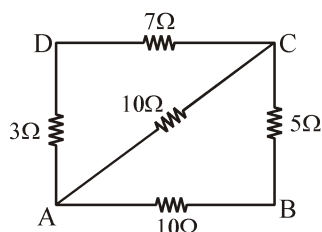
or $40R_2 - R_2^2 = 256$ or $R_2^2 - 40R_2 + 256 = 0$

or $(R_2 - 32)(R_2 - 8) = 0$, $\therefore R_2 = 32\Omega$ or 8Ω

$\therefore R_1 = 40 - 32 = 8\Omega$ or $R_1 = 40 - 8 = 32\Omega$

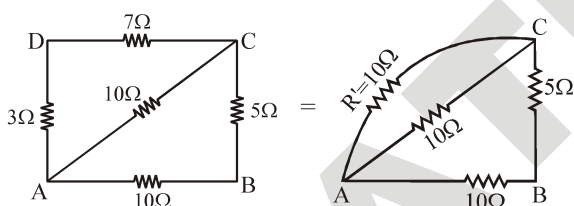
SE. 7

Find in the given network of resistors, the equivalent resistance between the points A and B, between A and D and between A and C.

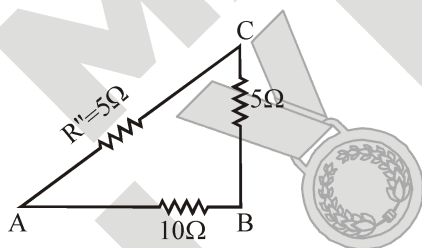


Ans. The resistors AD ($= 3\Omega$) and DC ($= 7\Omega$) are in series to give a total resistance $R' = 10\Omega$. The resistance $R' (= 10\Omega)$ and the resistor AC ($= 10\Omega$) are in parallel to give an effective resistance R'' ,

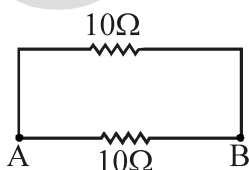
$$R' = 3\Omega + 7\Omega = 10\Omega$$



given by $R'' = \frac{10 \times 10}{10 + 10} = 5\Omega$



Now $R'' (= 5\Omega)$ and CB ($= 5\Omega$) are in series and give a total resistance $R''' = 5\Omega + 5\Omega = 10\Omega$. Finally $R''' = 10\Omega$ and AB ($= 10\Omega$) are in parallel. So, the equivalent resistance between A and B is,



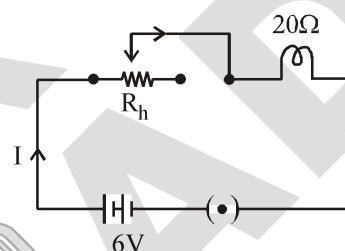
$$R_{AB} = \frac{10 \times 10}{10 + 10} = \frac{100}{20} = 5\Omega$$

By a similar reasoning as above, we can see that

$$R_{AD} = (39/16)\Omega \text{ and } R_{AC} = (15/4)\Omega$$

SE. 8

Suppose a 6-volt battery is connected across a lamp whose resistance is 20Ω through a variable resistor as shown in figure



If the current in the circuit is 0.25 A , calculate the value of the resistance from the resistor which must be used ?

Ans. Here, supply voltage, $V = 6\text{ volt}$.
Resistance of the lamp, $r = 20\Omega$
Current in the circuit, $I = 0.25\text{ A}$
Let R_1 be the resistance required from the variable resistance (a rheostat, R_h) to be placed in series with the lamp.
Total resistance in the circuit,
 $R = R_1 + r = R_1 + 20$

Applying Ohm's law, $I = \frac{V}{R}$ or $0.25 = \frac{6}{R_1 + 20}$

$$\text{or } R_1 + 20 = \frac{6}{0.25} = 24$$

$$\text{or } R_1 + 20 = \frac{6 \times 100}{25} = 24$$

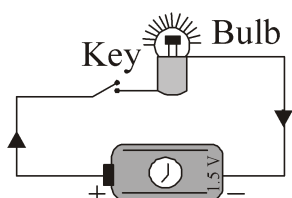
$$\text{or } R_1 = 24 - 20$$

$$\therefore R_1 = 4\Omega$$

NS. 1

What does an electric circuit mean ?

Ans. A continuous conducting path consisting of some electric components connected between the two terminals of a battery is called an electric circuit.



An electric circuit generally consisting of a bulb, a key, copper wires and a dry cell as shown in figure.

NS. 2

Define the unit of current

Ans. In S.I. system, the unit of current is ampere (A). When 1 coulomb of charge flows through a conductor in 1 second, then the current flowing through the conductor is called 1 ampere.

NS. 3

Calculate the number of electrons constituting one coulomb of charge.

Ans. Charge, $Q = 1\text{C}$

Charge on an electron $q = 1.6 \times 10^{-19}\text{C}$

No. of electrons constituting 1C of charge

$$\frac{1\text{C}}{1.6 \times 10^{-19}\text{C}} = 6.25 \times 10^{18} \text{ electrons}$$

NS. 4

Name a device that helps to maintain a potential difference across a conductor.

Ans. A battery consisting of one or more electric cells is used to maintain a potential difference across a conductor.

NS. 5

What is meant by saying that the potential difference between two points is 1 V?

Ans. Potential difference between two points in a current-carrying conductor is said to be 1 volt if 1 joule of work is done to carry a charge of 1 coulomb from one point to the other, i.e.,

$$1\text{volt} = \frac{1\text{joule}}{1\text{coulomb}} = 1\text{J}\text{C}^{-1}$$

NS. 6

How much energy is given to each coulomb of charge passing through a 6 V battery?

Ans. Charge, $Q = 1\text{C}$

Applied voltage, $V = 6\text{V}$

Then,

Work done in moving a charge of 1 C

under the voltage of $6\text{V} = 1\text{C} \times 6\text{V} = 6\text{J}$

Thus, an energy of 6 J should be given during the passage of one coulomb of charge through a 6 V battery.

NS. 7

On what factors does the resistance of a conductor depend?

Ans. The resistance (R) of a conductor depends upon:

(i) its length (l) where $R \propto l$.

(ii) its cross-sectional area (A) where $R \propto 1/A$

(iii) Nature of material

(iv) Temperature

$$\text{Thus, } R = \rho \frac{l}{A}$$

NS. 8

Will current flow more easily through a thick wire than a thin wire of the same material when connected to the same source? Why?

Ans. The current flows more easily through a thick wire than through a thin wire. This is due to the reason that the resistance R of a thick wire of large area of cross-section is less than that of a thin wire of small cross-section area as

$$R \propto \frac{1}{A}$$

NS. 9

Let the resistance of an electrical component remain constant while the potential difference across the two ends of the component decreases to half its former value. What change will occur in the current through it?

Ans. Since $I = V/R$, when potential difference becomes $V/2$, current becomes $1/2$ as the resistance (R) of the component remains constant.

NS. 10

Why are the coils of electric toasters and electric irons made of an alloy rather than a pure metal?

Ans. Alloys are used for making the coils in electric toaster and electric iron because alloys have higher melting point than pure metals. So, the coils made from alloys do not melt or get deformed and alloys do not get oxidised or burn readily at high temperatures.

NS. 11

Use the data in Table 1(12.2 in NCERT) to answer the following:

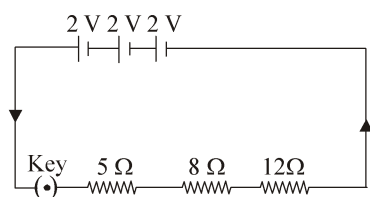
- (a) Which among iron and mercury is a better conductor?
- (b) Which material is the best conductor?

Ans. (a) Iron is a better conductor than mercury as resistivity (ρ) for iron ($10.0 \times 10^{-8} \Omega \text{ m}$) is less than that for mercury ($94 \times 10^{-8} \Omega \text{ m}$).
 (b) Silver is the best conductor as its resistivity (ρ) is the least, i.e., $1.60 \times 10^{-8} \Omega \text{ m}$.

NS. 12

Draw a schematic diagram of a circuit consisting of a battery of three cells of 2 V each, a 5 Ω resistor, a 8 Ω resistor, and a 12 Ω resistor, and a plug key, all connected in series.

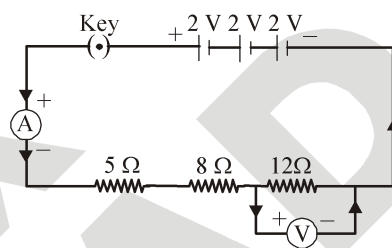
Ans. The schematic circuit diagram is shown here:



NS. 13

Redraw the circuit of question-12, putting in an ammeter to measure the current through the resistors and a voltmeter to measure the potential difference across the 12 Ω resistor. What would be the reading in the ammeter and the voltmeter?

Ans. The complete circuit diagram is given below:



For the whole circuit,
 Total resistance = $5 \Omega + 8 \Omega + 12 \Omega = 25 \Omega$
 Total applied voltage = $2 \text{ V} + 2 \text{ V} + 2 \text{ V} = 6 \text{ V}$
 Then,
 current flowing through the resistors,

$$I = \frac{V}{R} = \frac{6 \text{ V}}{25 \Omega} = 0.24 \text{ A}$$

So, the ammeter will show a reading of 0.24 A.
 Voltage across the 12 Ω resistor = IR
 $= 0.24 \text{ A} \times 12 \Omega = 2.88 \text{ V}$
 So, the voltmeter will show a reading of 2.88 V

NS. 14

Judge the equivalent resistance when the following are connected in parallel:

- (a) 1 Ω and $10^6 \Omega$,
- (b) 1 Ω and $10^3 \Omega$ and $10^6 \Omega$

Ans. (a) For a parallel combination,

$$\frac{1}{R} = \frac{1}{1 \Omega} + \frac{1}{10^6 \Omega} = \frac{10^6 + 1}{10^6 \Omega}$$

$$R = \frac{10^6 \Omega}{10^6 + 1} \simeq 1 \Omega$$

(1 is negligible as compared to 10^6)

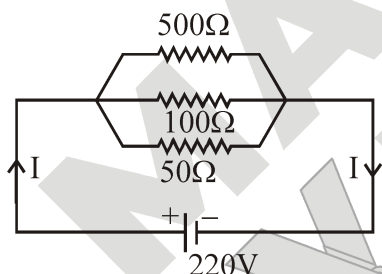
(b) For the other parallel combination, we can write

$$\begin{aligned} \frac{1}{R} &= \frac{1}{1\Omega} + \frac{1}{10^3\Omega} + \frac{1}{10^6\Omega} \\ &= 1\Omega^{-1} + 0.001\Omega^{-1} + 0.000001\Omega^{-1} \\ &= 1.001\Omega^{-1} \\ R &= \frac{1}{1.001}\Omega = 0.999\Omega \simeq 1\Omega \end{aligned}$$

NS. 15

An electric lamp of 100Ω , a toaster of resistance 50Ω and a water filter of resistance 500Ω are connected in parallel to a 220V source. What is the resistance of an electric iron connected to the same source that takes as much current as all three appliances and what is the current through it?

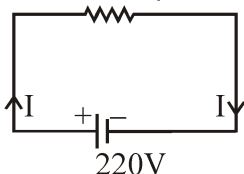
Ans. Resistance of the electric lamp, $R_1 = 100\Omega$
 resistance of toaster, $R_2 = 50\Omega$
 resistance of water filter, $R_3 = 500\Omega$
 Since R_1 , R_2 and R_3 are connected in parallel, their equivalent resistance (R_p) is given by



$$\begin{aligned} \frac{1}{R_p} &= \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{100} + \frac{1}{50} + \frac{1}{500} \\ &= \frac{5+10+1}{500} = \frac{16}{500} \end{aligned}$$

or $R_p = \frac{500}{16} = \frac{125}{4}\Omega$

$$R_p = \frac{125}{4}\Omega$$



Current through the three appliances, i.e.,

$$I = \frac{V}{R_p} = \frac{220\text{V}}{(125/4)\Omega} = 7.04\text{A}$$

Since the electric iron connected to the same source (i.e., 220V), takes as much current as all three appliance, i.e., I , its resistance is equal to R_p ,

i.e., $R_p = \frac{125}{4}\Omega = 31.25\Omega$

NS. 16

What are the advantages of connecting electrical devices in parallel with the battery instead of connecting them in series?

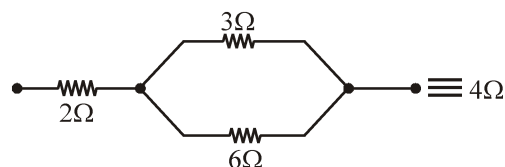
Ans. (a) When a number of electrical devices are connected in parallel, each device gets the same potential difference as provided by the battery and it keeps on working even if other devices fail. This is not so in case the devices are connected in series because when one device fails, the circuit is broken and all devices stop working.
 (b) Parallel circuit is helpful when each device has different resistance and requires different current for its operation as in this case the current divides itself through different devices. This is not so in series circuit where same current flows through all the devices, irrespective of their resistances.

NS. 17

How can three resistors of resistances 2Ω , 3Ω and 6Ω be connected to give a total resistance of

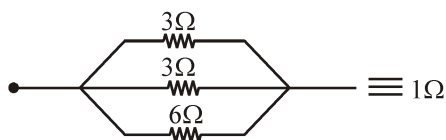
- (a) 4Ω (b) 1Ω ?

Ans. (a) Following combination will give a total resistance of 4Ω



Thus, the resistances of 3Ω and 6Ω are connected in parallel and this combination is combined with 2Ω , resistance in series.

(b) By connecting all the three resistances in parallel.



NS. 18

What is (a) the highest, (b) the lowest total resistance that can be secured by combinations of four coils of resistances 4 Ω, 8 Ω, 12 Ω, 24 Ω?

Ans. (a) Highest resistance = $R_1 + R_2 + R_3 + R_4 = 4 \Omega + 8 \Omega + 12 \Omega + 24 \Omega = 48 \Omega$

(b) If R_p is the lowest resistance, Then

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{4} + \frac{1}{8} + \frac{1}{12} + \frac{1}{24}$$

$$= \frac{6 + 3 + 2 + 1}{24\Omega} = \frac{12}{24\Omega} = \frac{1}{2\Omega}$$

$$\Rightarrow \frac{1}{R_p} = \frac{1}{2}, \therefore R_p = 2\Omega$$

So, the lowest resistance of the combination = 2Ω

NS. 19

Why does the cord of an electric heater not glow while the heating element does?

Ans. The cord of an electric heater is made of thick copper wire and has much lower resistance than its element. For the same current (I) flowing through the cord and the element, heat produced (I^2Rt) in the element is much more than produced in the cord. Consequently, the element becomes very hot and glows whereas the cord does not become hot and as such does not glow.

NS. 20

Compute the heat generated while transferring 96000 coulombs of charge in one hour through a potential difference of 50 V.

Ans. Here, $Q = 96000 \text{ C}$, $t = 1 \text{ h} = 60 \times 60 = 3600 \text{ s}$,
 $V = 50 \text{ V}$

Heat produced, $W = QV = 96000 \text{ C} \times 50 \text{ V} = 48 \times 10^5 \text{ J}$, $\therefore W = 48 \times 10^5 \text{ J}$

NS. 21

An electric iron of resistance 20 Ω takes a current of 5 A. Calculate the heat generated in 30 s.

Ans. Resistance, $R = 20 \Omega$

Current, $I = 5 \text{ A}$

Time, $t = 30 \text{ s}$

$$\text{Heat generated} = I^2Rt = (5 \text{ A})^2 \times 20 \Omega \times 30 \text{ s}$$

$$= 25 \times 20 \times 30 \text{ J} = 15000 \text{ J} = 15 \text{ kJ}$$

NS. 22

What determines the rate at which energy is delivered by the current?

Ans. Rate at which energy is delivered by the current is called electric power.

Electric power is determined by

(a) The potential difference across the conductor in volts.

(b) The current in amperes.

NS. 23

An electric motor takes 5 A from a 220 V line. Determine the power and energy consumed in 2h.

Ans. Here, $I = 5 \text{ A}$, $V = 220 \text{ V}$, $t = 2 \text{ h}$

$$= 2 \times 60 \times 60 = 7200 \text{ s}$$

$$\text{Power, } P = VI = 220 \times 5 = 1100 \text{ W}$$

Energy consumed, W

$$= VI t = 220 \times 5 \times 7200 = 7920000 \text{ J}$$

NS. 24

A piece of wire of resistance R is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is R' then the ratio R/R'

(a) 1/25

(b) 1/5

(c) 5

(d) 25

Ans. Resistance of each one of the five parts = $\frac{R}{5}$

Resistance of five parts connected in parallel is given by

$$As R = \frac{\rho l}{A}, l = \frac{RA}{\rho} = \frac{R(\pi D^2 / 4)}{\rho} = \frac{\pi R D^2}{4\rho}$$

$$[\because A = \pi r^2 = \pi(D/2)^2 = \pi D^2 / 4]$$

$$or l = \frac{3.14 \times 10 \times (0.5 \times 10^{-3})^2}{4 \times 1.6 \times 10^{-8}} m = 122.7 m$$

$$Since, R = \frac{\rho l}{\pi D^2 / 4} = \frac{4\rho l}{\pi D^2}, R \propto 1/D^2.$$

When D is doubled, R becomes $\frac{1}{4}$ times.

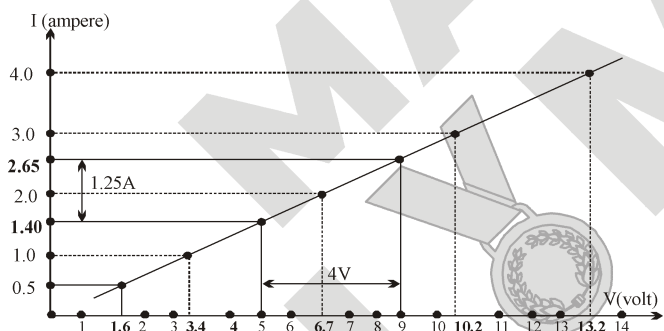
NS. 30

The value of current, I, flowing in a given resistor for the corresponding value of potential difference, V, across the resistor are given here :

I(ampere)	0.5	1.0	2.0	3.0	4.0
V(volt)	1.6	3.4	6.7	10.2	13.2

Plot a graph between V and I and calculate the resistance of the resistor.

Ans. The V-I graph is as shown in figure.



For V = 4 V (i.e., 9 V – 5 V), I = 1.25 A (i.e., 2.65 A – 1.40 A).

$$Therefore, R = \frac{V}{I} = \frac{4V}{1.25A} = 3.2 \Omega$$

The value of R obtained from the graph depends upon the accuracy with which the graph is plotted.

NS. 31

When a 12 V battery is connected across an unknown resistor, there is a current of 2.5 mA in the circuit. Find the value of the resistance of the resistor.

Ans. Here, V = 12 V, I = 2.5 mA = 2.5×10^{-3} A
Resistance of the resistor,

$$R = \frac{V}{I} = \frac{12V}{2.5 \times 10^{-3} A} = 4800 \Omega = 4.8 k\Omega$$

NS. 32

A battery of 9 V is connected in series with resistors of 0.2 Ω , 0.3 Ω , 0.4 Ω , 0.5 Ω and 12 Ω . How much current would flow through the 12 Ω resistor?

Ans. Since all the resistors are in series, equivalent resistance,

$$R_s = 0.2 \Omega + 0.3 \Omega + 0.4 \Omega + 0.5 \Omega + 12 \Omega = 13.4 \Omega$$

Current through the circuit,

$$I = \frac{V}{R_s} = \frac{9V}{13.4 \Omega} = 0.67A$$

In series, same current (I) flows through all the resistors. Thus, current flowing through 12 Ω resistor = 0.67 A

NS. 33

How many 176 Ω resistors (in parallel) are required to carry 5 A on a 220 V line?

Ans. Let there be n resistors in parallel. Then the equivalent resistance is given by,

$$R = \frac{176 \Omega}{n}$$

$$From Ohm s law, R = \frac{V}{I} = \frac{220 V}{5 A}$$

$$So, \frac{176 \Omega}{n} = \frac{220 V}{5 A}$$

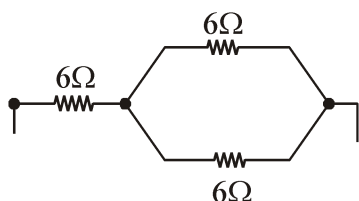
$$or n = 4$$

So, four resistors of 176 Ω each are required.

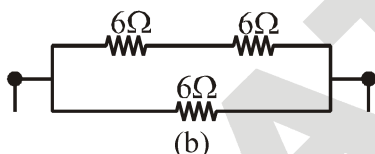
NS. 34

Show how would you connect three resistors, each of resistance $6\ \Omega$, so that the combination has a resistance of (a) $9\ \Omega$, (b) $4\ \Omega$?

Ans. (a) The resistance of the combination is higher than each of the resistances. We can obtain $9\ \Omega$ by coupling $6\ \Omega$ and $3\ \Omega$ in series. A parallel combination of two $6\ \Omega$ resistors is equivalent to $3\ \Omega$. So, (a) to obtain $9\ \Omega$, circuit, the combination given below is possible.



(b) To obtain a combination of $4\ \Omega$, we have to connect two $6\ \Omega$ resistors in series and then connect the third $6\ \Omega$ resistor in parallel of the series combination as shown in the figure (b).



NS. 35

Several electric bulbs designed to be used on a $220\ \text{V}$ electric supply line, are rated $10\ \text{W}$. How many lamps can be connected in parallel with each other across the two wires of $220\ \text{V}$ line if the maximum allowable current is $5\ \text{A}$?

Ans. In a parallel combination, each bulb has the voltage equal to that of the main line, and the sum of the currents drawn by each bulb would be equal to the allowable current.

From the given data,
Current flowing through each bulb

$$= \frac{\text{Wattage}}{\text{Voltage}} = \frac{10\ \text{W}}{220\ \text{V}} = \frac{1}{22}\ \text{A}$$

Maximum allowed current = $5\ \text{A}$

No. of bulbs which can be connected

$$= \frac{5\ \text{A}}{1/22\ \text{A}} = 22 \times 5 = 110$$

NS. 36

A hot plate of an electric oven connected to a $220\ \text{V}$ line has two resistance coils A and B, each of $24\ \Omega$ resistance, which may be used separately, in series, or in parallel. What are the currents in the three cases?

Ans. Here, potential difference, $V = 220\ \text{V}$
resistance of each coil, $r = 24\ \Omega$

(i) When each of the coils A or B is connected separately, current through each coil, i.e.,

$$I = \frac{V}{r} = \frac{220\ \text{V}}{24\ \Omega} = 9.2\ \text{A}$$

(ii) When coils A and B are connected in series, equivalent resistance in the circuit, $R_s = r + r = 2r = 48\ \Omega$ Current through the series

$$\text{combination, i.e., } I_s = \frac{V}{R} = \frac{220\ \text{V}}{48\ \Omega} = 4.6\ \text{A}$$

(iii) When the coils A and B are connected in parallel, equivalent resistance in the circuit,

$$R_p = \frac{r}{2} = \frac{24\ \Omega}{2} = 12\ \Omega$$

Current through the parallel combination,

$$\text{i.e., } I_p = \frac{V}{R_p} = \frac{220\ \text{V}}{12\ \Omega} = 18.3\ \text{A}$$

NS. 37

Compare the power used in the $2\ \Omega$, resistor in each of the following circuits:

(i) a $6\ \text{V}$ battery in series with $1\ \Omega$, and $2\ \Omega$ resistors, and

(ii) a $4\ \text{V}$ battery in parallel with $12\ \Omega$ and $2\ \Omega$ resistors.

Ans. (i) Since $6\ \text{V}$ battery is in series with $1\ \Omega$ and $2\ \Omega$ resistors, current in the circuit,

$$I = \frac{6\ \text{V}}{1\ \Omega + 2\ \Omega} = \frac{6\ \text{V}}{3\ \Omega} = 2\ \text{A}$$

Power used in $2\ \Omega$ resistor,

$$P_1 = I^2 R = (2\ \text{A})^2 \times 2\ \Omega = 8\ \text{W}$$

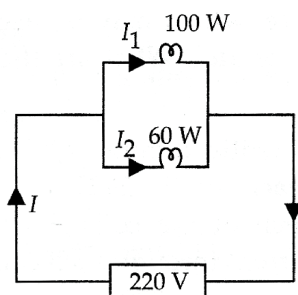
(ii) Since 4 V battery is in parallel with 12 Ω, and 2 Ω resistors, potential difference across 2 Ω resistors, V = 4 V.
Power used in 2 Ω resistor,

$$P_2 = \frac{V^2}{R} = \frac{(4V)^2}{2\Omega} = 8W$$

Clearly, $\frac{P_1}{P_2} = \frac{8W}{8W} = 1$

NS. 38

Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to electric mains supply.



What current is drawn from the line if the supply voltage is 220 V?

Ans. Since both the bulbs are connected in parallel and to a 220 V supply, the voltage across each bulb is 220 V. Then
Current drawn by 100 W bulb,

$$I_1 = \frac{\text{Power rating}}{\text{Voltage applied}} = \frac{100W}{220V} = 0.454A$$

Current drawn by 60 W bulb,

$$I_2 = \frac{60W}{220V} = 0.273 A$$

Total current drawn from the supply line,
 $I = I_1 + I_2 = 0.454 A + 0.273 A = 0.73 A$

NS. 39

Which uses more energy, a 250 W TV set in 1 h or a 1200 W toaster in 10 minutes?

Ans. Energy consumed by TV set = 250 W × 1 h
= 250 J s⁻¹ × 60 × 60 s = 900, 000 J

Energy consumed by toaster

$$= 1200 W \times 10 \text{ min}$$

$$= 1200 \text{ J s}^{-1} \times 10 \times 60 \text{ s} = 720, 000 \text{ J}$$

Thus, the TV set will use more energy.

NS. 40

An electric heater of resistance 8 Ω draws 15 A from the service mains for 2 hours. Calculate the rate at which heat is developed in the heater.

Ans. Resistance, R = 8 Ω, Current, I = 15 A,
Time, t = 2h

$$\text{Rate of generation of heat} = I^2 \times R = (15 \text{ A})^2 \times 8 \Omega = 15 \times 15 \times 8 \text{ W} = 1800 \text{ W}$$

NS. 41

Explain the following:

- (a) Why is tungsten used almost exclusively for filament of electric lamps?
- (b) Why are the conductors of electric heating devices, such as toasters and electric irons, made of an alloy rather than a pure metal?
- (c) Why is the series arrangement not used for domestic circuits?
- (d) How does the resistance of a wire vary with its area of cross-section?
- (e) Why are copper and aluminium wires usually employed for electricity transmission?

Ans. (a) Tungsten has a high melting point (3380°C) and becomes incandescent (i.e., emits light at a high temperature) at 2400 K.

(b) The resistivity of an alloy is generally higher than that of pure metals of which it is made of.

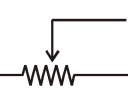
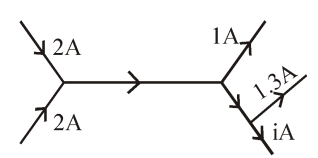
(c) In series arrangement, if any one of the appliances fails or is switched off, all the other appliances stop working because the same current is passing through all the appliances.

(d) The resistance of a wire (R) varies inversely as its cross-sectional area (A) as $R \propto 1/A$

(e) Copper and aluminium wires possess low resistivity and as such are generally used for electricity transmission.

EXERCISE – I

ONLY ONE CORRECT TYPE

1. The potential at a point is 20V. The work done in bringing a charge of 0.5 C from infinity to this point will be :
(A) 20 J (B) 10 J (C) 5 J (D) 40 J
2. A negative charge released from a point A moves along the line AB. The potential at A is 15V, and it varies uniformly along AB. The potential at B
(A) may be 10V (B) may be 15V
(C) may be 20V (D) must be 15V
3. Joule/coulomb is the same as
(A) watt (B) volt
(C) ampere (D) ohm
4. On which of the following no 'plus' or 'minus' sign is marked ?
(A) a cell (B) an ammeter
(C) a voltmeter (D) a resistor
5. An ammeter is always connected in and a voltmeter in The suitable words, in order, for the blanks are
(A) series, series (B) parallel, parallel
(C) parallel, series (D) series, parallel
6. In a metal :
(A) all the electrons are free to move
(B) all the electrons are bound to their parent atoms
(C) there are no electrons
(D) some electrons are free to move
7. Consider the following statements :
A. In series connection, the same current flows through each element.
B. In parallel connection, the same potential difference gets applied across each element.
(A) Both A and B are correct
(B) A is correct but B is wrong
(C) A is wrong but B is correct
(D) Both A and B are wrong
8. When a body is negatively charged by friction, it means :
(A) the body has acquired excess of electrons
(B) the body has acquired excess of protons
(C) the body has lost some electrons
(D) the body has lost some neutrons
9. If a charged body attracts another body, the charge on the other body :
(A) must be negative
(B) must be positive
(C) must be zero
(D) may be negative or zero, positive
10. A neutral body has equal amount of :
(A) Both positive and negative charges
(B) Only positive charge
(C) Only negative charge
(D) No charge at all
11. A sure test of electrification is :
(A) Attraction (B) Repulsion
(C) Friction (D) Induction
12. The space around a charge, is called its :
(A) Potential (B) Electrical Field
(C) Field intensity (D) Potential difference
13. Electrons are constantly in motion within metals but there is no currents until a potential difference. is established across it because :
(A) Electrons do not take part in conduction of current
(B) Electrons become only free when potential difference is applied across the conductor
(C) In the absence of potential difference the motion of electrons in conductor is random so $\vec{V}_{av} = 0$.
(D) None of these
14.  this symbol represents :
(A) Galvanometer
(B) Fixed resistance
(C) Rheostat
(D) Filament bulb
15. Figure shows, current in a part of electrical circuit, then the value of current 'i' is :

(A) 1.7 A (B) 3.7 A
(C) 13 A (D) 1.0 A

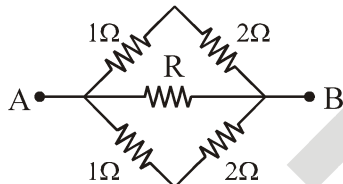
16. A piece of wire of resistance R is cut into five equal parts. These parts are then connected in parallel. If the equivalent resistance of this combination is R' then the ratio R/R' is :

- (A) $1/25$ (B) $1/5$
(C) 5 (D) 25

17. Two conducting wires of the same material and of equal lengths and equal diameters are first connected in series and then parallel in a circuit. The ratio of equivalent resistance in series and parallel combinations would be :

- (A) $1 : 2$ (B) $2 : 1$
(C) $1 : 4$ (D) $4 : 1$

18. The equivalent resistance between point A and B in the figure is 1Ω . What is the value of unknown resistance R .



- (A) 1Ω (B) 3Ω
(C) $6W$ (D) $9W$

19. A wire of resistance R is cut into n equal parts. These parts are then connected in parallel. The equivalent resistance of combination will be :

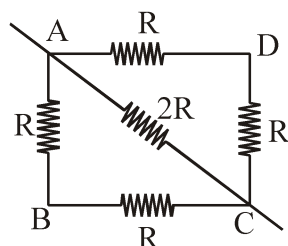
- (A) nR (B) R/n
(C) n/R (D) R/n^2

20. Three resistance each of 8Ω are connected to a triangle. The resistance between any two terminals will be :

- (A) 12Ω (B) 2Ω
(C) 6Ω (D) $\frac{16}{3}\Omega$

21. In the given circuit, the effective resistance between points A and C will be :

- (A) $\frac{3}{2}R$
(B) $6R$
(C) $\frac{2}{3}R$
(D) $3R$



22. Two heater wires of equal length are first connected in series and then in parallel with a battery. The ratio of heat produced in the two cases is :

- (A) $2 : 1$ (B) $1 : 2$
(C) $4 : 1$ (D) $1 : 4$

23. How much electrical energy in kilowatt hour is consumed in operating ten, 50 watt bulbs for 10 hours per day in a month of 30 days ?

- (A) 15 (B) 150
(C) 1500 (D) 15000

24. Law of heating are given by :

- (A) Faraday (B) Joule
(C) Ohm (D) Maxwell

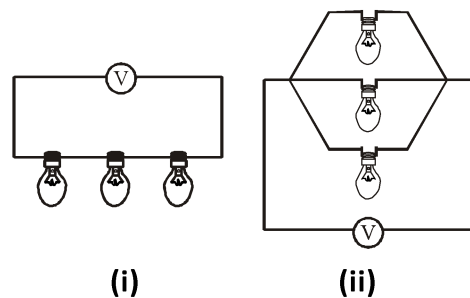
25. Melting point of fuse wire must be :

- (A) Moderate (B) High
(C) Low (D) Infinite

PARAGRAPH TYPE

PARAGRAPH # 1

Three incandescent bulbs of 100 W each are connected in series in an electric circuit. In another circuit another set of three bulbs of the same wattage are connected in parallel to the same source.



26. Which of the following statement is true for the bulbs in two circuits ?

- (A) Bulbs in both circuits glow with the same brightness.
(B) Brightness of the bulb in both circuits can not be compared.
(C) Bulbs in series combination will glow more brightly
(D) Bulbs in parallel combination will glow more brightly.

27. If one of the bulb in both the circuit get fused then :

- (A) The rest of the bulbs in circuit (i) and circuit (ii) will stop working
- (B) The rest of the bulbs in circuit (i) and (ii) will continue to glow.
- (C) The rest of the bulbs in circuit (i) will continue to glow and in circuit (ii) will stop working.
- (D) The rest of the bulbs in circuit (i) will stop working and in circuit (ii) will continue to glow.

PARAGRAPH # 2

A room has two tube lights, a fan and a TV. Each tube light draws 40 W, the fan draws 80 W, and the TV draws 60W on the average, the tube lights are kept on for five hours, the fan for twelve hours and the TV for eight hours every day. The rate for electrical energy is Rs. 3.10 per kWh.

28. The energy consumed by each tube light in a day is :

- (A) 0.2 kWh
- (B) 0.3 kWh
- (C) 0.4 kWh
- (D) 0.5 kWh

29. The total energy consumed in a day

- (A) 1.84 kWh
- (B) 1.25 kWh
- (C) 2.84 kWh
- (D) 2.25 kWh

30. The cost of electricity used in this room in a 30 day month is :

- (A) Rs. 174.12
- (B) Rs. 171.12
- (C) Rs. 170.12
- (D) Rs. 175.12

MATCH THE COLUMN TYPE

31. Column I

- (a) Some Metallic conductors
- (b) Smallest independent charge
- (c) Static electricity
- (d) Repulsion
- (A) a-q, b-s, c-r, d-p
- (B) a-r, b-q, c-p, d-s
- (C) a-s, b-r, c-q, d-p
- (D) a-p, b-r, c-s, d-q

Column II

- (p) Like charge
- (q) Follow Ohm’s law
- (r) Charge at rest
- (s) Electron

32. Column I

- (a) Series combination of resistors
- (b) Parallel combination of resistors
- (c) Voltmeter
- (d) Current Electricity
- (A) a-q, b-s, c-r, d-p
- (B) a-r, b-q, c-p, d-s
- (C) a-s, b-p, c-q, d-r
- (D) a-p, b-r, c-s, d-q

Column II

- (p) Minimum resistance
- (q) Potential difference
- (r) Charge in motion
- (s) Maximum resistance

EXERCISE – II

VERY SHORT ANSWER TYPE

1. A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit ?
2. Define the unit of current and electric potential ?
3. Name a device that helps to maintain a potential difference across a conductor.
4. What is the commercial unit of electrical energy ? Represent it in terms of joules.
5. A dry cell usually has a small cap at one end a flat surface at the other end. Which of the two is at a higher potential ?
6. What is the shape of the graph between V and i, where V is the potential difference between the ends of a wire and i is the current in it ?
7. Name three electrical appliances in which the heating effect of electric current is used.
8. Two bulbs have rating 100W, 220V and 60W, 220V. Which one has a greater resistance ?
9. You have two resistors of resistances 30Ω and 60Ω . What resistances can you get by combining the two ?
10. A wire of resistance 10Ω is bent to form a closed circle. What is the resistance across a diameter of the circle ?

SHORT ANSWER TYPE

1. Calculate the number of electrons constituting one coulomb of charge ?
2. On what factors does the resistance of a conductor depend ?
3. Why are coils of electric toasters and electric irons made of an alloy rather than a pure metal ?
4. How much energy is given to each coulomb of charge passing through a 6V battery ?
5. What is the difference between a conductor and an insulator ? Give one example of each.

LONG ANSWER TYPE

1. What is electrical resistivity ? In a series electrical circuit comprising a resistor made up of a metallic wire, the ammeter reads 5A. The reading of the ammeter decreases to half when the length of the wire is doubled. Why ?
2. Explain the following :
 - (a) Why is the tungsten used almost exclusively for filament of electric lamps ?
 - (b) Why are the conductors of electric heating devices, such as bread-toasters and electric irons, made of an alloy rather than a pure metal ?
 - (c) How does the resistance of a wire vary with its area of cross-section ?
3. Define electric current and state its unit and State ohm's law how can it verify ?
4. Deduce the expression for the equivalent resistance of the parallel combination of two resistances R_1 and R_2 .
5. Deduce the expression for the equivalent resistance of the two resistances R_1 and R_2 connected in series.

TRUE / FALSE TYPE

1. It is not possible to have a particle with charge 20×10^{-19} C.
2. An electron released from rest at a point A moves towards a nearby point B. The potential at A is higher than the potential at B.
3. A metal has a large number of electrons, but a nonmetal has only a small number of electrons.
4. The positive terminal of a cell is connected to the end A, and the negative terminal is connected to the end B of a metallic wire AB. Electrons flow in the wire in the direction B to A.
5. If two equal resistances are connected in parallel, the equivalent resistance is halved.

Answer Key

EXERCISE – I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	C	B	D	D	D	A	A	D	A	B	B	C	C	A
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
D	D	B	D	D	C	D	B	B	C	D	D	A	A	B
31	32													
A	C													

EXERCISE – II

VERY SHORT ANSWER TYPE

1. 300C 9. 90W, 20W 10. 2.5W

SHORT ANSWER TYPE

4. 6 J

TRUE / FALSE

1. T 2. F 3. F 4. T 5. T

FILL IN THE BLANKS

1. increase 2. 25 C 3. charge 4. 5A
5. positive

NUMERICAL PROBLEMS

1. 0.2J 2. 1500C 3. 1.5×10^{20} electrons 4. 1.2A
5. 60W, 0.1A

SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : ELECTRICITY)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

NOTES :

1. In the status, put “completed” only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.



Space for Notes :

A large rectangular area filled with horizontal dotted lines, intended for writing notes.



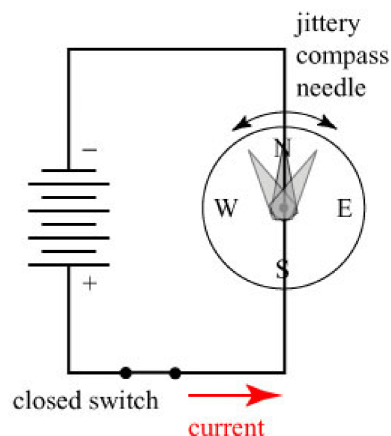
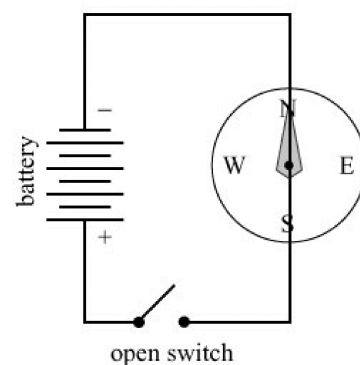
MAGNETIC EFFECT OF ELECTRIC CURRENT

2

Concepts

Introduction

1. Magnet
2. Magnetic field and Magnetic field lines
 - 2.1 Plotting magnetic field lines of magnet
 - 2.2 Properties of magnetic field lines
3. Magnetic effect of current
 - 3.1 Magnetic field due to a current carrying conductor
 - 3.2 Rules to find the direction of magnetic field
 - 3.3 Magnetic field due to current carrying circular coil
4. Magnetic field due to solenoid
5. Electro magnet (Temporary Magnet)
 - 5.1 Application of electromagnet
 - 5.2 Difference between bar magnet & electromagnet
 - 5.3 Method of demagnetising a permanent magnet
6. Force on a current-carrying conductor in a magnetic field
 - 6.1 Motion of charged particle in a magnetic field (Lorentz force)
7. Magnetic flux & Electromagnetic induction
 - 7.1 Magnetic flux
 - 7.2 Electromagnetic induction
8. Direct current and alternating current
9. Electric Motor and generator
 - 9.1 Electric motor
 - 9.2 Generator or dynamo
 - 👉 DC Generator
 - 👉 AC Generator
10. Difference between AC generator and DC MOTOR
11. Domestic electric circuits



Solved Examples

NCERT Solutions

Exercise – I (Competitive Exam Pattern)

Exercise – II (Board Pattern Type)

Answer Key



INTRODUCTION

Origin : Around 120 A.D. near Magnesia in Asia Minor, an ore of iron Fe_3O_4 was found in abundance. This ore of iron, which was found attracting small pieces of iron is Magnetite, Hence, the name ‘magnet’ was given to the pieces that exhibited this property.

Magnetism : It’s a branch of physics in which we study about behaviour and characteristic of magnet. It was studied by William Gilbert. For a substance to be a magnet. It should attract small pieces of iron and should always come to rest in N-S direction when suspended freely.

Classification of materials : All substances that we see and touch can be categorised as.

(a) Magnetic materials : The substances which are attracted by a magnet are called magnetic materials.

Eg. : Iron, cobalt, nickel and their alloys.

(b) Non magnetic materials : The substances which are not attracted by a magnet are non magnetic materials.

Eg. : Wood, Glass.

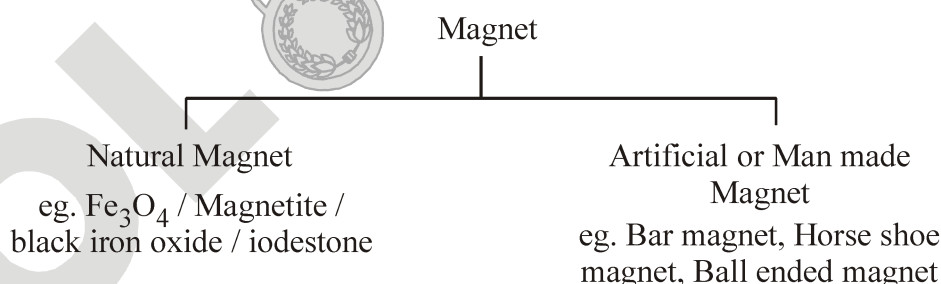
1. MAGNET

(i) **Magnet :** It’s a substance which attract material madeup of Fe, Ni and Co and align in geographical north south direction when suspended freely.

(ii) **Magnetic poles :** The places where the attracting power of a bar magnet is maximum are called ‘poles’. Poles are regions or small areas not the points. Poles are situated near the ends of bar magnet, not exactly at the ends.

If ‘ l ’ is length of magnet then distance between 2 poles is around $0.84 l$.

(ii) **Types of magnet :**



(iv) **Properties of magnet :** William Gilbert of England was the first person to study and record the properties of a magnet in a book titled “The magnet”. Let us study important properties of magnets.

(A) **Attractive property :** It attracts small pieces of iron towards it i.e. it has attractive property.

LAB TIME

Let's Do & Learn



Spread out some iron filings over a sheet of paper. Now, move a bar magnet over the filings taking care that all parts of the magnet move through iron filing and observe how the iron filings are distributed all over the magnet.

You will notice that most of the iron filings cling near the ends of the magnet while there are a few iron filings near the middle (see figure)

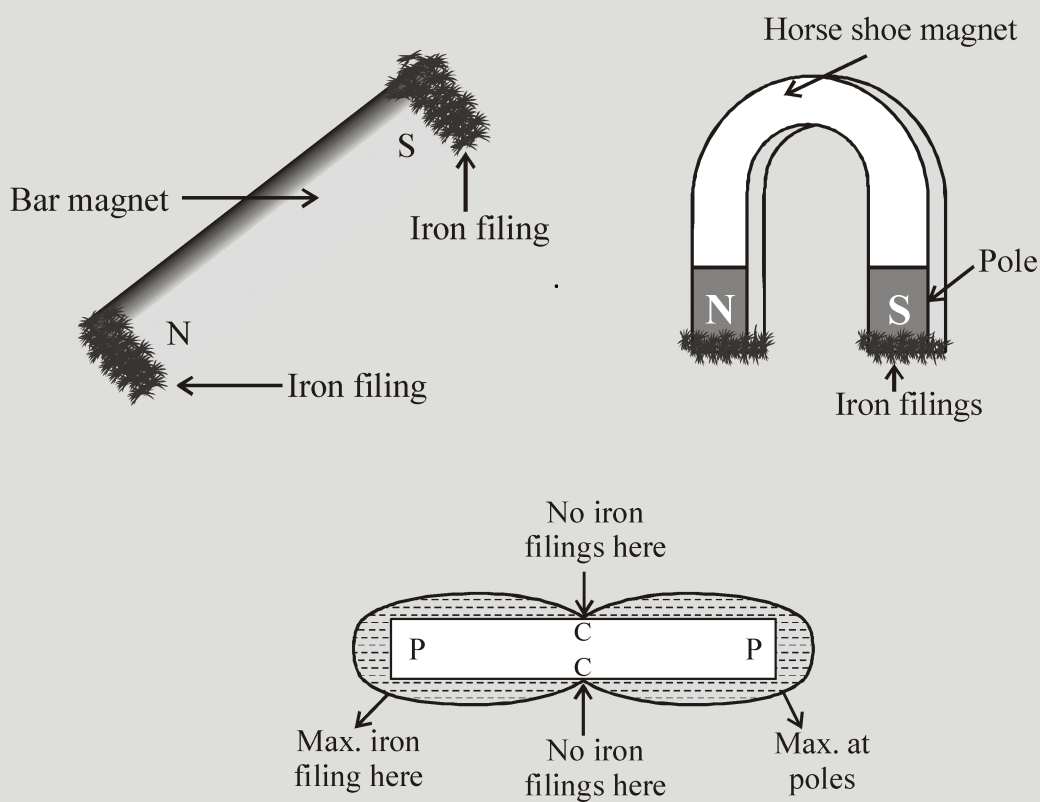


Figure : Type of magnet

(B) Directional property :

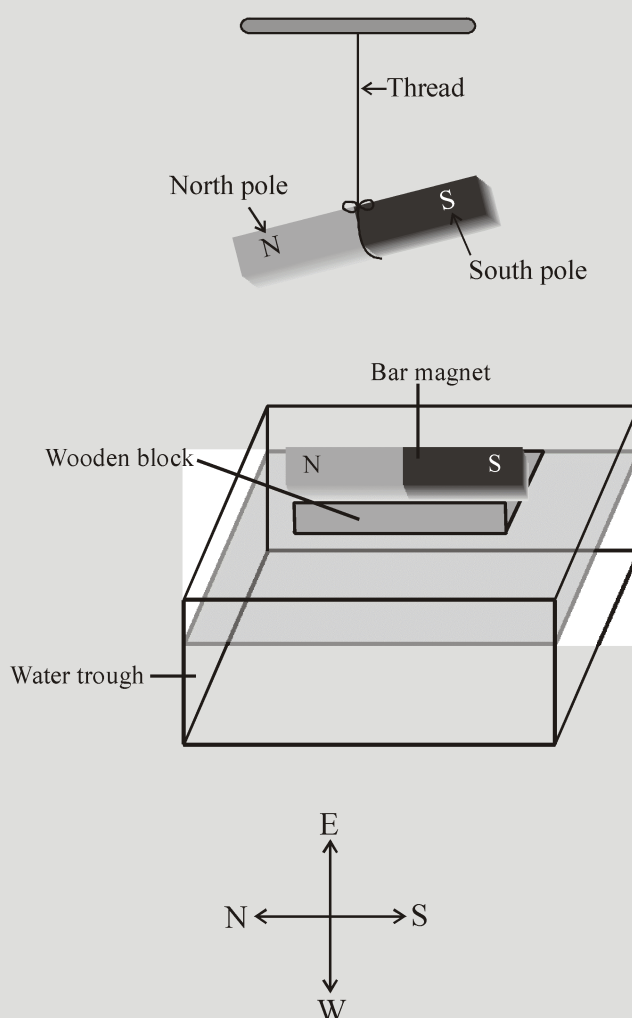
When magnet suspended freely, it always points in north-south direction. Thus magnet possess directional property.

LAB TIME

Let's Do & Learn



Take a bar magnet and suspend it freely as shown in figure or float it on a block of wood in water. The magnet comes to rest after sometime. Disturb it a little from its position of rest and see what happens. You will find that the magnet always comes to rest in the north-south direction.



The end of the magnet that points towards the North is called the North Pole (N-Pole) and the other end of the magnet pointing towards the South is called the South Pole (S-Pole). A magnet always points in the north-south direction when suspended freely.

(C) Like poles repel each other :

Like poles of magnet repel each other and unlike poles attract each other. This means, South-South or North-North poles repel while South-North pole attract.

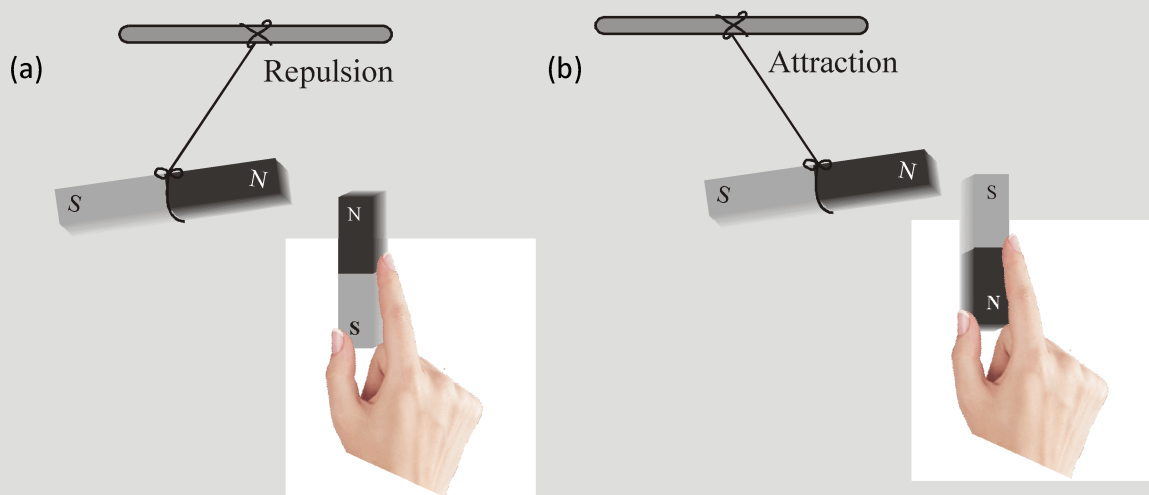
LAB TIME
Let's Do & Learn 

Take two bar magnets. Suspend one magnet with a piece of thread.

It will come to rest in the north-south direction. Hold the other magnet in your hand and bring its north pole near the north pole of the suspended magnet, as shown in figure (a). What do you see ?

You will find that the north pole of the suspended magnet is repelled, i.e., north pole moves away.

Now bring the south pole of the magnet in the hand near the north pole of the suspended magnet (figure b). You will find that the north pole of the suspended magnet will be attracted towards the south pole of the other magnet, i.e., north pole of the suspended magnet will come close to the south pole of the magnet in hand.



(D) Magnetic poles always exist in pairs :

If a bar magnet is broken into two pieces you will see that each piece behaves as a whole magnet. This shows that new poles are formed at the broken ends as shown in the figure. If these pieces are broken again, each smaller piece still remains a whole magnet with two opposite poles. Even a very small piece of a magnet is a whole magnet. Thus, we see that even the smallest piece of a magnet has north and south poles and we cannot separate the two poles.

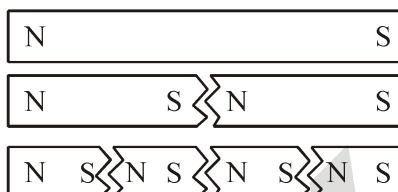


Figure : Bar magnet

2. MAGNETIC FIELD AND MAGNETIC FIELD LINES

Magnetic field : The most striking thing about magnets is the attraction and repulsion between them. How do we explain these forces between two magnets ? We say that a magnet produces a magnetic field in the space around it, which exerts a force on any other magnet placed in it. Each point in this field has a particular strength. The field at each point also has a definite direction.

Magnetic field lines : Magnetic field line is an imaginary line such that tangent to it at any point gives the direction of magnetic field at that point in space. Magnetic field lines are drawn to represent magnetic field. Magnetic field lines can be drawn with the help of magnetic compass. Magnetic field lines are also called as magnetic lines of force.

2.1 PLOTTING MAGNETIC FIELD LINES OF MAGNET

To trace the magnetic field lines, place the bar magnet NS on a sheet of paper and mark its boundary. Mark a point A near the north pole of the given magnet. Place the compass needle (figure) such that one of its ends (south) lies exactly over point A.

Mark point B on the paper at the opposite (north) end to the compass needle. Move the compass needle so that the south end of the compass needle lies over B and mark point C at the north end of the needle and so on. Go on doing so till a path is reached near the south pole of the given magnet. Join all these points with a free hand curve so as to form a smooth dotted curve.

Mark an arrow head to show the direction of magnetic field line, which will be north pole to south pole outside the magnet. This dotted curve marked with an arrow head represents a magnetic field line. Similarly starting from other points near the north pole of the magnet, draw other magnetic field lines. Magnetic field lines plotted for a bar magnet are as shown in figure.

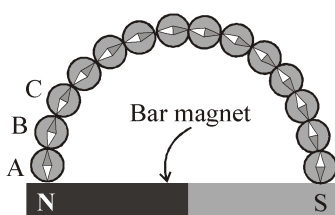


Figure : Direction of magnetic field

2.2 PROPERTIES OF MAGNETIC FIELD LINES

- (i) They form closed continuous curves. They repel each other and are in a state of tension.
- (ii) Externally, they move from north pole of a magnet to its south pole.
- (iii) Inside the magnet they move from south pole to north pole.
- (iv) The tangent drawn to the curve at any point on it gives the direction of the magnetic field at that point.
- (v) Magnetic lines of force do not intersect each other because at the intersection point there are two direction of magnetic field, which is not possible.
- (vi) Magnetic field intensity depends on number of magnetic lines of force. If magnetic lines of force are higher then magnetic field intensity is also high.
- (vii) In a uniform magnetic field, the magnetic lines force are parallel to each other.

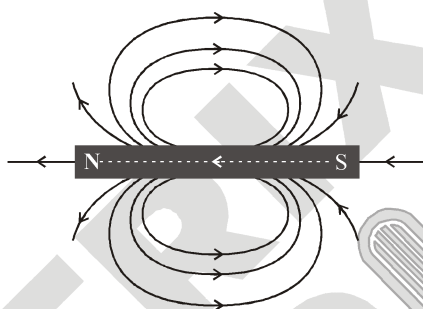


Figure : Properties of magnetic field

3. MAGNETIC EFFECT OF CURRENT

Electric current is also a source of magnetism, oersted, by performing experiments, concluded that **Moving charges or electric current produce a magnetic field in surrounding space.**

3.1 MAGNETIC FIELD DUE TO A CURRENT CARRYING CONDUCTOR

(i) **Experimental arrangement :** The magnetic effect of current has been represented by a simple experiment, as shown in figure. In this experiment a conductor AB is connected to the end of battery through a key K. The wire AB has been placed parallel above the needle.

(ii) **Proccesure :**

Case 1 : When there is no current in the wire A B compass needle remains in north south direction.

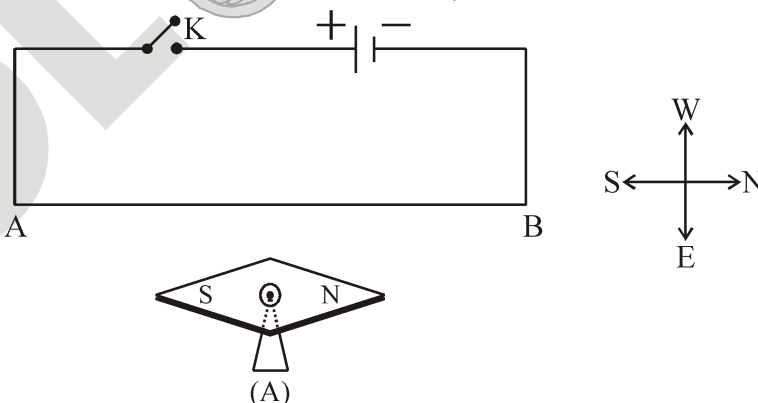


Figure : Circuit with no current

Case 2 : When key is closed then current starts flowing in the wire from A to B, the north pole of magnetic needle gets deflected towards west direction.

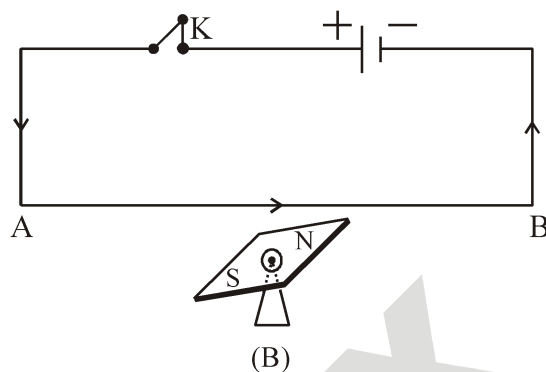


Figure : Circuit with anticlockwise current

Case 3 : By the reversing the direction of current the direction of deflection is also reversed

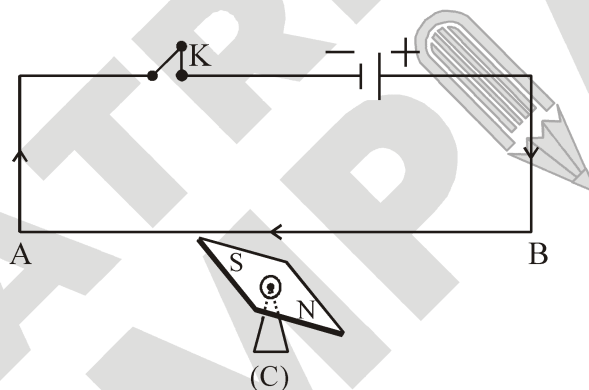


Figure : Circuit with clockwise current

(iii) Conclusion : By increasing the current or bringing the needle near the wire the deflection increases. It is evident from the above experiment that when current flows in the wire, a magnetic field around the wire is developed whose direction depends on the direction of current. And the intensity of the magnetic field depend on the intensity of current. Thus, the original source of magnetic field is the flow of current in the wire.

If you move a compass away from a current-carrying wire, you will notice that as the distance of the compass from the wire increases, the deflection of its needle decreases. This mean that the strength of the magnetic field reduces with distance from the wire. For a long, straight current-carrying wire, the strength of the magnetic field is inversely proportional to the distance.

LAB TIME

Let's Do & Learn



When a current is passed through a conducting wire, a magnetic field is produced around it. The direction of magnetic field due to a straight current carrying wire can be checked by means of a small compass needle or by iron filings.

Experimental arrangement & Working : We take a sheet of smooth cardboard with a hole at the centre. Place it horizontally and pass a wire vertically through the hole. Sprinkle some iron filings on the cardboard and pass an electric current through the wire. Gently tap the cardboard. We find that the iron filings arrange themselves in concentric circles around the wire as shown in figure. If a small compass needle is kept anywhere on the board near the wire, the direction in which the north pole of the needle point gives the direction of the magnetic field (i.e., magnetic lines of force) at that point.

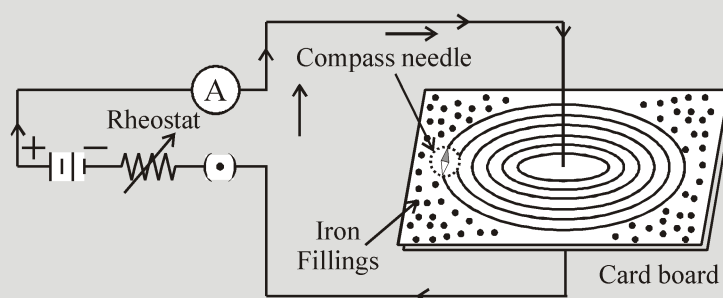


Figure : Iron filings

Pattern of magnetic lines of force :

The magnetic lines of force form concentric circles near the wire, with their plane perpendicular to the straight conductor and with their centres lying on its axis. If the direction of current in the wire is reversed, the direction of lines of force is also reversed.

On increasing the strength of current in the wire, the lines of force becomes denser and iron filings are arranged in circles upto a larger distance from the wire, showing that the magnetic field strength has increased.

3.2 RULES TO FIND THE DIRECTION OF MAGNETIC FIELD

It is obtained by following rules :

I. Snow Rule : According to the rule if current flows in the conductor from **South to North direction**, and conductor is kept **Over** the needle, then north pole of the needle will deflect towards **West direction**

II. Ampere’s swimming rule : Imagine a man swimming along the wire in the direction of current (such that the current enters at his feet and leaves him at his head). i.e. his face towards the magnetic needle, then the north pole of the needle will be deflected towards his left hand.

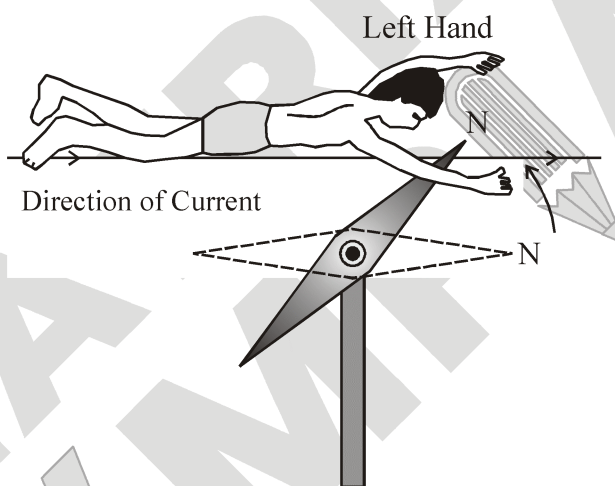


Figure : Ampere’s Swimming Rule

III. Maxwell’s cork screw rule : Imagine a right handed cork screw lying with its axis coincides with the current carrying wire. It is now rotated such that it advances in the direction of the current, the direction in which the screw rotates gives the direction of the magnetic lines of force.

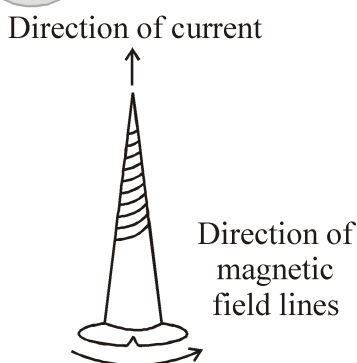


Figure : Maxwell’s cork screw rule

IV. Right hand thumb rule : If we hold the current carrying conductor in the right hand such that the thumb points in the direction of current, then the fingers encircle the wire in the direction of magnetic lines of force.

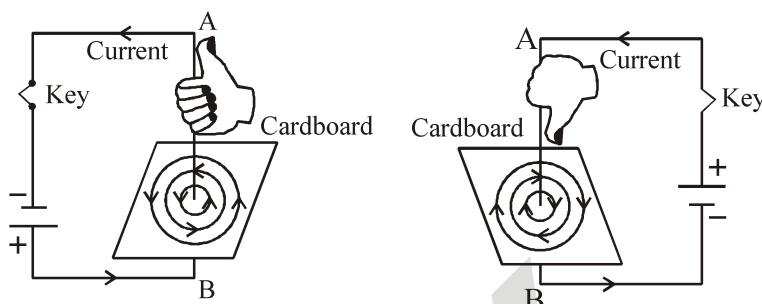


Figure : Right hand thumb rule

3.3 MAGNETIC FIELD DUE TO CURRENT CARRYING CIRCULAR COIL

(i) Experimental arrangement and process :

A piece of wire bent in the form of a ring (or coil) is passed through a horizontal cardboard C at two points P and Q at the opposite ends of a diameter of the ring and then some iron filings are scattered on the cardboard. The ends of the coil are connected to a battery through a rheostat and a key. When a strong electric current is passed through the coil by closing the key and the cardboard is gently tapped we find that the iron filings arrange themselves in a definite pattern representing the magnetic lines of force due to the current carrying coil.

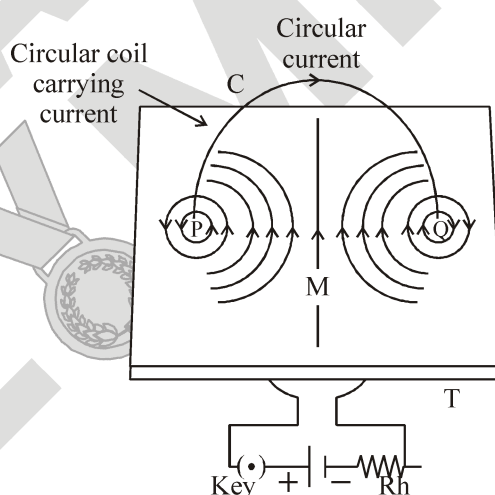


Figure : Magnetic field due to current carrying wire

(ii) Pattern of magnetic line of force :

- The magnetic lines of force are nearly circular near the wire.
- Within the space enclosed by the wire, the lines of force are in the same direction.
- Near the centre of the coil, the lines of force are nearly parallel and the magnetic field may be assumed to be practically uniform for a small space around the centre.
- At the centre, the lines of force are along its axis and at right angle to the plane of the coil.

(e) The magnetic field strength is increased if the number of turns in the coil is increased and the strength of current in the coil is increased.

(iii) Magnitude of magnetic field : The magnitude of magnetic field B produced by a current-carrying circular wire at its centre is :

Directly proportional to the current I passing through the circular wire and inversely proportional to the radius r of the circular wire.

i.e. $B \propto I$ and $B \propto \frac{1}{r}$

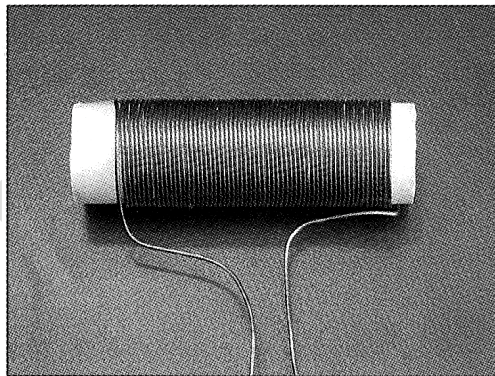
(iv) Direction of magnetic field : The direction of the magnetic field (B) at a point on the axis of a current-carrying circular coil or a loop it can be found from the following right-hand thumb rule.

If the fingers of the right hand are curled along the direction of the current in a loop, the stretched thumb gives the direction of the magnetic field.

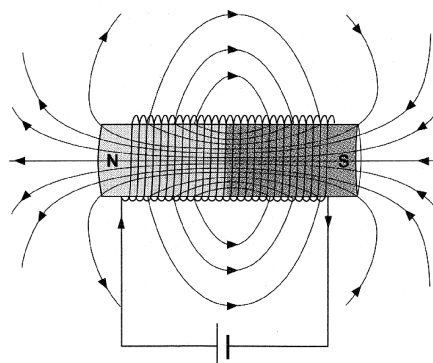
4. MAGNETIC FIELD DUE TO SOLENOID

When a long insulated wire is tightly wound in the shape of a spring, with closely spaced turns that lie side by side, we get a solenoid [figure (a)]. Generally, a solenoid is made by winding wire over a nonconducting cylindrical tube. A solenoid differs from a circular coil in that the length of the solenoid is much greater than its diameter. So, if a long, straight conducting wire is bent into a coil of several closely loops, the resulting device is called solenoid.

When a current enters a solenoid at one end, it passes through each turn before coming out at the other end. Each turn produces its own magnetic field. The net magnetic field is as represented by the magnetic field lines in figure b.



(a)



(b)

Figure : (a) A solenoid (b) Magnetic field lines due to a solenoid

(i) Characteristics of Magnetic field due to solenoid :

(a) The pattern of field lines outside the solenoid is similar to that of a bar magnet [figure (b)]. Actually, a current-carrying solenoid behaves like a bar magnet of the same shape. It also has opposite poles at its ends.

(b) The magnetic field inside a long current-carrying solenoid is nearly uniform and is parallel to the axis of the solenoid. But near the ends the magnetic field decreases.

(ii) Direction of magnetic field in solenoid :

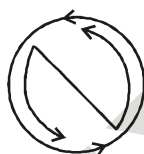
The long solenoid behave like a bar magnet because at the ends of the solenoid magnetic field lines are similar like bar magnet. So, ends of the solenoid behave like either South pole or North pole. To finding the north pole of a solenoid is to check which end gets repelled by the North pole of a bar magnet or Another rule of finding the polarity at the ends of solenoid is below.

Rule for determining polarity at the ends :

If at any end, the current in the coil (or loop) is clockwise, then the face of the coil towards the observer behaves as a south pole.



If at any end the current in the coil is anticlockwise, the the face of the coil towards the observer behaves as a north pole.



(iii) Dependence of magnetic field inside the solenoid :

The strength of magnetic field produced by a current carrying solenoid depends upon :

- (a) The number of turns per unit length in the solenoid :** Larger the number of turns per unit length in the solenoid, greater will be the magnetic field produced.
- (b) The Strength of current in the solenoid :** Larger the current passed through solenoid, stronger will be the magnetic field produced.
- (c) The nature of 'core material' used in making solenoid :** The use of soft iron rod as core in a solenoid produces the strongest magnet.



Focus Point

How are the fields of a current-carrying solenoid and coil different ?

The field inside a current-carrying solenoid is quite uniform for the most part. It only decreases near the ends. The field of current-carrying coil is not uniform. It changes with distance from the centre.

5. ELECTRO MAGNET (TEMPORARY MAGNET)

When a current passes through the solenoid, a magnetic field is produced inside it. The iron bolt (or any other iron object) placed in this field gets magnetized, i.e., it becomes a magnet. However, when the current is switched off, the magnetic field inside the solenoid becomes zero, and the bolt loses its magnetism. A magnet formed temporarily due to the magnetic field of a current is called an **Electromagnet**.

Electromagnets have the following properties.

- (i) Unlike a permanent magnet, the electromagnet's magnetism is not permanent.
- (ii) The electromagnet has poles at its ends. However, the end at which a pole appears is not fixed. The poles get interchanged when the direction of current through the solenoid is changed.

The iron used in nails, bolts, etc., is a **soft magnetic material**, and is called **soft iron**. Such a material becomes magnetized in a magnetic field, but loses its magnetism once the field is removed. Electromagnets are made by winding wire over a core (such as a rod) made of a soft magnetic material. This is to ensure that the electromagnet loses its magnetism once the current is switched off. If you put a rod made of a hard magnetic material such as carbon steel in a magnetic field for some time, the rod will become a permanent magnet. Strong permanent magnets are actually made this way.

LAB TIME

Let's Do & Learn



An iron nail or a bolt will not attract other iron or steel objects.

But what happens if they are placed inside a solenoid carrying a current? Let us find out.

Wound a solenoid directly over an iron bolt or nail, using 5-8 feet of thick enamelled copper wire. (In these wires, the enamel coating acts as the insulator). Use adhesive tape to keep the turns in place. Scrape off the enamel from the free ends of the wire, and connect them to a battery through a switch. Now, close the switch. The bolt will attract iron and steel objects placed near it. If you turn the current off, the bolt will no longer attract these objects.

5.1 APPLICATION OF ELECTROMAGNET

- (i) In factories very strong electromagnets are used with cranes for lifting very heavy iron ingots and steel scraps, from one place to other.
- (ii) In hospitals they are used for removing small steel splinters from the eyes of a patient.
- (iii) In office and houses they are used in electric bells.
- (iv) To separate iron ore from muddy impurities in metallurgical industries.
- (v) Electromagnet also used for medical purpose because an electric current always produces a magnetic field. Even weak ion currents that travel along the nerve cells in our body produce magnetic fields. When we touch something, our nerves carry an electric impulse to the muscles we need to use. The impulse produces a temporary magnetic field. These fields are very weak and are one billionth of the earth's magnetic field. Heart and brain are the two main organs in the human body where the magnetic field produced is significant. The magnetic field inside the body forms the base of obtaining the images of different body parts. This is done by using a technique called Magnetic Resonance Images (MRI). Analysis of these images helps in medical diagnosis. Magnetism has thus, got important used in medicine.

5.2 DIFFERENCE BETWEEN BAR MAGNET & ELECTROMAGNET

S. No.	Bar magnet (Permanent magnet)	Electromagnet (Temporary magnet)
1	The bar magnet is a permanent magnet.	An electromagnet is a temporary magnet, Its magnetism is only for the duration for which current passes through it, so the magnetism of an electromagnet can be switched on or switched off as desired.
2	A permanent magnet produces a comparatively weak force of attraction.	An electromagnet can produce very strong magnetic force.
3	The strength of a permanent magnet cannot be changed.	The strength of an electromagnet can be changed by changing the number of turns in its coil or by changing the current passing through it.
4	The (north-south) polarity of permanent magnet is fixed and cannot be changed.	The polarity of an electromagnet can be changed by changing the direction of current in its coil.

Note : Permanent magnet are usually made of alloys such as carbon-steel, chromium-steel, cobalt-steel, tungsten-steel, nipermag and alnico, Nipermag is an alloy of iron, nickel, aluminium and titanium whereas ALNICO is an alloy of aluminium, nickel and cobalt.

Permanent magnets of these alloys are much more stronger than those made of ordinary steel, such strong permanent magnets are used in microphones, loudspeakers, electric clocks, ammeters, voltmeters, speedometers and many other devices.

5.3 METHOD OF DEMAGNETISING A PERMANENT MAGNET

- (i) Magnet can be demagnetised by :
- Self-demagnetisation, if the magnet is stored without using magnetic keepers.
 - Dropping it from a height or by rough handling.
 - Heating or hammering the magnet.
- (ii) Magnet can be demagnetised by placing it within a solenoid and passing high frequency AC through it.

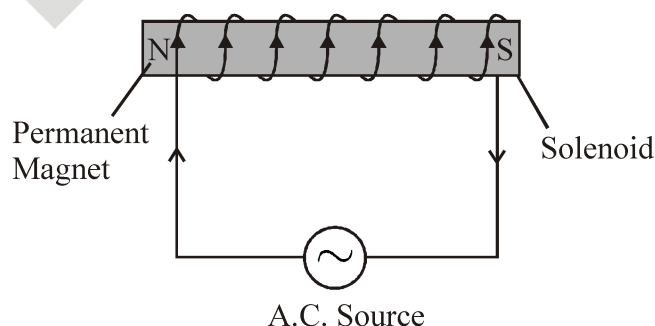


Figure : Demagnetisation

6. FORCE ON A CURRENT-CARRYING CONDUCTOR IN A MAGNETIC FIELD

Immediately after Oersted’s discovery of electric currents producing magnetic fields and exerting forces on magnets, Ampere suggested that magnet must also exert equal and opposite force on a current-carrying conductor. When a current carrying conductor is kept in a magnetic field (not parallel to it), a force acts on it. This force is created due to the interaction of magnetic field of the current in the conductor and the external magnetic field on the conductor. As a result of this superposition, the resultant magnetic field on one side of conductor is weaker than on the other side. Hence the conductor experiences a resultant force in one direction.

LAB TIME

Let's Do & Learn

Take a small aluminium rod AB. Suspend it horizontally by means of two connecting wires from a stand. Now, place a strong magnet in such a way that the rod is between the two poles with the field directed upwards. If a current is passed in the rod from B to A, We will observe that the rod gets displaced. This displacement is caused by the force acting on the current-carrying rod. The magnet exerts a force on the rod directed outward perpendicular from the plane of paper, with the result the rod will get outward perpendicular from the plane of paper. If we reverse the current or interchange the poles of the magnet, the deflection of the rod will reverse, indicating thereby that the direction of the force acting on it gets reversed. This shows that there is a relationship among the directions of the current, the field and the motion of the conductor.

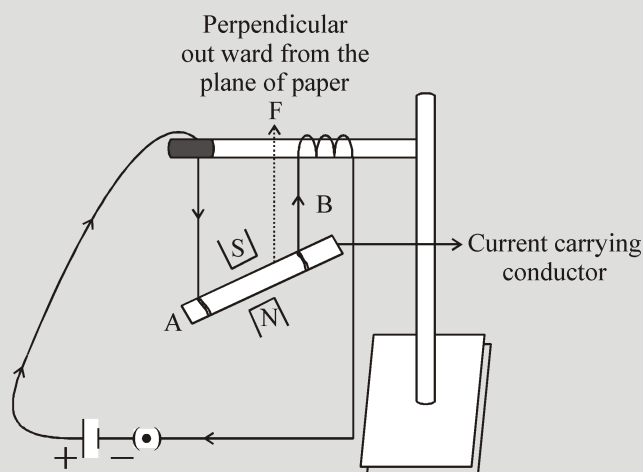


Figure : Force on current carrying conductor

Conclusion : We know that current flows from the positive to the negative terminal of a battery. Also, the direction of the field of a magnet is from the north to the south pole. So, based on your observations in the activity, we can say that the following are true for a current-carrying conductor placed in a magnetic field.

- A current-carrying conductor experiences a force in a magnetic field.
- The direction of the force depends on the direction of the magnetic field and is perpendicular to it.
- The direction of the force depends on the direction of the current and is perpendicular to it.

(i) Magnitude of Force :

In above figure AB is a conductor of length l . It carries I current. It is kept in uniform magnetic field at angle θ . then the force acting on the conductor by magnetic field.

$$F = IB \sin \theta$$

Case I : If $\theta = 0$ or 180 , $\sin 0^\circ = 0$, $\sin 180^\circ = 0$

So, $F = 0$

Case II : $\theta = 90^\circ$

$$F = IB \sin 90^\circ \quad (\because \sin 90^\circ = 1)$$

$$F = IB \text{ (Maximum)}$$

(ii) Direction of force on current carrying conductor

The direction of force is obtained by the Fleming’s left hand rule.

I. Fleming’s left hand rule : If we stretch the forefinger, middle finger and the thumb of our left hand in such a way that they are mutually perpendicular to each other as shown in figure the forefinger indicates the direction of the magnetic field and the middle finger indicates the direction of current, then the thumb will indicate the direction of force on the conductor.

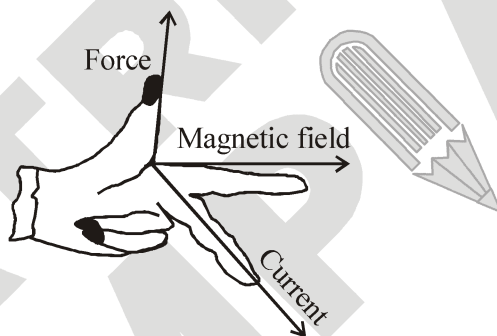


Figure : Fleming's left hand rule

II. Right hand palm rule : If we stretch our right hand such that thumb is a right angles to the fingers, then if fingers represent the direction of external magnetic field (B) and the thumb, the direction of current, then the force acting on the conductor is represented by the force acting outside and normal to the palm.

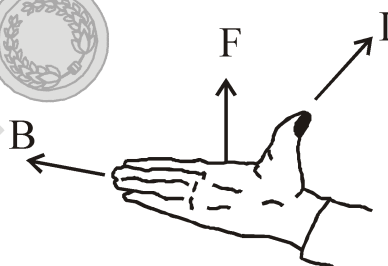


Figure : Right hand palm rule

Note :

- (i) Force on a current-carrying conductor placed parallel or antiparallel to magnetic field is zero.
- (ii) Force experienced by the conductor is maximum when placed perpendicular to magnetic field.
- (iii) If $B = 0$, $F = 0$, i.e. the coil placed in field free area doesn't experience any force.

6.1 MOTION OF CHARGED PARTICLE IN A MAGNETIC FIELD (LORENTZ FORCE)

(i) Magnitude of force

When a charged particle of charge q is moving with velocity v in a magnetic field B at an angle θ , then force acting on the particle

$$F = qvB \sin \theta$$

θ = Angle between \vec{v} and \vec{B}

This force is called Lorentz force

Case I : If $\theta = 0^\circ$ or 180° , $\sin 0^\circ = 0$, $\sin 180^\circ = 0$

So, $F = 0$

Then also particle will move in same direction in straight line with same speed.

Case II : If $\theta = 90^\circ$

$$F = qvB \sin 90^\circ = qvB \text{ (maximum)}$$

In this case the charged particle will move in circular path and plane of the circle is perpendicular to B .

Case III : If θ lies between 0° and 90° .

Then the path of the particle is helical or helix (like a spring).

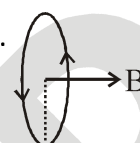
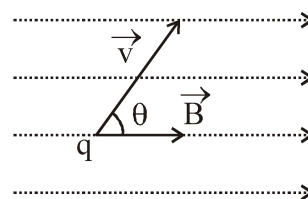


Figure : Lorentz force

(ii) Direction of Lorentz Force : The direction of force is obtained by the Fleming’s left hand rule.

Fleming’s left hand rule :

If we stretch the forefinger, middle finger and the thumb of our left hand in such a way that mutually perpendicular to each other as shown in figure the forefinger indicates the direction of the magnetic field and the middle finger is in the direction of velocity of the charge, then Lorentz force will act in the direction of thumb. (for positive charge).

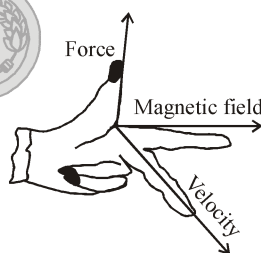


Figure : Fleming’s left hand rule

Example 1

A wire of length 0.04 m is placed perpendicular to a uniform magnetic field of magnitude 0.30 T. Calculate the force on the wire when the current flowing through it is 5.0 A.

Solution:

The force acting on a current-carrying wire placed in a magnetic field is given by :

$$F = B \times I \times L$$

Here, Magnitude of magnetic field, $B = 0.30 \text{ T}$

Current, $I = 5.0 \text{ A}$

Length of wire, $L = 0.04 \text{ m}$

Putting these values in the above formula, we get :

Force = $0.30 \times 5.0 \times 0.04 = 0.06 \text{ N}$

Thus, the force is 0.06 N .

7. MAGNETIC FLUX & ELECTROMAGNETIC INDUCTION

7.1 MAGNETIC FLUX

If we consider a plane perpendicular to a uniform magnetic field, then the product of the magnitude of the field and the area of the plane is called the magnetic flux (ϕ) linked with that plane. The magnetic flux linked with this plane is given by :

$$\phi = BA$$

If the magnetic field \vec{B} , instead of being perpendicular to the plane, makes an angle θ with the perpendicular to the plane as shown in figure, then the magnetic flux linked with the plane will be equal to the product of the component of the magnetic field perpendicular to the plane and the area of the plane.

Thus, $\phi = (B \cos\theta) A = BA \cos \theta$ (i)

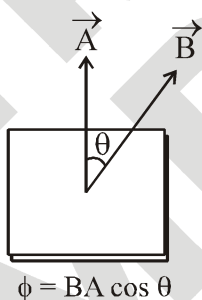


Figure : Magnetic flux

Case I : If $\theta = 0^\circ$, then from equation (i)

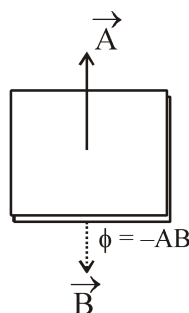
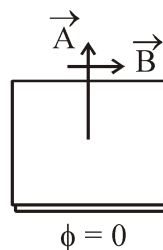
$$\phi = BA \cos 0^\circ = BA \text{ (outgoing flux)}$$

Case II : If $\theta = 90^\circ$, then from equation (i)

$$\phi = BA \cos 90^\circ = 0$$

Case III : If $\theta = 180^\circ$, then from equation (i)

$$\phi = BA \cos 180^\circ = -BA \text{ (incoming flux)}$$



ϕ is positive if the outward normal to the plane is in the same direction as \vec{B} . It is negative if the outward normal is opposite to \vec{B} .

(i) S.I. unit of B and ϕ : The S.I. unit of magnetic flux ϕ is weber (Wb). Since $B = \phi / A$, the magnetic field is also expressed in weber/metre², (Wb-m²). That is why the magnetic field induction B is also called the magnetic flux density.

(ii) Definition of magnetic flux density (B) :

$$\therefore B = \frac{\phi}{A}, \text{ if } A = 1 \text{ metre}^2, \text{ then } B = \phi$$

In a magnetic field the number of lines of force (flux) passing through per metre² perpendicular to the field is equal to the magnetic flux density.

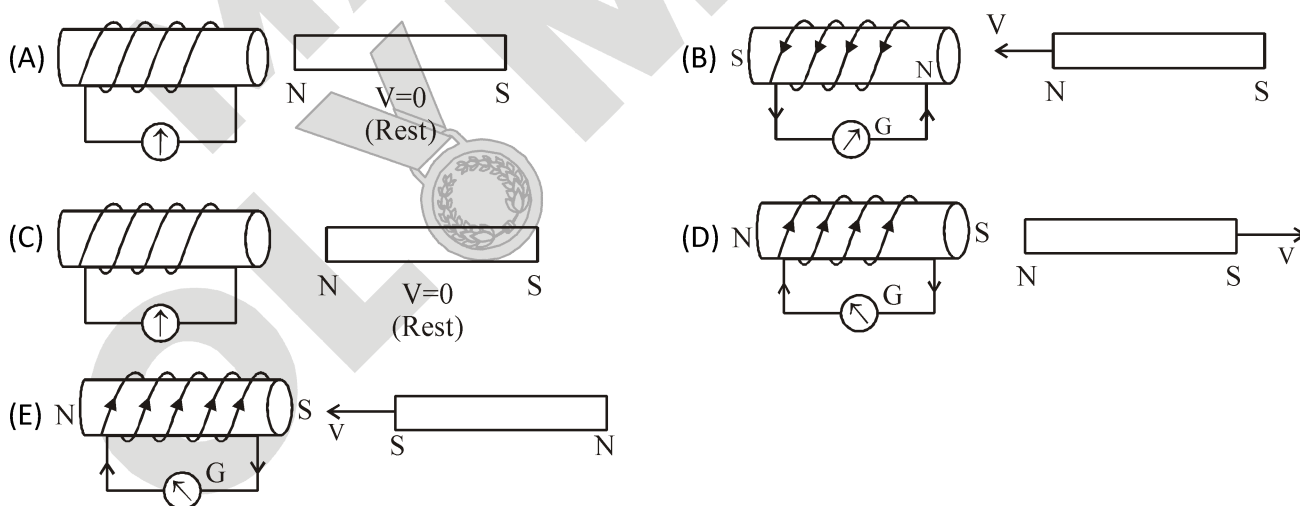
7.2 ELECTROMAGNETIC INDUCTION

When an electric current is passed through a conductor, a magnetic field is produced around the conductor. Faraday thought that as a magnetic field is produced by electric current, it should be possible to produce an electric current by the magnetic field. According to him, whenever there is a change in the magnetic lines of force associated with a conductor, an electromotive force (e.m.f.) is set up at the ends of the conductor which lasts as long as the change is taking place. This phenomenon is called electromagnetic induction.

(A) Faraday's Experiments : Wound an insulated copper wire on a wooden cylinder so as to form a solenoid coil. Connect the two ends of the coil to the galvanometer. A magnet is placed along the axis of the coil.

(i) When the magnet is stationary, there is no deflection in the galvanometer. The pointer reads zero as shown in figure (A).

(ii) When the north pole of the magnet is brought near the coil, the current flows in the coil in direction shown in the figure (B) and the galvanometer shows the deflection towards the right.



(iii) If we stop the motion of the magnet, the pointer of the galvanometer comes to the zero position as shown in figure (C). Thus the current in the coil flows so long as the magnet is moving. If the magnet is taken away from the coil, the current again flows in the coil but in the direction opposite to that shown in figure (D) and therefore the pointer of the galvanometer deflects towards the left side.

- (iv) If south pole of the magnet is brought towards the coil, the current in the coil flows in the direction opposite to that shown in figure (E) and so the pointer of the galvanometer deflects towards the left.
- (v) Similar deflection is observed in the galvanometer if the magnet is kept stationary and the coil is moved

(B) Conclusion :

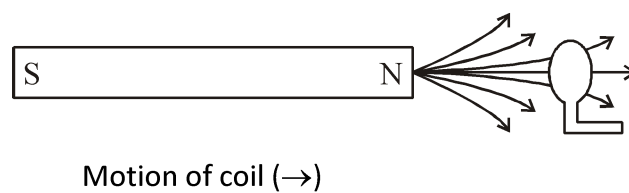
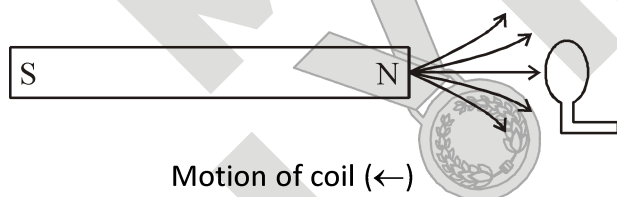
We conclude the following from the above activity.

- (a) A current flows through a coil as long as a magnet moves near the coil, the coil moves near the magnet or both of them move. So, a current flows in the coil when there is relative motion between the magnet and the coil.
- (b) While there is relative motion between the magnet and the coil, the magnetic field around the coil keeps changing. So, the changing magnetic field causes a current in the coil.
- (c) The direction of the current depends on the direction of the magnetic field. That is why it changes when the pole facing the coil is changed.
- (d) The direction of the current depends on whether the magnetic field around the coil is increasing or decreasing. The magnetic field around the coil increases as the coil and magnet come closer, and decreases as they move apart. That is why the current flows in one direction on moving the magnet toward the coil in the opposite direction on moving the magnet away from the coil.

A current produced by a changing magnetic field is called an induced current. So, **the phenomenon in which an electric current is induced in a circuit because of a changing magnetic field is called electromagnetic induction.**

(C) Explanation : When the magnet and coil are relatively at rest, the total number of magnetic lines of force due to the magnet passing through the coil (i.e. the magnetic flux linked with the coil) remains constant, therefore no e.m.f. is induced in the coil and the galvanometer shows no deflection.

When there is relative motion between the coil and magnet, the magnetic flux linked with the coil changes. If the coil is moved towards the magnet, the magnetic flux through the coil increases as shown in figure. Due to change in magnetic flux linked with the coil, an e.m.f. is induced in the coil. This e.m.f. causes a current to flow if the circuit of the coil is closed.



(D) Faraday’s law of electromagnetic induction : Faraday formulated the following two laws of the electromagnetic induction.

- (i) Whenever there is a change in magnetic flux linked with a conductor, an e.m.f. is induced. The induced e.m.f. lasts so long as there is a change in magnetic flux cut by the conductor.
- (ii) The magnitude of the e.m.f. induced is directly proportional to the rate of change of magnetic flux cut by the conductor. If the rate of change of magnetic flux remains uniform, a steady e.m.f. is induced. If change in flux is $\Delta\phi$ in time Δt , then induced e.m.f.,

$$E = \frac{\Delta\phi}{\Delta t}$$

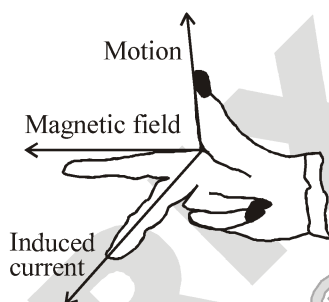
S.I. unit of induced e.m.f. is $\frac{\text{weber}}{\text{sec.}} = \text{volt}$

If the circuit of conductor is closed, a current flows in the conductor due to the e.m.f. induced across its ends.

$$i = \frac{1}{R} \frac{\Delta\phi}{\Delta t}$$

(E) Direction of induced e.m.f. : The direction of induced e.m.f. (and hence the direction of induced current) can be obtained by any of the following rules :

(I) Fleming’s right hand rule : Stretch the thumb, middle finger and forefinger of your right hand in such a way that mutually perpendicular to each other as shown in figure. If the forefinger indicates the direction of the magnetic field and the thumb indicates the direction of motion of the conductor, then the middle finger will indicate the direction of induced current.

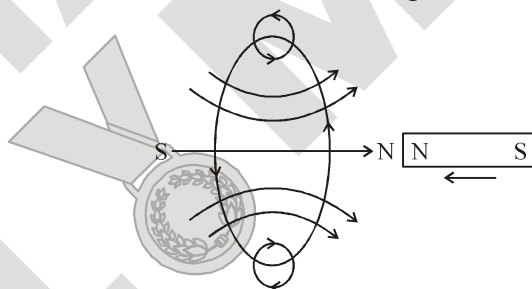


(II) Lenz’s law : This law gives us the direction of current induced in a circuit

According to Lenz’s law, the direction of induced current is such that it oppose the cause due to which it is induced.

The law refers to induced currents, which means that it applies only to closed circuits. If the circuit is open, there will be no induced current.

For example, In figure, when the magnet is moved towards the loop, a current is induced in the loop. The induced current produces its own magnetic field which opposes the motion of the magnet. Thus the induced current must be anticlockwise as shown in figure below.



8. DIRECT CURRENT AND ALTERNATING CURRENT

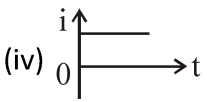
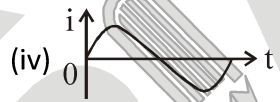
Many electrical devices are based on the electricity like Fans, mixies, CD players, motorized toys, etc., use motors. Motors are of different types. Some, like the motor in a toy car, work only on batteries, while others, like the motor of an electric pump, work on the household electric supply. Actually, the current drawn from a battery and the household supply are different in nature. When an electrical device such as a bulb is connected to a battery, the current in the circuit always flows from the positive terminal (higher potential) of the battery to the negative terminal (lower potential). A current that always flows in the same direction through an electrical device is called a direct current (DC). However, the direction of the current flowing through the bulb of a reading lamp connected to the household supply changes rapidly every second. Such a current is called an alternating current (AC).

(i) Direct Current (DC) : The electric current, whose magnitude and direction do not vary with time is called 'direct current'. Usually, DC is produced by a cell or a battery.

(ii) Alternating Current (AC) : The electric current, whose magnitude varies with time and direction reverses periodically, provided its amplitude is constant, is called 'alternating current'.

In India, the frequency of AC is 50 Hz i.e., 50 cycles per second. In one cycle, the direction of AC changes twice, thus, in one second, the direction of AC changes $50 \times 2 = 100$ times. In other words, AC changes direction after every $1/100$ second.

(iii) Difference between Direct Current (DC) & Alternating Current (AC)

Direct Current (D.C.)	Alternating Current (A.C.)
(i) A current whose magnitude does not change to with respect to time is called Direct Current.	(i) A current whose magnitude changes with respect time is called Alternating Current.
(ii) It is produced by cell and battery.	(iii) It is produced by thermal, water, wind, nuclear power plant.
(iii) It is less harmful.	(iii) It is more harmful.
(iv) 	(iv) 
(v) It is measured by ammeter.	(v) It is measured by hot wire instruments
(vi) It is base of electronics.	(vi) It is base of electricity

(iv) Advantages of AC over DC :

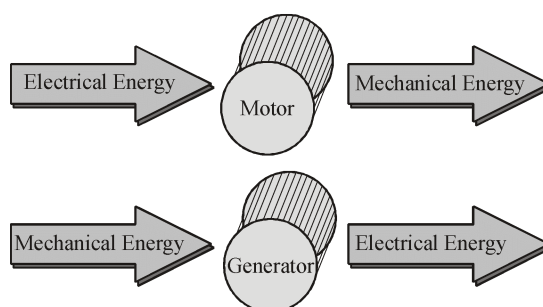
- (a) AC voltages can be easily increased (step up) or decreased (step down) with the help of transformers.
- (b) Long distance transmission takes place at high voltage (i.e., less current) to minimise heat losses. This is done easily by using AC voltage because an AC voltage can easily be increased by using a transformer.
- (c) The cost of generation of AC is less than that of DC.
- (d) AC devices are simple, robust and require less care as compared to DC devices.

(v) Disadvantages of AC over DC :

- (a) AC is more dangerous than DC.
- (b) A device operating at 220 V AC has to sustain a peak value of approximately 310 V.
- (c) For process like electrolysis or electroplating, AC cannot be used, only DC can be used.
- (d) An alternating current flows mainly on the surface of conductor (called skin effect). Thus, instead of a single thick wire, for AC, we have to use several thin wires twisted to form a main wire, which increases its cost of manufacturing.

9. ELECTRIC MOTOR AND GENERATOR

Electric motors and generators that work on DC or AC are only slightly different in construction. The principles of physics involved in both are the same. The fact that a current-carrying conductor experiences a force in a magnetic field is used in the electric motor. And, the fact that a changing magnetic field induces a current in a conductor is used in an electric generator. In an electric motor, electrical energy is converted into mechanical (kinetic) energy. On the other hand, a generator converts kinetic energy into electrical energy.



9.1 ELECTRIC MOTOR

An electric motor is a device which uses electricity to rotate a rod, known as the shaft. The rotation of the shaft can be used to rotate anything (e.g., a wheel, the blades of a fan, etc.) attached to it. The basic principal, design and working of a DC electric motor are described below.

Principle of a Electric Motor : A motor works on the principle that when current carrying coil is placed in a magnetic field then it experiences a force that force rotates the shaft attached to coil. In this way electric energy supplied to the motor is converted into the mechanical energy of rotation.

Construction of a DC Motor : The design of an electric motor is shown in figure (a). A motor basically consists of a **coil** placed in a magnetic field. The coil is formed by winding many turns of insulated copper wire over a soft iron core. The core and the coil together form the **armature**. The armature is fixed on the shaft of the motor and kept between the poles of strong magnet. The two free ends of the coil are connected to the two halves of a metallic split ring (a ring split in two separate parts). The split ring forms what is called the split-ring commutator or simply, commutator. When the shaft the two halves, C_1 and C_2 , of the commutator. The external conducting edges of C_1 and C_2 touch two conducting stationary brushes (usually made of carbon) B_1 and B_2 respectively. A potential difference is applied across the brushes by connecting them to a source of DC, for example, a battery.

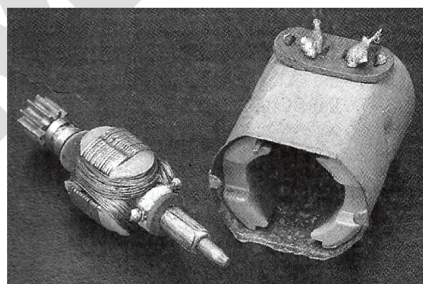
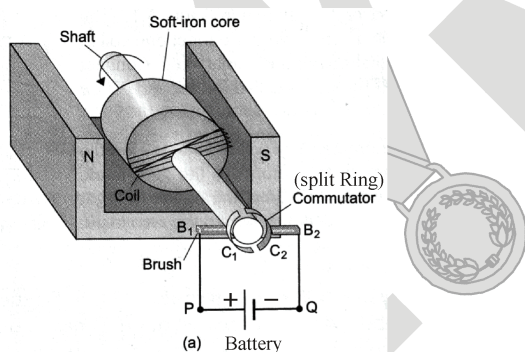


Figure (a) Construction of a DC motor

Figure (b) The essential parts of DC motor

Working of a DC motor :

(i) Current in the coil ABCD enters from the source battery through conducting brush B_1 and flows back to the battery through brush B_2 . The current in arm AB of the coil flows from A to B and in arm CD it flows from C to D, that is, opposite to the direction of current through arm AB. That is, the current flows along the path ABCD.

(ii) On applying Fleming's left hand rule, we find that the force acting on arm AB pushes it downwards while the force acting on arm CD pushes it upwards. Thus, the coil and the axle, mounted free to turn about an axis, start rotating [see figure (a)]

(iii) After half rotation, C_2 makes contact with the brush B_1 and C_1 with brush B_2 . Thus, the current in the coil gets reversed and flows along the path DCBA. As a result, the directions of force acting on the two arms AB and CD are also reversed. The arm AB of the coil that was earlier pushed down is now pushed up and the arm CD previously pushed up is now pushed down. Due to this, the direction of rotation of the coil remains unchanged [See fig. (b)]. The reversing of the current is repeated after every half rotation, giving rise to a continuous rotation of the coil and the axle in the anticlockwise direction.

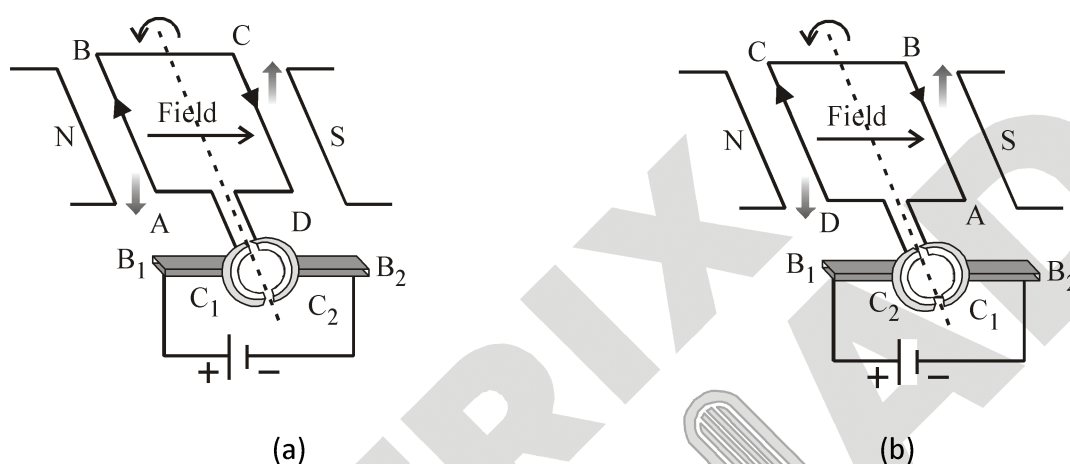
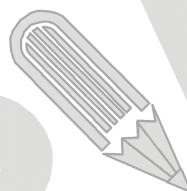


Figure : DC Motor



Focus Point

(i) The function of carbon brushes is to make contact with the rotating rings of the commutator and through them to supply current to the coil. It should be noted that any one brush touches only one ring at a time, so that when the coil rotates, the two brushes will touch both the rings one by one.

(ii) The function of commutator : In figure (a) the brush B_1 is connected to the positive terminal of the battery, and B_2 is connected to the negative terminal. So, a current flows in the coil along ABCD ($A \rightarrow B \rightarrow C \rightarrow D$). Figure (b) shows the position of the coil after half a rotation from the initial position. As a result of the rotation, the brushes with which the two halves of the commutator were in contact have got interchanged. This has reversed the battery connections to the two arms of the coil. Therefore, the current now flows along DCBA. That is, the direction of the current in the two arms of the coil has got reversed. Such a change takes place for each half-rotation. In this way, the commutator changes the direction of the current in the coil after each half-rotation.

(iii) If the commutator is not used, the direction of current in an arm of the coil will always remain the same. So, the direction of the force on the arm will not change, and the coil will not be able to complete one rotation. For example, when the arm AB is near the north pole, the downward force will turn it anticlockwise. And when it is near the south pole, the downward force will swing it back, clockwise. Thus, the rotation will not be completed.

9.2 GENERATOR OR DYNAMO

This is a device which convert mechanical energy into electrical energy using the principal of electromagnetic induction.

Principal of Generator :

When a conducting loop is rotated in a magnetic field, an electric current is induced in the loop. This fact is used in an electric generator, in which a coil is rotated in a magnetic field to produce electricity.

DC Generator

Construction of a DC generator :

Figure shows the basic design of a DC generator, which is very similar to that of a DC motor. The armature of the generator consists of a coil of many turns wound over a soft iron core. The armature is placed between the poles of a strong magnet. The ends of the coil are connected to a split-ring commutator. Two carbon brushes, B_1 and B_2 , press tightly against the two halves of the commutator. The brushes are connected to the fixed terminals, P and Q, of the generator. Electric devices such as an electric bulb can be connected to these terminals, as shown in the figure.

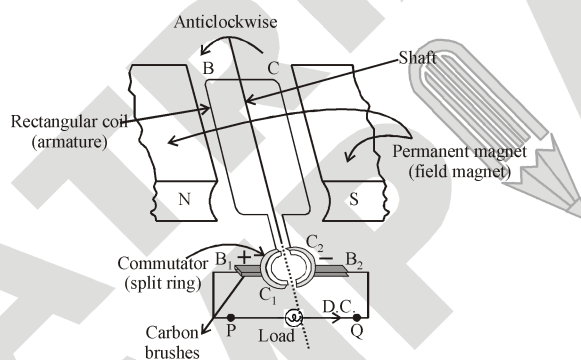


Figure : DC generator

To generate electricity, the shaft, on which the coil is mounted, needs to be rotated. Generally, this is done by a small diesel engine. In the case of the dynamo of a bicycle, the rotating wheel rotates the shaft. In power stations, steam, water or wind falling on the blades of a turbine rotates the generator's shaft. As the coil rotates in the magnetic field, electricity is generated. When an electrical device is connected across the terminals are left open, there is no current, but a potential difference appears between them.

Working of a DC generator

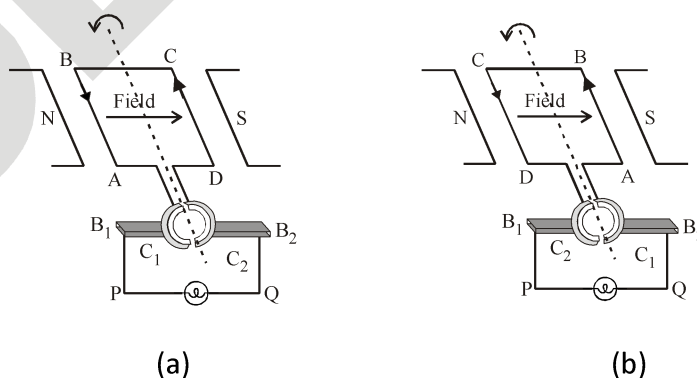


Figure : DC generator

Suppose that the generator coil ABCD is initially in the horizontal position. Again suppose that the coil ABCD is being rotated in the anticlockwise direction between the poles N and S of a horseshoes type magnet.

(a) As the coil rotates in the anticlockwise direction, the side AB of the coil moves down cutting the magnetic lines of force near the N-pole of the magnet and side DC moves up, cutting the lines of force near the S-pole of the magnet in figure. Due to this, induced current is produced in the sides AB and DC of the coil. On applying Fleming’s right hand rule to the sides AB and DC of the coil we find that the current in them are in the directions B to A and D to C respectively. Thus, we get an effective induced current in the direction BADC. Due to this the brush B_1 becomes a positive (+) pole and brush B_2 becomes negative (-) pole of the generator.

(b) After half revolution the sides AB and DC of the coil will interchange their positions. The side AB will come on the right hand side and start moving up whereas side DC will come on the left-hand side and start moving down. But when sides of the coil interchange their positions, then the two commutator half rings C_1 and C_2 automatically change their contacts from one carbon brush to the other. Due to this change, the current keeps flowing in the same direction in the circuit. The brush B_1 will always remain positive terminal and brush B_2 will always remain negative terminal of the generator. Thus, a DC generator supplies a current in one direction by the use of a commutator consisting of two half-rings of copper.

AC Generator

When a coil (conductor) is rotated in a magnetic field, the magnetic flux linked with it changes and therefore an alternating current is induced in the coil.

(i) Construction of AC generator : Figure shows the basic design of an AC generator. The armature of the generator consists of a coil of many turns wound over a soft iron core. The armature is placed between the poles of a strong magnet. The ends of the coil are connected to two cylindrical slip rings, C_1 and C_2 , mounted on the shaft. Each slip ring is permanently in contact with a carbon brush. The brushes are connected to the fixed terminals, P and Q. Electric devices such as an electric bulb can be connected to these terminals, as shown in figure.

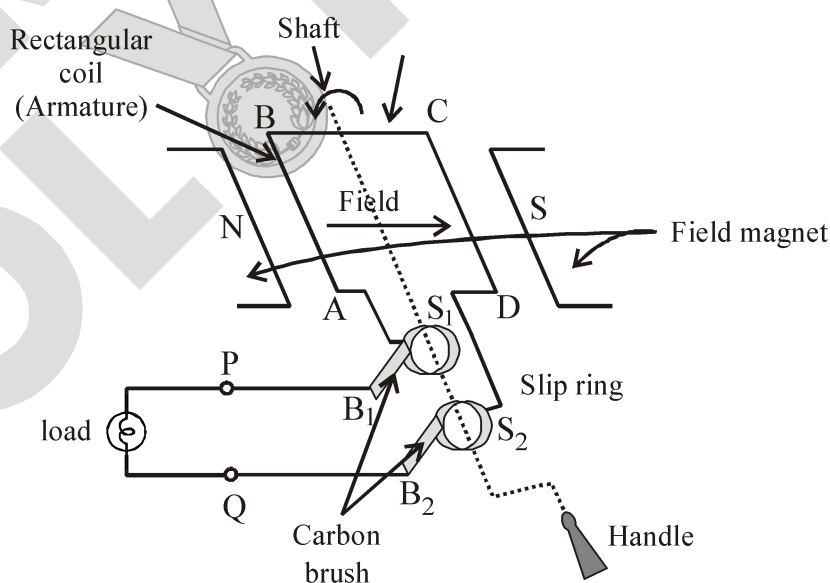


Figure : AC generator

(ii) **Working of AC generator** : Suppose that the generator coil ABCD is initially in the horizontal position. Again suppose that the coil ABCD is being rotated in the anticlockwise direction between the poles N and S of a horse-shoe type magnet.

(a). As the coil rotates in the anticlockwise direction, the side AB of the coil moves down cutting the magnetic lines of force near the N-pole of the magnet and side CD moves up, cutting the lines of force near the S-pole of the magnet. Due to this, induced current is produced in the sides AB and DC of the coil. On applying Fleming’s right-hand rule to the sides AB and DC of the coil, we find that the currents are in the directions B to A and D to C. Thus, the induced currents in the two sides of the coil are in the same direction and we get an effective induced current in the direction BADC or we can say from P to Q.

(b). After half revolution, the sides AB and DC of the coil will interchange their positions. The side AB will come on the right hand side and side DC will come on the left hand side. So, after half a revolution, side AB starts moving up and side DC starts moving down. As a result of this, the direction of induced current in each side of the coil is reversed after half a revolution and we find that effective induced current in the direction CDAB or we can say from Q to P. Since the direction of induced current in the coil is reversed after half revolution so that polarity (positive and negative) of the two ends of the coil also changes after half revolution.

The end of coil which was positive in the first half of rotation becomes negative in the second half. And the end which was negative in the first-half revolution becomes positive in the second half of revolution. Thus, in 1 revolution of the coil, the current changes its direction 2 times.

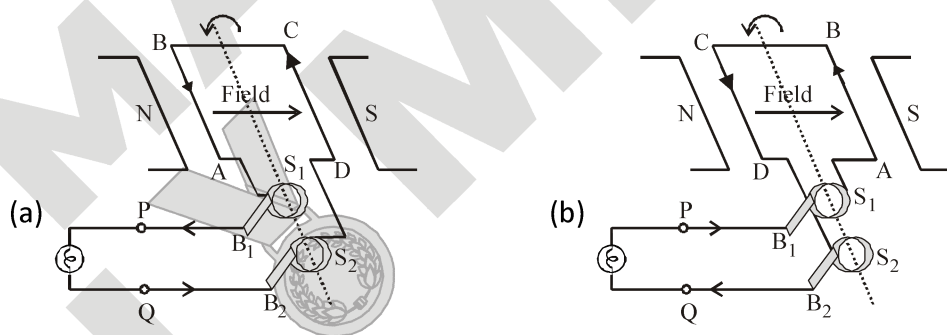


Figure : AC generator

After every half revolution, each side of the generator coil starts moving in the opposite direction in the magnetic field. The side of the coil which was initially moving upwards, after half revolution, it starts moving downwards. Due to the change in the direction of motion of the two sides of the coil in the magnetic field after every half revolution, the direction of current produced in them also changes after every half revolution.

10. DIFFERENCE BETWEEN AC GENERATOR AND DC MOTOR

S. No.	AC Generator	DC Motor
(i)	A generator is a device which converts the mechanical energy into electrical energy.	It is a device which convert electrical energy into mechanical energy.
(ii)	It works on the principle of electromagnetic induction.	It works on the principle of force acting on a current carrying conductor placed in a magnetic field.
(iii)	In a generator the mechanical energy is used in rotating the armature coil in a magnetic field so as to produce electrical energy.	In a DC motor, electrical energy is provided by the DC source to flow current in the armature coil placed in a magnetic field due to which the coil rotates.
(iv)	A generator makes use of two coaxial slip rings.	A DC motor makes use of two parts of a slip ring which act as a commutator.

11. DOMESTIC ELECTRIC CIRCUITS

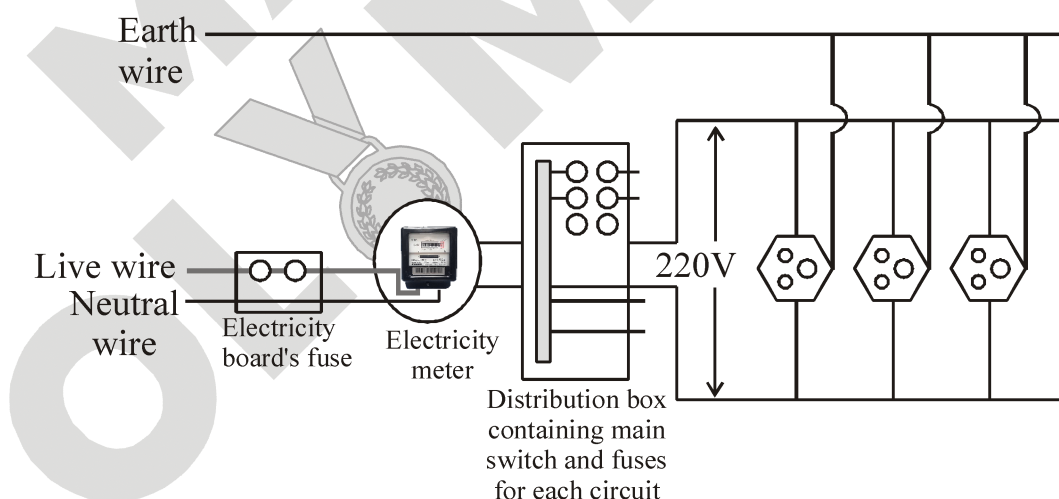


Figure : A domestic electric circuit

(i) The power supply to houses are given through overhead electric poles having aluminium wires or through underground cables. One wire of power supply is called live wire (or positive). Which has usually a red insulation cover. Another wire, with black insulation cover is called neutral wire (or negative). In our country, the potential difference between these two wires is 220 V.

(ii) These wires pass into an electricity meter through a main fuse at the meter-board in the house. The main fuse is joined in series with the live wire. Through the main switch, they are connected to the live wires in the house. The live wires supply electricity to separate circuits within the house. The live wires supply electricity to separate circuits within the house. The live wires supply electricity to separate circuits within the house. Mostly, two separate circuits are used, one of 15 A current rating for appliances with higher power ratings such as geysers, air conditioners, air coolers, refrigerators, etc. The other circuit is of 5A current rating for bulbs, tubelights, CFLs, fans, etc.

(iii) There is an earth wire, which has insulation of green colour, is usually connected to a metal plate deep in the earth near the house. This is used as a safety measure, particularly for the devices with a metallic body like electric press, toaster, table fan, refrigerator, etc. The metallic body is connected to the earth wire, which provides a low-resistance conducting path for the current. Thus, any leakage of current to the metallic body of the device will go into the earth through the earth wire, Thus, the user will not get a severe electric shock.

(iv) In each separate circuit, different devices can be connected across the live and neutral wires. Each device has a separate switch to 'on' or 'off' the flow of current through it. All the devices in domestic electric circuits are joined in parallel in other that each device has equal potential difference.

Overloading :

We know that electric fuse in a circuit prevents damage to the appliances and the circuit due to overloading.

Overloading is a condition in which excessively high current flows through a circuit.

Overloading can occur in the many ways :

(i) When the live wire and the neutral wire come into direct contact, the resistance in the circuit becomes very low and the current in the circuit abruptly increases. This is called **short-circuiting**. This usually occurs when the insulation of wires is damaged or there is a fault in the appliance.

(ii) Overloading can also occur due to an accidental hike in the supply voltage.

(iii) Sometimes, overloading is caused by connecting too many devices to a single socket.

Earthing of electric appliances:

In household circuits, we have three wires, the live wire, the neutral wire and the earth wire. One end of the earth wire is buried in the earth. we connected the earth wire to the metal cases of the electrical appliance by using a three-pinplug.

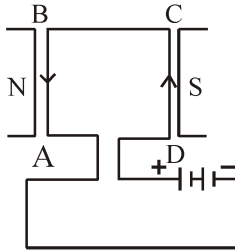
The metal casing of the appliance will now always remain at the zero potential of the earth. We say that the appliance has been earthed or grounded. If, by chance, the live wire touches the metal case of the electric iron(or any other appliance) which has been earthed, then the current passes directly to the earth through the earth wire.

it does not need our body to pass the current and therefore, we do not get an electric shock. Actually, a very heavy current flows through the earth wire and the fuse of household wiring blows out or melts. and it cuts off the power supply. In this way, earthing also saves the electrical appliance from damage due to excessive current.

SOLVED EXAMPLES

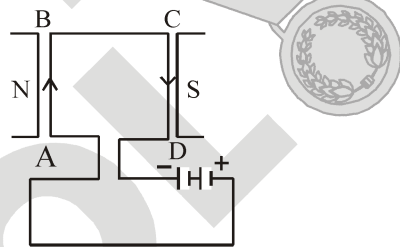
SE. 1

A rectangular coil ABCD is placed between the pole pieces of a horse-shoe magnet as shown in figure.



- (i) What is the direction of force on each arm?
- (ii) What is the effect of the forces on the coil?
- (iii) How is the effect of force on the coil changed if the terminals of the battery are interchanged?

Ans. (i) In figure, the current in the coil is in direction DCBA. By Fleming's left hand rule, in the arm AB, the force is outward at right angle to the plane of the coil. On the arm BC no force acts. On the arm CD, the force is inwards perpendicular to the plane of the coil. On the arm DA, no force acts, (ii) The force on the arms AB and CD are equal in magnitude, but opposite in direction. They form a clockwise couple. So the coil will rotate clockwise with the arm AB coming out and the arm CD going in. (iii) On interchanging the terminals of the battery, the coil will rotate anticlockwise.



SE. 2

Draw a diagram representing the magnetic field inside and outside a solenoid through which a current is flowing and mark with arrows, the direction of the current in the solenoid and the direction of the magnetic lines of force. Also mark the polarity at the faces of the solenoid.

Ans.

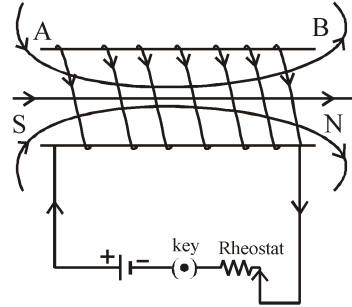


Figure shows the magnetic lines of force due to current carrying solenoid. The direction of current in the solenoid at the face A is clockwise, so it will have the south (S) polarity and the face B of the solenoid will have the north (N) polarity.

SE. 3

In the diagram, A and B represent two straight wires carrying equal currents in a direction at right angle to the paper and downward into the paper. Sketch separately the magnetic lines of force produced by each current carrying conductor. Give reason why the magnetic field at K will be zero.

Ans.

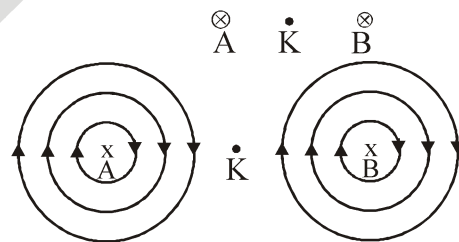


Figure shows the sketch of magnetic lines of force produced by current in wires A and B. The point K is equidistant from the wires A and B, the wires A and B carry equal current, so the magnetic fields at K due to wires A and B are equal in magnitude but opposite in direction. Magnetic field due to the wire A is downward to the plane of paper, while due to the wire B it is upward to the plane of paper. So the net magnetic field at K is zero.

SE. 4

What is an electromagnet ? What does it consist of?

Ans. An electromagnet is a temporary strong magnet and is just a solenoid with its winding on a soft iron core.

An electromagnet consists of a soft iron core placed inside a solenoid. The current in the solenoid can be adjusted with a rheostat in the circuit having a battery and a key. An electromagnet acquires the magnetic properties only when an electric current is passed through the solenoid. Once the current is switched off, it almost loses its magnetic properties as the retentivity (the ability to retain magnetism) of soft iron is very low.

SE. 5

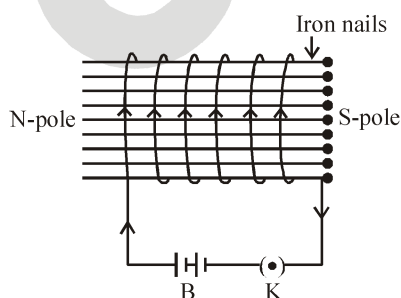
Name one material in each case which is used to make a (i) permanent magnet (ii) temporary magnet.

Ans. (i) Alnico (Aluminium, Nickel-Cobalt alloy of iron) (ii) Soft iron.

SE. 6

Describe an activity to show how can you make an electromagnet in your school laboratory.

Ans. Take some iron nails of equal lengths. Wound an insulated copper wire around them so as to form a solenoid. Connect this solenoid to battery (B) and a key (K) as shown in figure. When the key is closed, current flows through the insulated copper wire and the nails inside the solenoid get magnetised, with one of their ends as north-pole and the other as south-' pole. This arrangement. becomes an electromagnet.



SE. 7

Why do iron filings arrange themselves in a definite pattern when sprinkled around a magnet?

Ans. This is due to the reason that each piece of iron filings becomes a small magnet and experiences a force in a certain direction in the magnetic field due to the magnet.

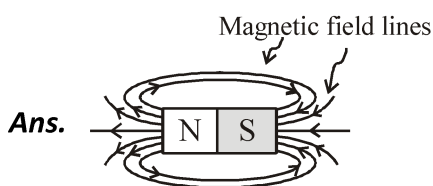
NS. 1

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

Ans. Compass needle gets deflected due to attractive or repulsive interactions between its magnetic field and the magnetic field of the bar magnet.

NS. 2

Draw magnetic field lines around a bar magnet.



NS. 3

List the properties of magnetic lines of force.

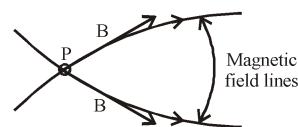
Ans. Some characteristic properties of the magnetic field lines are listed below:

- (a) Magnetic field lines start at the north pole and end at the south pole.
- (b) Magnetic field lines do not intersect each other, because there can't be two directions of the magnetic field at any one point.
- (c) The degree of closeness of the field lines depends upon the strength of the magnetic field. Stronger the field, closer are the field lines.

NS. 4

Why don't two magnetic lines of force intersect each other?

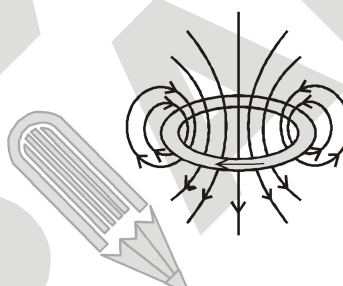
Ans. The direction of magnetic field (B) at any point is obtained by drawing a tangent to the magnetic field line at that point. In case, two magnetic field lines intersect each other at the point P as shown in figure, magnetic field at P will have two directions, shown by two arrows, drawn to each magnetic field line at P, which is not possible.



NS. 5

Consider a circular loop of wire lying in the plane of the table. Let the current pass through the loop clockwise. Apply the right-hand rule to find out the direction of the magnetic field inside and outside the loop.

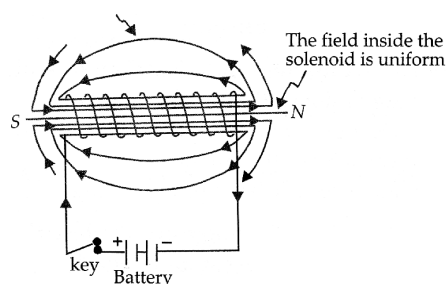
Ans. The magnetic field inside and outside the current-carrying loop is shown in the figure given below.



NS. 6

The magnetic field inside the solenoid in given region is uniform. Draw a diagram to represent it.

Ans. The field lines inside the solenoid are in the form of parallel straight lines. This indicates that the magnetic field inside the solenoid is uniform. This is shown in diagram below.



NS. 7

The magnetic field inside a long straight solenoid carrying current

- (a) is zero.
- (b) decreases as we move towards its end.
- (c) increases as we move towards its end.
- (d) is the same at all points.

Choose the correct option.

Ans. The correct answer is (b)
The magnetic field inside a current-carrying solenoid is constant in magnitude and direction, and acts along the axis of the solenoid.

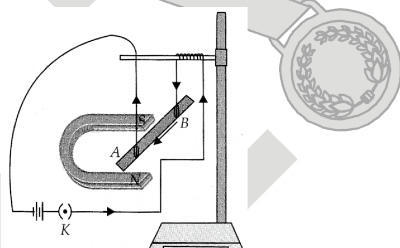
NS. 8
Which of the following property of a proton can change while it moves freely in a magnetic field? (There may be more than one correct answer)

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

Ans. The correct answers are (c) and (d).
Each moving charged particle in a magnetic field experiences a force. The direction of force experienced by a positive charge (i.e., a proton) is given by Fleming's left hand rule. The force acting on the proton would change both velocity and momentum.

NS. 9
In an activity demonstrating the force acting on a current-carrying conductor placed in a magnetic field as shown in figure, how do we think the displacement of rod AB will be affected if

(a) current in rod AB is increased?
(b) a stronger horse-shoe magnet is used?
(c) length of the rod AB is increased?



Ans. The displacement of the rod AB

(a) will increase when the current in rod AB is increased.
(b) will increase when a stronger horse-shoe magnet is used.
(c) will increase when length of the rod AB is increased.

NS. 10
A positively-charged particle(alpha-particle) projected towards west is deflected towards north by a magnetic field. The direction of magnetic field is

(a) towards south (b) towards east
(c) downward (d) upward

Ans. The correct answer is (d).
Apply Fleming's left-hand rule, we can infer that the direction of magnetic field is upwards.

NS. 11
State Fleming's left-hand rule.

Ans. Fleming's left-hand rule state as follows: Stretch out the thumb, the forefinger, and the second(middle) finger of the left hand so that these are at right angles to each other. If the forefinger gives the direction of the magnetic field (N to S), the second (middle) finger gives the direction of current (+ to -), then the thumb gives the direction of the force acting on the conductor.

Since the conductor will move in the direction of the force acting on it hence the thumb gives the direction of motion of the conductor.

NS. 12
What is the principle of an electric motor?

Ans. An electric motor is based upon the magnetic effect of current. When an electric current is passed through a conductor placed at right angle to a magnetic field, a force perpendicular both to the magnetic field and the conductor acts on it. This makes the conductor to move. The direction of motion of the conductor is given by Fleming's left-hand rule.

NS. 13
What is the role of the split ring in an electric motor?

Ans. The role of split ring is to change the direction of current flowing through the coil after each half-rotation.

NS. 14

Explain different ways to induce current in a coil.

- Ans.** (a) By keeping the magnet in a fixed position and moving the coil towards and away from the magnet.
 (b) By pushing or pulling a bar magnet into or away from a coil.

NS. 15

State the principle of an electric generator.

- Ans.** Electric generators are based on the principle of electromagnetic induction, that is, when a conductor is moved perpendicular to magnetic field or vice-versa, an induced current is produced.

NS. 16

Name some source of direct current.

- Ans.** Dry cell, Lead-acid battery

NS. 17

Which sources produce alternating current?

- Ans.** AC generator, Thermal power station, Hydroelectric station.

NS. 18

Choose the correct option. A rectangular coil of copper wire is rotated in a magnetic field. The direction of the induced current changes once in each

- (a) two revolutions
- (b) one revolution
- (c) half revolution
- (d) one fourth revolution

- Ans.** The correct answer is (c).

NS. 19

Name two safety measures commonly used in electric circuits and appliances.

- Ans.** The safety devices that are used in electric circuits and appliances are, (a) Fuse (b) Earthing. MCBs are also used as safety devices in electrical circuits.

NS. 20

An electric oven of 2 kW power rating is operated in a domestic electric circuit 220 V that has a current rating of 5 A. What result do you expect? Explain.

- Ans.** Rating of the oven = 2 kW Line voltage = 220 V

Then, Current drawn by the oven = $\frac{\text{Power}}{\text{Voltage}}$

$$= \frac{2\text{kW}}{220\text{V}} = \frac{2000}{220} \text{A} = 9.1 \text{A}$$

Since the domestic circuit is rated for 5 A, and the oven draws a current of 9.1 A, the following might result.

- (a) The fuse (if there) will blow off.
- (b) The wiring may burn out.

NS. 21

What precaution should be taken to avoid the overloading of domestic electric circuits?

- Ans.** (a) Do not connect appliances exceeding the total load capacity of the circuit.
 (b) Provide fuses/MCBs of proper rating.

NS. 22

Which of the following correctly describes the magnetic field near a long straight wire?

- (a) The field consists of straight line perpendicular to the wire.
- (b) The field consists of straight lines parallel to the wire.
- (c) The field consists of radial lines originating from the wire.
- (d) The field consists of concentric circles centred on the wire.

- Ans.** The correct option is (d).

NS. 23

The phenomena of electromagnetic induction is

- (a) the process of charging a body
- (b) the process of generating magnetic field due to a current passing through a coil
- (c) producing induced current in a coil due to relative motion between a magnet and the coil
- (d) the process of rotating a coil of an electric motor

- Ans.** The correct option is (c).

NS. 24

The device used for producing electric current is called a:

- (a) generator (b) galvanometer
(c) ammeter (d) motor

Ans. The correct option is (a).

NS. 25

The essential difference between AC generator and a DC generator is that

- (a) AC generator has an electromagnet while a DC generator has permanent magnet,
(b) DC generator will generate a higher voltage,
(c) AC generator will generate a higher voltage,
(d) AC generator has slip rings while the DC generator has a commutator.

Ans. The correct option is (d).

NS. 26

At the time of short-circuit, the current in the circuit

- (a) reduces substantially
(b) does not change
(c) increases heavily
(d) varies continuously.

Ans. The correct answer is (c).

NS. 27

State whether the following statements are true or false.

- (a) An electric motor converts mechanical energy into electrical energy.
(b) An electric generator works on the principle of electromagnetic induction.
(c) The field at the centre of a long circular coil carrying current will be parallel straight lines.
(d) A wire with a green insulation is usually the live wire.

Ans. (a) False: An electric motor converts electric energy into mechanical energy.

- (b) True
(c) True
(d) False: A wire with a green insulation is usually the earth wire.

NS. 28

List three sources of magnetic fields.

Ans. (i) Natural and artificial magnets
(ii) Electromagnets (iii) A conductor, a coil and a solenoid carrying current (iv) Earth.

NS. 29

How does a solenoid behave like a magnet? Can you determine the north and south poles of a current carrying solenoid with the help of a bar magnet? Explain.

Ans. A current carrying solenoid behaves like a bar magnet and the polarities of its ends depend upon the direction of current flowing through it. In order to determine the polarities of its ends, place it in a brass hook and suspend it with a long thread so that it moves freely. Bring north pole of a bar magnet near one of its ends. In case the solenoid moves towards the bar magnet, that end of the solenoid is a south pole and in case the solenoid moves away from the magnet, that end of the solenoid is its north pole. The polarity of the other end of the solenoid can similarly be determined.

NS. 30

When is the force experienced by current-carrying conductor placed in a magnetic field is largest?

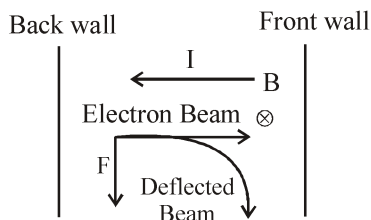
Ans. The force experienced by a current-carrying conductor placed in a magnetic field is the largest when the direction of the current is at right angles to the direction of the magnetic field.

NS. 31

Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of the magnetic field?

Ans. The direction of current I is opposite to the direction electron beam as shown in figure. Since the beam is deflected to the right side, the force, F acting on the beam is as shown.

Applying Fleming's left hand rule, it is found that magnetic field, B is acting vertically downwards (i.e., perpendicular to the plane of the paper and directed inwards) as shown by \otimes .



NS. 32

Draw a labelled diagram of an electric motor. Explain its principle and working. What is the function of a split-ring in an electric motor?

Ans. An electric motor is a device for converting electric energy into mechanical energy. Thus, an electric motor is the reverse of an electric generator.

There are two types of electric motors : (i) AC motor and (ii) DC motor. We shall here be describing DC motor. The principle of a DC motor is very much different from that of an AC motor. It is important to remember that all the electric appliances like fan, air-conditioner, coolers, washing machines, mixers and blenders work on AC (house-hold power supply) and as such have AC motors installed in them. Principle : When a coil carrying current is placed in a magnetic field, it experiences a torque. As a result of this torque, the coil begins to rotate. Construction : It consists of the following five parts:

1. **Armature** : The armature $abcd$ consists of a large number of turns of insulated copper wire wound over a soft iron core.
2. **Field Magnet**: The magnetic field B is supplied by a permanent magnet NS.
3. **Split-ring or Commutator** : These are two halves of the same metallic ring. The ends of the armature coil are connected to these halves which also rotate with the armature.

4. Brushes or Sliding Contacts : These are two flexible metal plates or carbon rods B_1 and B_2 which are so fixed that they constantly touch the revolving rings.

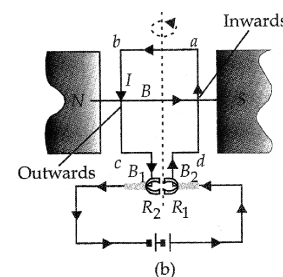
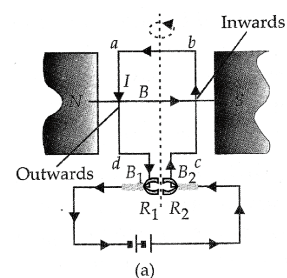
5. Battery : The battery consists of a few cells and is connected across the brushes. The brushes pass the current to the rings from where it is carried to the armature.

Working : The working of a DC motor will be clear from the following discussion.

(a) Let us suppose that the battery sends current to the armature in the direction shown in figure.

Applying **Fleming's Left Hand Rule (Motor Rule)**, we find that arm ad experiences a force which is acting outwards and perpendicular to it and arm bc experiences a force which is acting inwards and perpendicular to it. These two forces form a couple whose moment (i.e., torque) makes the armature rotate in the clockwise direction.

(b) After the armature has completed half a revolution (i.e., has turned through 180°), the direction of current in the arms ad and bc is reversed. Now arm bc experiences an outward force and arm ad experiences an inward force, as shown in figure. The armature thus continues to rotate about its axis in the same, i.e., clockwise direction.



Split-ring in an electric motor takes the current from the battery and passes it on to the coil through the brushes after reversing its direction after every half revolution. The reversal of current in the coil reverses the direction of forces acting on the sides of the loop.

NS. 33

Name some devices in which electric motors are used.

Ans. Electric fans, water-pumps, coolers, refrigerators, mixers, blenders, washing machines etc.

NS. 34

A coil of insulated copper wire is connected to a galvanometer. What would happen if a bar magnet is

- (i) pushed into the coil?
- (ii) withdrawn from inside the coil?
- (iii) held stationary inside the coil?

Ans. (i) The magnetic field lines (flux) linked with the coil changes (i.e., increases). As a result of this, an induced current flows in the coil and the galvanometer shows a momentary deflection (say towards right) i.e., the needle of the galvanometer moves momentarily in one direction.

(ii) The magnetic field lines (flux) linked with the coil changes (i.e., decreases). As a result of this, an induced current flows in the coil but in a direction opposite to that in case (i).

(iii) When the magnet is held stationary in the coil, there will be a magnetic flux in the coil but it will remain constant. Since the magnetic flux does not change, there is no induced current in the coil and the galvanometer shows no deflection.

NS. 35

Two circular coils A and B are placed close to each other. If the current in the coil A is changed, will some current be induced in the coil B? Given reason.

Ans. By changing current in the coil A, a current will be induced in the coil B which is placed close to A. This is due to the reason that magnetic field lines linked with A also get linked with B due to its being close to A. When the current in A changes, magnetic field lines linked with A change. Obviously, magnetic field lines linked with B also change. As a result of this, current is induced in the coil B. (This phenomenon is called mutual induction).

NS. 36

- State the rule to determine the direction of a
- (i) magnetic field produced around a straight conductor carrying current.
 - (ii) force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it, and
 - (iii) current induced in a coil due to its rotation in a magnetic field.

Ans. (i) **Right-Hand Thumb Rule** : Imagine the straight conductor in your right hand such that the thumb points in the direction of current. The direction of curling of fingers of the right hand gives the direction of magnetic field lines,

(ii) **Fleming's Left-Hand Rule** (or Motor rule): Stretch the thumb, the first finger and the central finger of the left hand so that they are mutually perpendicular to each other. If the first (fore)finger points in the direction of the magnetic field, the central finger points in the direction of current, then the thumb points in the direction of motion of the conductor (i.e., direction of force on the conductor),

(iii) **Fleming's Right-Hand Rule** (or Dynamo rule) : Stretch the thumb, the first finger and the central finger of the right hand so that they are mutually perpendicular to each other. If the first (fore)finger points in the direction of magnetic field, the thumb points in the direction of motion of the conductor, then the central finger points in the direction of induced current.

NS. 37

Explain the underlying principle and working of an electric generator by drawing a labelled diagram. What is the function of brushes?

Ans. An AC generator converts mechanical energy into electric energy.

Principal : Whenever in a closed circuit (i.e., a coil), the magnetic field lines changes, an induced current is produced.

Construction: It consists of the following four parts.

1. Armature : Armature (ABCD), also called the coil, consists of a large number of turns of insulated copper wire wound over a soft iron core. It revolves around an axle between the two poles of a strong magnet.

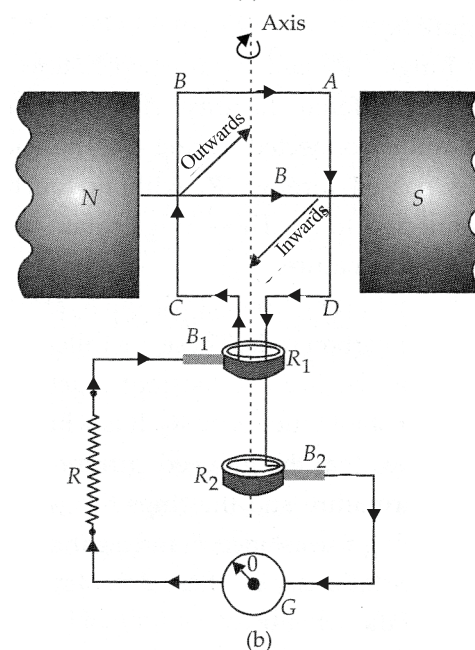
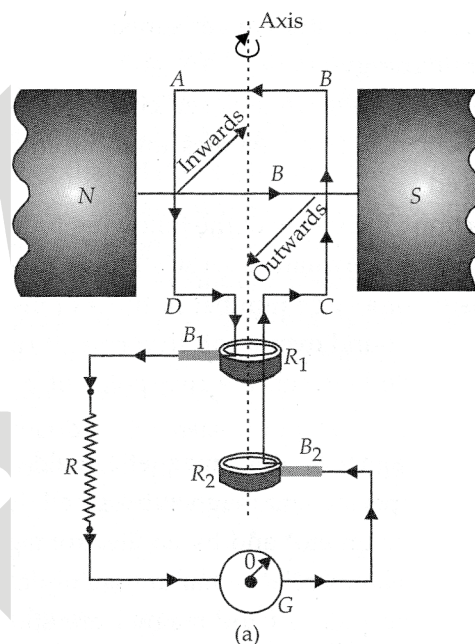
2. Field Magnet : The magnetic field (B) is supplied by a permanent magnet in a small dynamo (also called a magneto) and by an electromagnet in case of a big commercial dynamo (usually called a generator). The poles of the magnet are shown as N-S in figure (a).

3. Slip Rings : R_1 and R_2 are two hollow metal rings held at different heights. The end D of the armature coil is connected to ring R_1 . The end C of the coil is passed through R_1 without touching it and is connected to R_2 . These rings rotate with the rotation of the armature.

4. Brushes or Sliding Contact: B_1 and B_2 are flexible metal plates or carbon rods. These are called brushes or sliding contacts. B_1 is in constant touch with R_1 and B_2 is in constant touch with R_2 . It is with the help of these brushes that the induced current is passed on from the armature and the rings to the external circuit containing a resistance, R and a galvanometer, G. Brushes are stationary i.e. these do not rotate with the rotation of the armature.

Working : The working of an AC generator is clear from figure (a) and (b). As the armature is rotated about an axis (shown dotted), the magnetic flux linked with the armature changes. Therefore, an induced current is

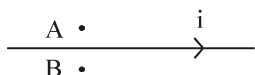
produced in the armature, (a) Let us suppose that the armature ABCD is rotating anticlockwise so that the arm AD moves inwards and BC moves outwards. Applying Fleming's right-hand rule, we find that the induced current in the armature and in the circuit is as shown in fig. (a) due to which G shows deflection towards the right.



EXERCISE – I

ONLY ONE CORRECT TYPE

- A magnetic field line is used to find the direction of-
(A) south-north (B) a bar magnet
(C) a compass needle (D) magnetic field
- An electric current passes through a straight wire. Magnetic compasses are placed at the points A and B. What is your observation ?

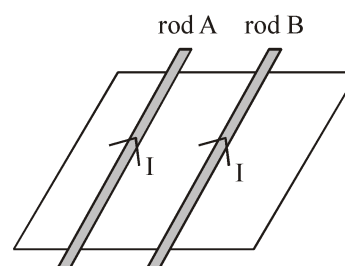


- Their needles will not deflect
 - Only one of the needles will deflect
 - Both the needles will deflect in the same direction
 - The needles will deflect in the opposite directions.
- The magnetic field lines due to a straight wire carrying a current are :
(A) Straight (B) Circular
(C) Parabolic (D) Elliptical
- The magnetic field lines inside a long current-carrying solenoid are nearly
(A) Straight (B) Circular
(C) Parabolic (D) Elliptical
- The direction of the force on a current-carrying wire placed in a magnetic field depends on :
(A) The direction of the current but not on the direction of the field
(B) The direction of the field but not on the direction of the current
(C) The direction of the current as well as the direction of the field
(D) Neither the direction of the current nor the direction of the field
- An electric current can be produced in a closed loop
(A) By connecting it to a battery, but not by moving a magnet near it
(B) By moving a magnet near the loop, but not by connecting a battery
(C) By connecting it to a battery, as well as by moving a magnet near it
(D) Neither by connecting a battery nor by moving a magnet near it

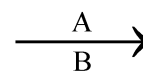
- Which of the following involves electromagnetic induction ?
(A) A rod is charged with electricity
(B) An electric current produces a magnetic field.
(C) A magnetic field exerts a force on a current carrying wire.
(D) The relative motion between a magnet and a coil produces an electric current.
- You have a coil and a bar magnet. You can produce an electric current by moving :
(A) The magnet, but not the coil
(B) The coil, but not the magnet
(C) Either the magnet or the coil
(D) Neither the magnet nor the coil
- An electric motor :
(A) provides a constant potential difference
(B) measures electric current
(C) either the magnet or the coil
(D) neither the magnet nor the coil
- A device that can be used to produce an electric current in a circuit is :
(A) an ammeter (B) a motor
(C) a generator (D) a galvanometer
- A commutator changes the direction of current in the coil of :
(A) a DC motor
(B) a DC motor and an AC generator
(C) a DC motor and a DC generator
(D) an AC generator
- An AC generator is connected to an electric appliance. In 10 revolutions of the armature, the current in the appliance changes direction :
(A) 5 times (B) 10 times
(C) 20 times (D) 40 times
- Which of the following describes the common domestic power supplied in India ?
(A) 220V, 100 Hz (B) 110 V, 100 Hz
(C) 220V, 50 Hz (D) 110V, 50 Hz
- When a bar magnet is broken into two pieces :
(A) we will have a single pole on each piece
(B) each piece will have two unlike poles
(C) each piece will have two like poles
(D) none of these

15. Magnetic field intensity is :
 (A) Scalar
 (B) Vector
 (C) Same times scalar sometimes vector
 (D) Nothing can be said
16. A cylindrical bar magnet is kept along the axis of a circular coil. If the magnet is rotated about its axis, then :
 (A) a current will be induced in the coil
 (B) no current will be induced in the coil
 (C) only emf will be induced in the coil
 (D) an emf and current both will be induced in the coil
17. The space around a magnet in which the presence can be felt by other magnet or magnetic material is called
 (A) Electric field (B) Magnetic field
 (C) Magnetic flux (D) None of these
18. A current carrying power line carries current from west to east. What will be the direction of magnetic field 1m above is ?
 (A) North to south (B) South to west
 (C) East to west (D) West to east
19. A wire of length 0.04m is placed perpendicular to a uniform magnetic field of magnitude 0.30 T. Calculate the force on the wire when the current flowing through it is 5.0 A.
 (A) 10 N (B) 0.06 N
 (C) 0.01 N (D) 0.02 N
20. A wire carrying a current of 5A is placed perpendicular to a magnetic induction of 2T. The force on each centimeter of the wire is :
 (A) 1 N (B) 100 N
 (C) 0.1 N (D) 10 N
21. Which of the following statement is not correct about two parallel conductors carrying equal currents in the same direction ?
 (A) Each of the conductors will experience a force
 (B) The two conductors will repel each other.
 (C) There are concentric magnetic lines of force around each conductor
 (D) Each of the conductors will move if not prevented from doing so

22. In the given figure, force on rod A and rod B are in direction respectively :



- (A) Rightward direction, Leftward direction
 (B) Rightward direction, Rightward direction
 (C) Leftward direction, Leftward direction
 (D) Leftward direction, Rightward direction
23. Lenz's law is a consequence of the law of conservation of :
 (A) energy (B) momentum
 (C) angular momentum (D) charge and mass
24. Current is induced in a coil by electromagnetic induction when :
 (A) Only the coil moves in a magnetic field
 (B) Only the magnet is moved into a coil
 (C) Coil and the magnet move with respect to each other
 (D) None of the above
25. An electric current is passed through a straight wire. Magnetic compasses are placed at the points A and B. True statement is :



- (A) Their needles will not deflect
 (B) Only one of the needles will deflect
 (C) Both the needles will deflect in the same direction
 (D) The needles will deflect in the opposite direction.

PARAGRAPH TYPE

PARAGRAPH # 1

The strength of the magnetic field produced by a current-carrying circular coil (or circular wire) depends on (i) Current flowing through the coil. (ii) Radius of the circular coil (iii) Number of turns of wire in the circular coil.

26. A long horizontal power line is carrying a current of 100 A in the east-west direction. The direction of magnetic field at a point 1.0 m below it is :
 (A) South to north (B) North to south
 (C) East to west (D) West to east
27. What type of curve we get, between magnetic field and distance along the axis of a current carrying circular coil ?
 (A) Straight line (B) Circular
 (C) Parabolic (D) None of these
28. If a current carrying straight conductor is placed in east-west direction, then the direction of the force experienced by the conductor due to earth's magnetic field is:
 (A) downward (B) upward
 (C) east west (D) west east

PARAGRAPH # 2

In house hold electric circuits, the mains supply is delivered to our homes using three core cable. The cable consists of three wires, live wire, neutral wire and earth wire. The live wire is at potential difference of 220 volts. The live wire is connected to electric meter through a fuse or a circuit breaker of higher rating. The neutral wire is connected directly to the electric meter.

29. Short circuit occurs when a live wire comes in contact with _____.
 (A) neutral wire (B) earth wire
 (C) conductor (D) insulator
30. Switches are connected in the
 (A) neutral wire (B) live wire
 (C) earth wire (D) fuse wire
31. For running appliances of higher rating such as electric iron, geysers, room heater etc, the domestic power line used is of :
 (A) 5A (B) 10A
 (C) 15A (D) 20A

MATCH THE COLUMN TYPE

32. Column I

Column II

- | | |
|--|--|
| (a) The end of bar magnet pointing towards north | (p) Almost straight lines inside a magnet |
| (b) The direction of field lines at the centre of the loop | (q) South to north |
| (c) Magnetic field lines at the centre of the loop | (r) North pole |
| (d) Generator | (s) Conversion of mechanical energy into electrical energy |
- (A) a-r, b-q, c-p, d-s
 (B) a-q, b-r, c-s, d-p
 (C) a-p, b-s, c-q, d-r
 (D) a-s, b-p, c-r, d-s

33. Column I

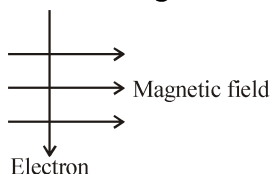
Column II

- | | |
|------------------------------|--|
| (a) Oersted | (p) Direction of force on a current-carrying wire placed in a magnetic field |
| (b) Fleming's left-hand rule | (q) Showed electricity and magnetism were related phenomena |
| (c) Right hand thumb rule | (r) Electromagnetic induction |
| (d) Michael Faraday | (s) Maxwell's corkscrew rule |
- (A) a-r, b-q, c-p, d-s
 (B) a-q, b-r, c-s, d-p
 (C) a-p, b-s, c-q, d-r
 (D) a-q, b-p, c-s, d-r

EXERCISE – II

VERY SHORT ANSWER TYPE

1. Name some sources of direct current.
2. Which sources produce alternating current ?
3. Draw magnetic field lines around a bar magnet.
4. An electron enters a magnetic field at right angles to it, as shown in figure below. Find the direction of force acting on the electron will be :

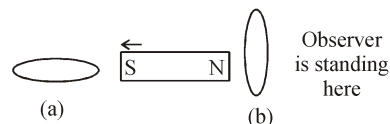


5. A positively-charged particle (alpha-particle) projected towards west is deflected towards north by a magnetic field. What will be the direction of magnetic field ?
6. A rectangular coil of copper wire is rotated in a magnetic field. How many times the direction of the induced current changes in one revolution ?
7. How can you find the direction of a magnetic field at a point through which the magnetic line of force is given ?
8. Sketch the shape of magnetic field lines near a straight wire carrying a current.
9. How will you show that the magnetic field produced by a current-carrying wire decreases with distance from the wire ?
10. A circular wire is carrying a current. Sketch the shape of the magnetic field lines in a plane that is perpendicular to the plane

SHORT ANSWER TYPE

1. What is the role of the split ring in an electric motor ?
2. Imagine that you are sitting in a chamber with your back to one wall. An electron beam, moving horizontally from back wall towards the front wall, is deflected by a strong magnetic field to your right side. What is the direction of magnetic field ?
3. Two circular coils A and B are placed closed to each other. If the current in the coil A is changed, will some current be induced in the coil B ? Give reason.

4. List the properties of magnetic lines of force.
5. Give the direction of induced current in the following figure.



LONG ANSWER TYPE

1. How does a solenoid behave like a magnet ? Can you determine the north south poles of a current carrying solenoid with the help of a bar magnet ? Explain.
2. A coil of insulated copper wire is connected to a galvanometer. What will happen if a bar magnet is (i) pushed into the coil, (ii) withdrawn from inside the coil, (iii) held stationary inside the coil.
3. State the rule to determine the direction of a :
(i) magnetic field produced around a straight current-carrying conductor.
(ii) force experienced by a current-carrying straight conductor placed in a magnetic field which is perpendicular to it, and
(iii) current induced in a coil due to its rotation in a magnetic field.
4. Describe an experiment to show that an electric current produces a magnetic field.
5. Describe an experiment to show that a magnetic field exerts a force on a current-carrying wire.

TRUE / FALSE TYPE

1. Fleming's left hand rule is used to find the direction of the magnetic field due to a straight current.
2. Maxwell's right-hand thumb rule is used to find the direction of the magnetic field due to a straight current.
3. The magnetic field at the centre of a current carrying coil is perpendicular to the plane of the coil.
4. When a coil is moved towards a bar magnet placed perpendicular to it, an electric current is induced in the coil.
5. If a coil and a magnet are moved in the same direction and with the same speed. An electric current will be induced in the coil.

SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : MAGNETIC EFFECT OF ELECTRIC CURRENT)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

NOTES :

1. In the status, put “completed” only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.



Space for Notes :

A large area for writing notes, consisting of 25 horizontal dotted lines spaced evenly down the page.



LIGHT : REFLECTION AND REFRACTION

3

Concepts

Introduction

1. Characteristics of light
2. Basic definition related to the light
3. Reflection of light
4. Plane mirror
 - 4.1 Difference between real and virtual image
 - 4.2 Characteristics of the image formed by a plane mirror
5. Reflection from spherical mirror
6. Refractive index
7. Refraction of light
 - 7.1 Laws of refraction
8. Refraction through glass slab
9. Apparent depth
 - 9.1 Effect of refraction of light
10. Total internal reflection
11. Spherical lenses

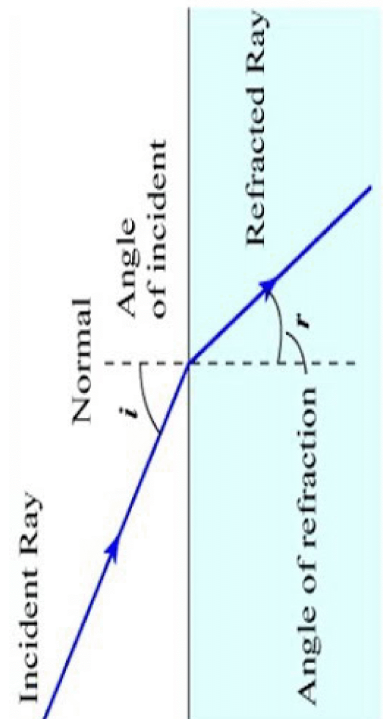
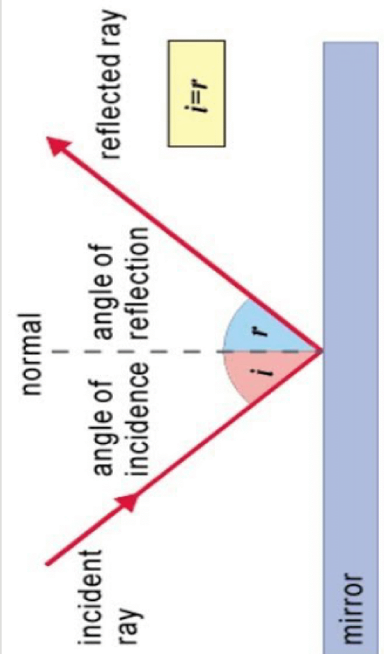
Solved Examples

NCERT Solutions

Exercise – I (Competitive Exam Pattern)

Exercise – II (Board Pattern Type)

Answer Key





INTRODUCTION

'Seeing' is one of the most common things we do. When light from an object enters our eyes, we see the object. This light can be that emitted by the object, as in the case of an electric bulb or a red-hot iron nail. It can also be the light bouncing off an object like a book. An object that emits light is a source of light. During the day, the sun acts as a natural source of light. Candles, oil lamps and electric bulbs are sources of light made by us. Most common phenomenon involving light can be understood by thinking of light as a wave, certain phenomenon can be explained only if we think of light as being made up of particles. We now understand that light shows the characteristics of both a wave and a particle.

1. CHARACTERISTICS OF LIGHT

- (i) Light has dual nature i.e. both wave and particle nature.
- (ii) Light does not need a material medium to travel, i.e., it can travel through a vacuum too. The best example of this is light travelling from the sun to the earth across vast expanses of space that have no material (or matter). Compare this with sound, which is also a wave. Sound needs a material medium to travel.
- (iii) Light waves travel at a tremendous speed-whose value scientists have fixed at 3×10^8 m/s. According to current scientific theories, no material particle can travel at a speed greater than that of light.
- (iv) A medium in which light can travel freely over large distances is called a transparent medium. Water, glycerine, glass and clear plastics are transparent. A medium in which light cannot travel is called opaque. Wood, metals, bricks, etc., are opaque. In materials like oil, light can travel some distance, but its intensity reduces rapidly. Such materials are called translucent.
- (v) The speed of light changes when it travels from one medium to another.
- (vi) Light travels from one point to another in a straight line which is known as rectilinear propagation of light.
- (vii) The light gets reflected when it falls on polished surfaces like mirror.
- (viii) The frequency of light remains same in all mediums.
- (ix) The light undergoes refraction when it travels from one transparent medium to another.

2. BASIC DEFINITION RELATED TO THE LIGHT

(A) Source of light : A body which emits light or reflect the light falling on it in all possible direction is said to be the source of light. The source can be point one or an extended one. the sources of light are of two types :

(i) Luminous Source : Any object which by itself emits light is called as a luminous source.

e.g. : Sun and stars (natural luminous sources), electric lamps, candles and lanterns (artificial luminous sources).

(ii) Non-luminous Source : Those objects which do not emit light but become visible only when light from luminous objects falls on them. They are called non-luminous sources.

e.g. : Moon, planets (natural non-luminous sources), wood, table (artificial non-luminous sources).

(B) Medium of light : Substance through which light propagates or tends to propagate is called medium of light.

(i) Transparent Object : Bodies that allow to pass light through them i.e. transmit light through them, are called transparent bodies.

e.g. : glass, water, air etc.

(ii) Translucent Object : Bodies that can transmit only a part of light through them are called translucent objects.

e.g. : Frosted or ground glass, greased paper, paraffin wax.

(iii) Opaque Object : Bodies that do not allow light to pass through them at all are said to be opaque object.

Eg. Chair, desk etc.



Focus Point

Depending on composition optical medium are divided into two type.

Homogeneous medium : An optical medium which has a uniform composition throughout is called homogeneous medium.

e.g. Vacuum, distilled water, pure alcohol, glass plastics, diamond, etc.

Heterogeneous medium : An optical medium which has different composition at different points is called heterogeneous medium.

E.g. Air, muddy water, fog, mist, etc.

(C) Ray of Light : The straight line path along which the light travels in a homogeneous medium is called a ray. It is represented by an arrow head on a straight line, the arrow head represents the direction of propagation of light.

(D) Beam of light : A bundle of rays is called a beam. It is of following three types :

(i) Convergent beam : It is a beam in which diameter of beam decreases in the direction of ray.

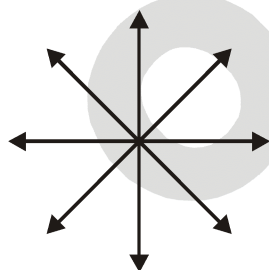
(ii) Divergent beam : It is a beam in which all the rays meet at a point when produced backward and the diameter of beam goes on increasing as the rays proceed forwards.

(iii) Parallel beam : It is a beam in which all the rays constituting the beam move parallel to each other and diameter of beam remains same.

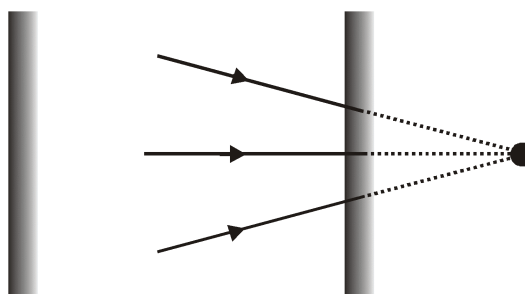
(E) Object : An optical object is decided by incident rays only. It is of two kinds :

(i) Real object : When the incident rays diverge in all the directions and the point of divergence gives the position of real object.

(ii) Virtual object : When the incident rays converge at a point and the point of convergence gives the position of virtual object.



Real object



Virtual object



Focus Point

Virtual object cannot be seen by human eye because for an object or image to be seen by eyes, rays received by eyes must be diverging.

3. REFLECTION OF LIGHT

(A) Definitions of Reflection :

The phenomena of bouncing back of light in same medium after striking at the interface of two media is called reflection of light.

(B) General definitions about Reflection :

(i) **Mirror** : A smooth polished surface from which regular reflection can take place is called mirror. MM' is the mirror as shown in figure.

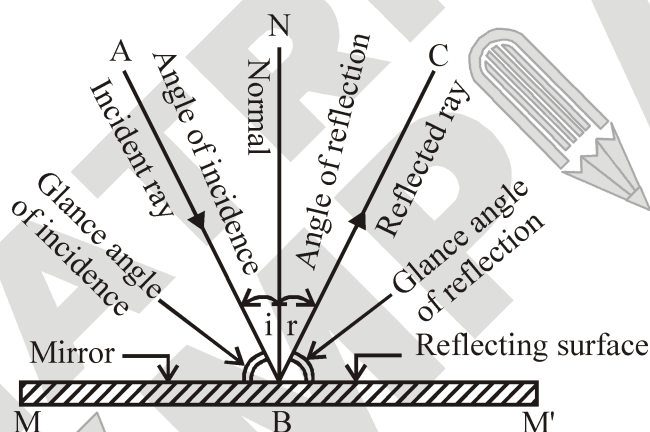


Figure : Reflection of light

(ii) **Incident ray** : A ray of light which travels towards the mirror is called incident ray. Ray AB is incident ray in figure.

(iii) **Point of incidence** : The point on the mirror, where an incident ray strikes is called point of incidence. 'B' is the point of incidence in figure.

(iv) **Reflected ray** : A ray of light which bounces off the surface of a mirror, is called reflected ray. BC is reflected ray in figure.

(v) **Normal** : the perpendicular drawn at the point of incidence, to the surface of mirror is called normal. BN is normal in figure.

(vi) **Angle of incidence** : The angle made by the incident ray with the normal is called angle of incidence. $\angle ABN$ is the angle of incidence in figure. It is denoted by $\angle i$.

(vii) **Angle of reflection** : The angle made by the reflected ray with the normal is called angle of reflection. $\angle CBN$ is the angle of reflection in figure. It is denoted by $\angle r$.

(viii) **Glance angle of incidence** : The angle which the incident ray makes with the mirror is called glance angle of incidence. $\angle MBA$ is the glance angle of incidence in figure.

(ix) **Glance angle of reflection** : The angle which the reflected ray makes with the mirror is called glance angle of reflection. $\angle M'BC$ is the glance angle of reflection in figure.

Types of Reflection :

(i) Regular reflection : The reflection of a parallel beam of light from a mirror so that the reflected rays are parallel to each other as shown in figure (a) are called regular reflection. Regular reflection takes place from the objects like looking glass, still water, oil, highly polished metals, etc.

(ii) Irregular reflection : The reflection of light from a rough irregular surface such as walls of a room, page of a book randomly in various directions not parallel to each other as shown in figure (b) are called irregular reflection. The reflection which takes places from ground, walls, trees, suspended particles in air, and a variety of other objects, which are not very smooth, is irregular reflection.

Note : Laws of reflection are always valid no matter whether reflection is regular or irregular.

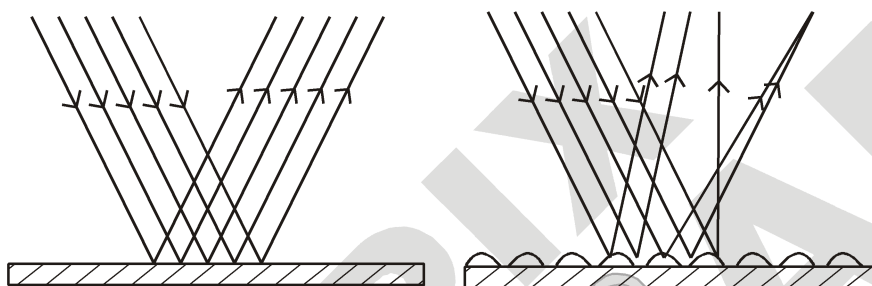


Figure : (a) Regular reflection

(b) Irregular reflection

Laws of reflection : The phenomenon of reflection is governed by following two laws :

(i) First law : The incident ray, the reflected ray and the normal to the reflecting surface at the point of incidence, all lie in same plane.

(ii) Second law : The angle of incidence is equal to the angle of reflection. $\angle i = \angle r$

Note : The laws of reflection are valid for any smooth reflecting surface irrespective of geometry.

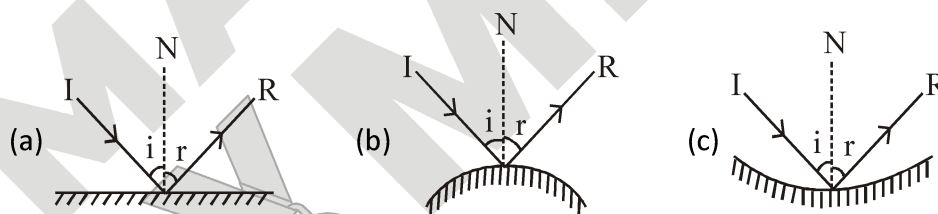


Figure : Mirrors

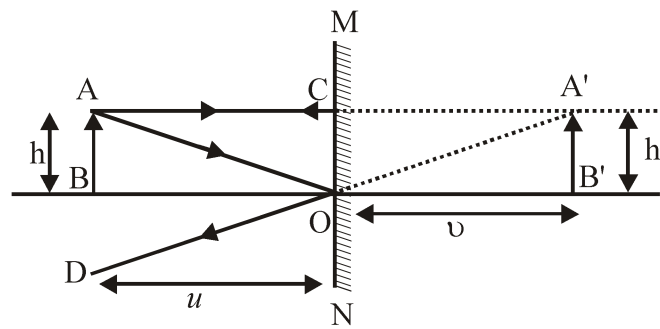
4. PLANE MIRROR

A highly polished plane (flat) surface is called a plane mirror, e.g. looking glass. The having short, oblique lines represents the back side of the plane mirror. The image formed by a plane mirror can be seen only by looking into the mirror.

Formation of image by plane mirror

- The image formed by the mirror is a virtual image and it is erect (up right).
- The image in a plane mirror lies as far behind the mirror as the object is in front of the mirror, i.e., object distance (u) = image distance (v).





- The image is of the same size as the object.

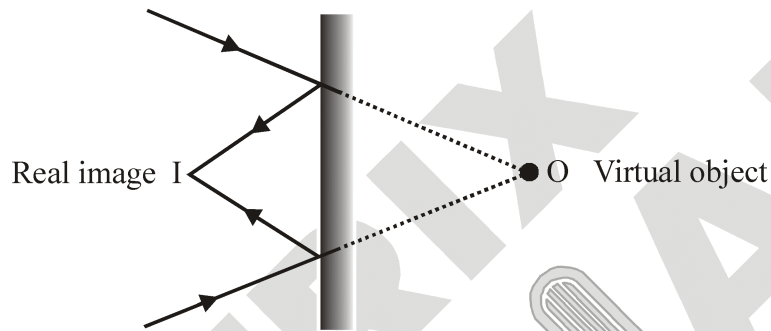


Figure : Plane mirror showing real image formation of a virtual object

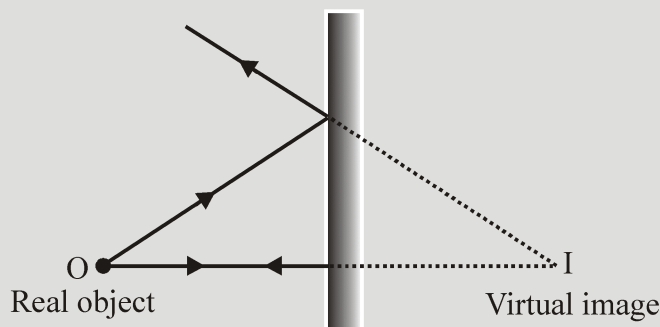
[∵ AB (height of the object) = A'B' (height of the image).]



Focus Point

An optical image is decided by reflected or refracted rays only. It is of two types :

(a) Real image : This is formed due to real intersection of reflected or refracted rays. Real image can be obtained on screen.



Plane mirror forming virtual image of a real object

(b) Virtual image : This is formed due to apparent intersection of reflected or refracted light rays. Virtual image can't be obtained on screen.

4.1 DIFFERENCE BETWEEN REAL AND VIRTUAL IMAGE

S.No.	Real image	Virtual image
1.	A real image is formed when two or more reflected rays meet at a point in front of the mirror.	A virtual image is formed when two or more rays appear to be coming from a point behind the mirror.
2.	A real image can be obtained on a screen.	A virtual image cannot be obtained on a screen.
3.	A real image is inverted with respect to the object.	A virtual image is erect with respect to the object.

4.2 CHARACTERISTICS OF THE IMAGE FORMED BY A PLANE MIRROR

- (i) The image formed by a plane mirror is virtual.
- (ii) The image formed by a plane mirror is erect.
- (iii) The size of the image formed by a plane mirror is same as that of the size of the object. If object is 10 cm high, then the image of this object will also be 10 cm high.
- (iv) The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of it. Suppose, an object is placed at 5 cm in front of a plane mirror then its image will be at 5 cm behind the plane mirror.
- (v) The image formed by a plane mirror is laterally inverted, i.e., the right side of the object appears as the left side of its image and vice-versa.

Lateral inversion

When an asymmetric object is placed in front of plane mirror, then the right side of the object appears to be the left side of image and the left side of the object appears to be the right side of its image. This change of sides of an object seen in the image is called left-right inversion or lateral inversion. The image is inverted side ways, thus, also called 'side ways inversion' (see figure).

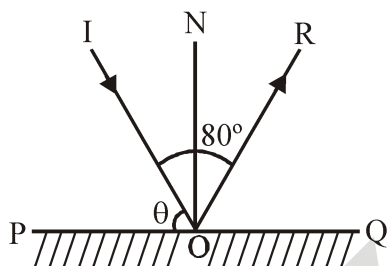


Figure : Lateral inversion of image in a Plane mirror

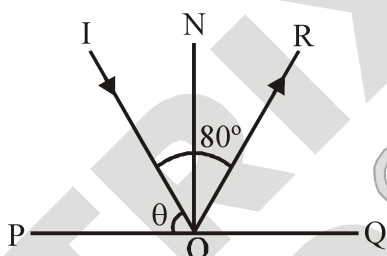
Example 1

A ray of light is incident on a plane mirror making an angle θ with it.

If the angle between the incident and reflected rays is 80° , find the value of θ .



Solution :



Because $\angle i = \angle r$ and $\angle IOR = 80^\circ = \angle i + \angle r = 2\angle i$ or $\angle i = 40^\circ$

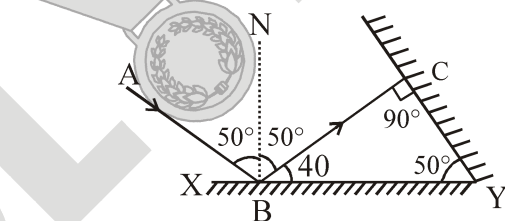
Now $\angle PON = \angle POI + \angle ION$

$90^\circ = \theta + \angle i = \theta + 40^\circ$ or $\theta = 50^\circ$

Example 2

Light ray AB incidents on a polished surface XY at an angle of 50° . The second polished surface is placed in such a way that the reflected ray BC from polished surface XY retraces its path. Find the angle of inclination of two polished surface.

Solution :



Ray BC retraces its path when A fall on second polished surface perpendicularly, so as per figure $\angle BYC$ will be equal to 50° .

Example 3

A ray falls on a plane mirror, making an angle 30° with mirror, then after reflection find the angle between incident ray and reflected ray.

Solution :

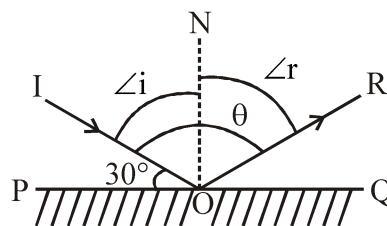
$$i + 30^\circ = 90^\circ$$

Angle of incidences, $i = 90 - 30 = 60^\circ$

So, angle of reflection, $r = 60^\circ$

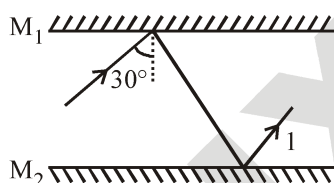
Angle between incident ray and reflected ray,

$$i + r = 60 + 60 = 120^\circ$$



Example 4

Two mirror are placed parallel to each other according to given figure. What will be the angle made by rays-1 with mirror M_1 , after third reflection in degree ?



Solution :

$$\angle OAB = 30^\circ$$

$$\angle BAC = \angle OAB = 30^\circ (i = r)$$

$$\angle DCA = \angle BAC = 30^\circ (\text{alternate interior angles})$$

$$\angle DCE = \angle ACD = 30^\circ (i = r)$$

$$\angle CEF = \angle DCE = 30^\circ (\text{alternate interior angles})$$

$$\angle DEF = 90^\circ$$

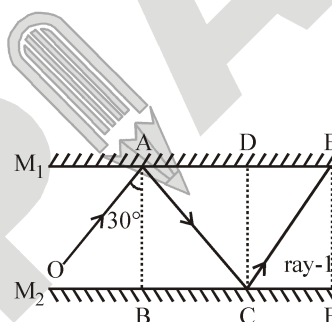
$$\angle DEF = \angle DEC + \angle CEF$$

$$\Rightarrow 90^\circ = \angle DEC + \angle CEF$$

$$\Rightarrow \angle DEC = 90^\circ - 30^\circ$$

$$\Rightarrow \angle DEC = 60^\circ$$

\therefore The angle made by ray-1 with mirror m_1 , after third reflection = $\angle DEC = 60^\circ$.



5. REFLECTION FROM SPHERICAL MIRROR

Spherical Mirror :

(A) Definition :

A mirror whose reflecting surface is a part of a hollow sphere of glass is known as spherical mirror. For example, a dentist uses a curved mirror to examine the teeth closely, large curved mirrors are used in telescopes. These are of two types convex and concave. In concave mirror, reflecting surface is concave but in convex mirror, reflecting surface is convex.



Figure : Convex mirror

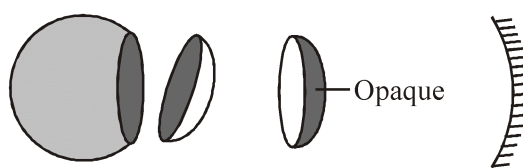
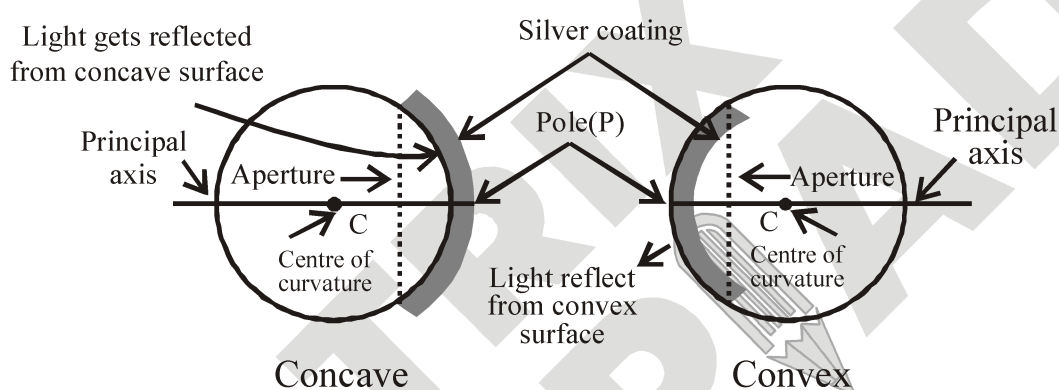


Figure : Concave mirror

(B) Concave and Convex Mirror :

Convex mirror is a spherical mirror, whose inner (cave type) surface is silvered and reflection takes place at the outer (convex) surface. Concave mirror is a spherical mirror, whose outer bulged surface is silvered and reflection takes place from the inner hollow (cave type) surface.

(C) Some terms related to spherical mirror :



- (i) **Pole (P)** : The central point of a mirror is called its pole.
- (ii) **Centre of curvature (C)** : The centre of the sphere of which the mirror is a part is called centre of curvature.
- (iii) **Radius of curvature (R)** : The radius of the sphere of which the mirror is a part is called radius of curvature.
- (iv) **Principal axis** : The straight line joining the pole and the centre of curvature is called the principal axis.
- (v) **Aperture** : The size of the mirror is called its aperture.
- (vi) **Principal focus (F)** :

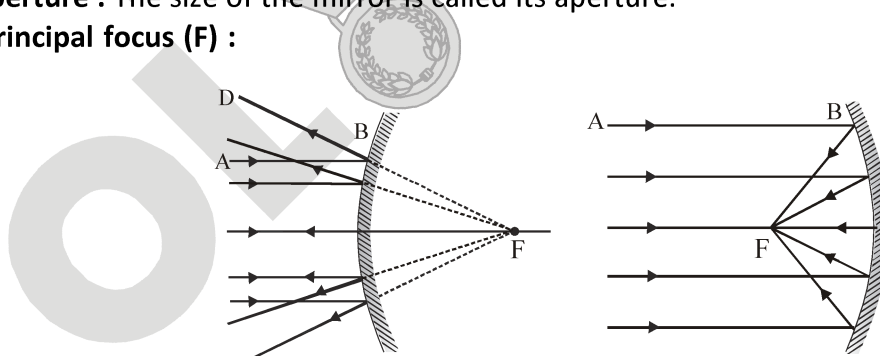


Figure : Convex mirror and Concave mirror

- (vii) **Focal length (f)** : The distance between the pole and the focus is called the focal length. The focal length is half the radius of curvature.
- (viii) **Focal plane** : A plane passing through the principal focus and at right angles to the principal axis of a spherical mirror is called the focal plane.

(D) Rules for the formation of images by concave and convex mirrors :

(i) A ray incident parallel to the principal axis actually passes (concave) or appears to pass (convex) through the focus.

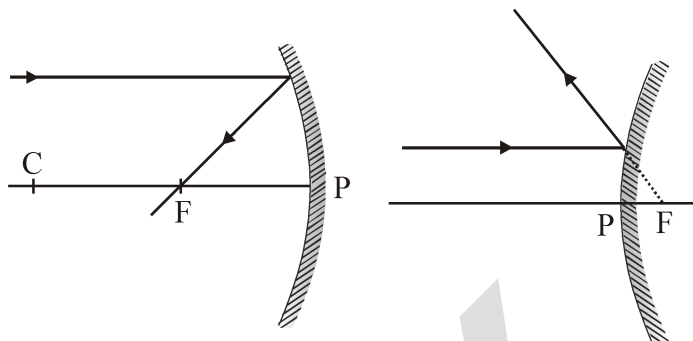


Figure : Concave mirror and Convex mirror

(ii) A ray incident through the centre of curvature (C) falls normally and is reflected back along the same path.

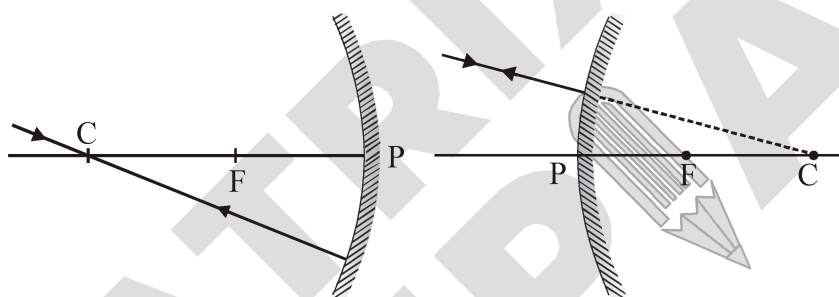


Figure : Concave mirror and Convex mirror

(iii) A ray incident through the focus is reflected parallel to the principal axis.

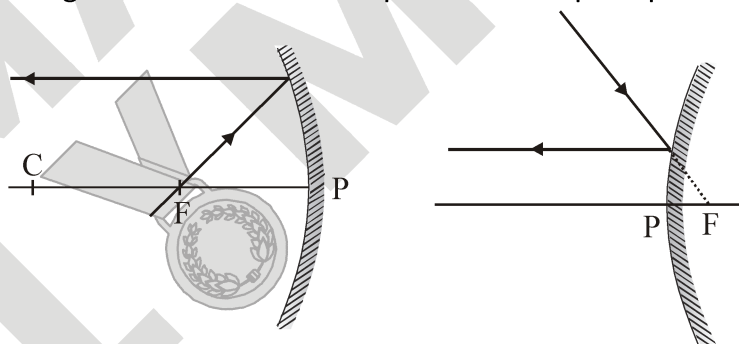


Figure : Concave mirror and Convex mirror

(E) Formation of Images by convex mirror :

(i) When the object is placed at infinity then image is formed at the focus. The image formed is virtual, erect and extremely diminished.

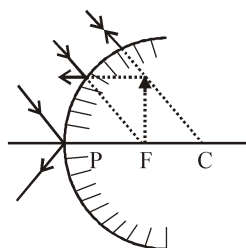


Figure : Convex mirror

(ii) When the object is placed between infinity and pole then the image is formed between the focus and the pole. The image formed is virtual, erect and diminished.

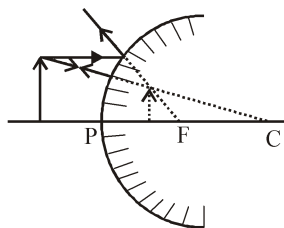


Figure : Convex mirror

Image formation by a convex mirror :

The image formed by a convex mirror is always behind the mirror, that is, it is always virtual and erect. Also, the size of image is always diminished, that is, its size is always smaller than that of the object.

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

(F) Formation of images by concave mirror :

(i) When the object is placed between the pole and the focus, then the image formed is virtual, erect and magnified.

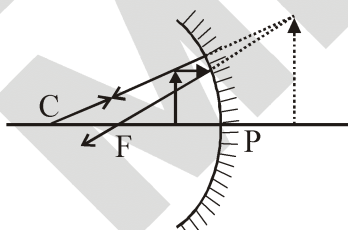


Figure : Convex mirror

(ii) When the object is placed at the focus then the image is formed at infinity. The image is extremely magnified.

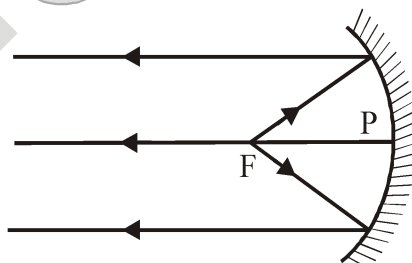


Figure : Concave mirror

(iii) When the object is placed between the focus and the centre of curvature then the image is formed beyond the centre of curvature. The image formed is real, inverted and bigger than the object.

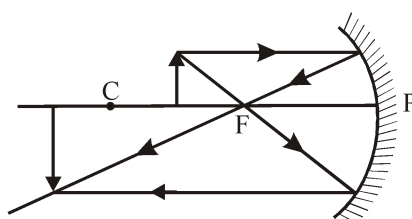


Figure : Concave mirror

(iv) When the object is placed at the centre of curvature, then the image is formed at the centre of curvature. The image formed is real, inverted and equal to the size of the object.

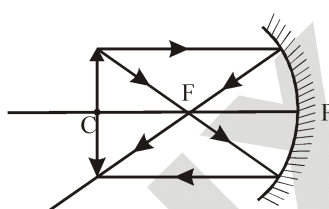


Figure : Concave mirror

(v) When the object is placed beyond the centre of curvature, then the image is formed between the focus and centre of curvature. The image formed is real, inverted and diminished.

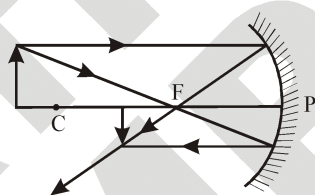


Figure : Concave mirror

(vi) When the object is placed at infinity then the image is formed at the focus. The image formed is real, inverted and extremely diminished in size.

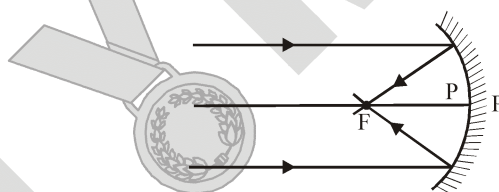


Figure : Concave mirror

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

(G) Uses of concave mirror :

- (i) They are used as shaving mirrors.
- (ii) They are used as reflectors in car head-lights, search lights, torches and table lamps.
- (iii) They are used by doctors to concentrate light on body parts like ears and eyes which are to be examined.
- (iv) Large concave mirrors are used in the field of solar energy to focus sun-rays on the objects to be heated.
- (v) **Solar cookers :** When a parallel beam of sunlight falls on a concave mirror, this beam is brought to the focus of the mirror (see figure). As a result of this, the temperature of an object (say a container containing uncooked food) placed at the focus increases considerably. Hence the food in the container is cooked.

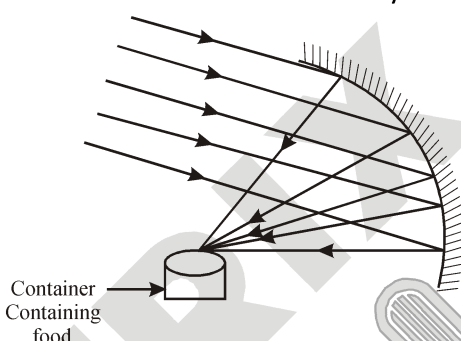


Figure : Spherical Reflector type solar cooker

(H) Uses of convex mirror : Convex mirror is used as rear view mirror in automobiles like cars, trucks and buses to see the traffic at the back side. It is also used in street lamps.

(I) Sign convention or measuring distance in concave and convex mirror :

- (i) All distances are measured from the pole, of mirror
- (ii) The incident ray is taken from left to right.
- (iii) Distances measured in the same direction as that of the incident ray are taken to be +ve.
- (iv) Distances measured in a direction opposite to the incident ray are taken to be –ve.
- (v) Distances measured upwards and perpendicular to principal axis are taken +ve.
- (vi) Distances measured downwards and perpendicular to principal axis are taken –ve.

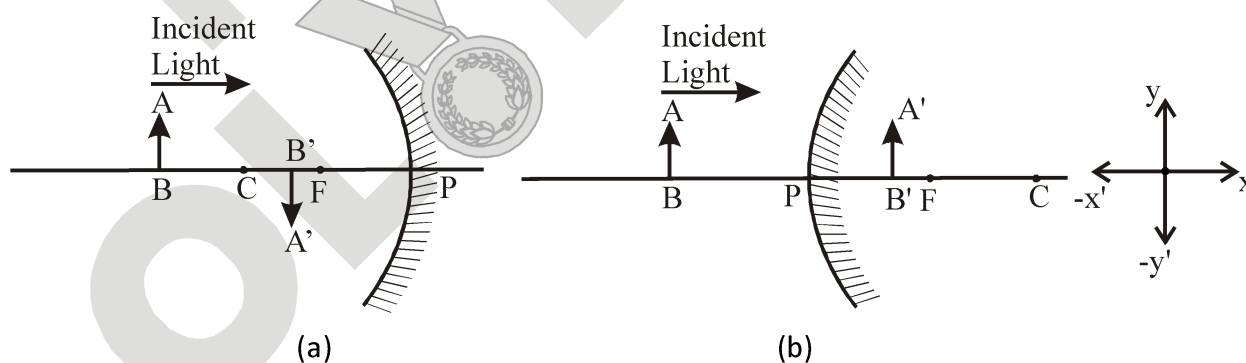


Figure : Sign convention in concave and convex mirror

$\left. \begin{array}{l} \text{Focal length of concave mirror is } -ve \\ \text{Focal length of convex mirror is } +ve \\ \therefore \text{ For real image } v \text{ is } -ve \\ \text{for virtual image } v \text{ is } +ve \end{array} \right\}$

These signs are according to the rectilinear co-ordinate system.

(J) Mirror formula :

The mirror formula is a relation relating the object distance (u), the image distance (v) and the focal length (f) of a mirror.

The **mirror formula** is : $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Above equation is known as mirror formula and is valid for both concave and convex mirrors. However, the quantities must be substituted with proper signs.

(i) Power of mirror : Optical power of a mirror is given by :

$$P \text{ (in Diopter)} = \frac{1}{f \text{ (in meter)}}$$

(ii) Relation between focal length (f) and radius of curvature (R) :

$$R = 2f \text{ or } f = \frac{R}{2}$$

(K) Magnification of concave mirror :

The linear magnification of a spherical mirror is the ratio of height of the image (h_2) formed by the mirror to the height of the object (h_1) i.e.

$$\text{Linear magnification, } m = \frac{\text{Height of image}}{\text{Height of object}} = \frac{h_2}{h_1}$$

The linear magnification is a number that simply tell us how much taller the images is than the object. For example, if $m = 1$, it means that the image and the object are of the same height.

Another formula for magnification is :

$$m = -\frac{v}{u} = \frac{f}{f-u}$$

The arbitrary minus sign given to linear magnification has nothing to do with the relative sizes of the object and the image but we can use it to tell whether the image is erect or inverted w.r.t. object.



Focus Point

Always draw a rough ray diagram while solving a numerical problem. Otherwise we will be confused as to which distance should be taken as +ve & which –ve.

For virtual image : m is +ve [as virtual image is erect $\therefore h_2$ is +ve as well as h_1 is +ve]

For real image : m is –ve [as real image is always inverted $\therefore h_2$ is –ve while h_1 is +ve]

Example 5

How can we distinguish between a plane mirror, a concave mirror and a convex mirror without touching them?

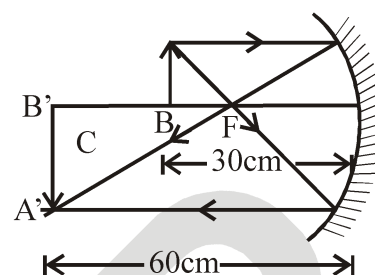
Solution :

We can distinguish between them by bringing our face close to each of them. All of them will produce different types of image of our face.

A plane mirror will produce an image of same size as our face. A concave mirror will produce a magnified image and our face will look much bigger. A convex mirror will produce a diminished image and our face will look small.

Example 6

A 2.0 cm long object is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror is 30 cm and its image is formed 60 cm from the mirror on the same side of the mirror as the object. Find the height of the image formed



Solution :

$$u = -30 \text{ cm}, v = -60 \text{ cm}$$

$$\therefore m = \frac{h_2}{h_1} = -\frac{v}{u} = -\frac{(-60)}{(-30)} = -2$$

$$\Rightarrow h_2 = -2h_1 = -2 \times 2 = -4 \text{ cm}$$

\therefore Height of the image is 4 cm. It is inverted.

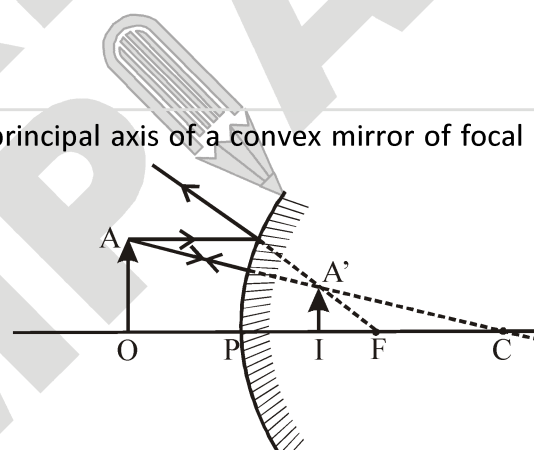
Example 7

A 1.2 cm long pin is placed perpendicular to the principal axis of a convex mirror of focal length 12 cm, at a distance of 8 cm from it.

(a) Find the location of the image.

(b) Find the height of the image.

(c) Is the image erect or inverted ?



Solution :

Here f is +ve so $f = 12 \text{ cm}$

Also, $u = -8 \text{ cm}$.

(a) Using, $\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ or $\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{12} - \frac{1}{(-8)} = \frac{1}{12} + \frac{1}{8} = \frac{5}{24} \therefore v = \frac{24}{5} \text{ cm} = 4.8 \text{ cm}$

(b) Given, $h_1 = 1.2 \text{ cm}$; We know, $\frac{h_2}{h_1} = -\frac{v}{u} \Rightarrow h_2 = -\frac{v}{u} \times h_1 = -\frac{4.8}{-8} \times 1.2 = \frac{4.8}{8} \times 1.2 = 0.72 \text{ cm}$

(c) Image formed is erect.

Example 8

A 2 cm high object is placed at a distance of 32 cm from a concave mirror. The image is real, inverted and 3cm in size. Find the focal length of the mirror and the position of the image.

Solution :

We have, $m = \frac{-v}{u} = \frac{h_i}{h_o}$; From the question, $h_i = -3 \text{ cm}$ and $h_o = 2 \text{ cm}$.

$$\therefore m = \frac{h_i}{h_o} = \frac{-3 \text{ cm}}{2 \text{ cm}} = -1.5 \quad \text{or} \quad -\frac{v}{u} = -1.5 \quad \text{or} \quad \frac{v}{-32 \text{ cm}} = 1.5 \quad \text{or} \quad v = -48 \text{ cm}$$

We have $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{-32\text{cm}} + \frac{1}{(-48\text{cm})} = \frac{-5}{96\text{cm}}$ or $f = \frac{-96\text{cm}}{5} = -19.2\text{ cm}$.

So the focal length of the concave mirror is 19.2 cm and the image is formed 48 cm in front of it.

Example 9

A concave mirror forms an erect image of an object placed at a distance of 10 cm from it. The size of the image is double that of the object. Where is the image formed ?

Solution :

From the question, $\frac{h_i}{h_o} = +2$ (erect image) or $-\frac{v}{u} = 2$ or $v = -2u = -2(-10\text{cm}) = +20\text{ cm}$

Thus, the image is formed 20 cm behind the mirror (from the position sign of v).

Example 10

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

Solution :

Given, object size, $h_1 = +4\text{ cm}$; object distance, $u = -25\text{cm}$;
Focal length, $f = -15\text{cm}$; image distance ; $v = ?$; image size, $h_2 = ?$
Mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{v} + \frac{1}{(-25)} = \frac{1}{(-15)} \text{ or } \frac{1}{v} - \frac{1}{25} = -\frac{1}{15}$$

$$\text{or } \frac{1}{v} = \frac{1}{25} - \frac{1}{15} = \frac{3-5}{75} = \frac{-2}{75} \text{ or } v = \frac{-75}{2} = -37.5\text{ cm}$$

The screen should be placed at 37.5 cm from the mirror.

$$\text{Now, magnification, } m = \frac{h_2}{h_1} = -\frac{v}{u}$$

$$\text{or } h_2 = -\frac{v}{u} \times h_1 = -\frac{(-75/2)}{(-25)} \times (+4) = -\frac{3}{2} \times 4 = -6\text{cm}$$

The image is real, inverted and enlarged

Example 11

A 4.5 cm needle is placed 12 cm away from a convex mirror of focal length 15 cm. Give the location of the image and the magnification. Describe what happens as the needle is moved farther from the mirror.

Solution :

Given, object distance, $u = -12\text{ cm}$; focal length ; $f = +15\text{ cm}$;
object size, $h_1 = +4.5\text{ cm}$; image distance, $v = ?$; magnification, $m = ?$
image size, $h_2 = ?$
Mirror formula,

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{v} + \frac{1}{(-12)} = \frac{1}{(+15)} \text{ or } \frac{1}{v} - \frac{1}{12} = \frac{1}{15}$$

$$\text{or } \frac{1}{v} = \frac{1}{15} + \frac{1}{12} = \frac{4+5}{60} = \frac{9}{60} \text{ or } v = +(60/9) \text{ cm} = +6.67 \text{ cm}$$

$$\text{Now, magnification, } m = -\frac{v}{u} = \frac{(+60/9)}{(-12)} = +\frac{5}{9} = +0.55$$

$$\text{Also, magnification, } m = \frac{h_2}{h_1} \text{ or } +\frac{5}{9} = \frac{h_2}{(+4.5)} \text{ or } h_2 = +\frac{5}{9} \times (+4.5) = +2.5 \text{ cm}$$

Image is virtual, erect and diminished.

If the needle (object) is moved farther from the mirror, its image moves away from the mirror i.e., from pole towards the focus. The image remains virtual and erect but it gradually decreases in size. When the object becomes infinitely far away, the image is formed at the focus and it is a point sized image. But, the image never goes beyond the focus in a convex mirror.

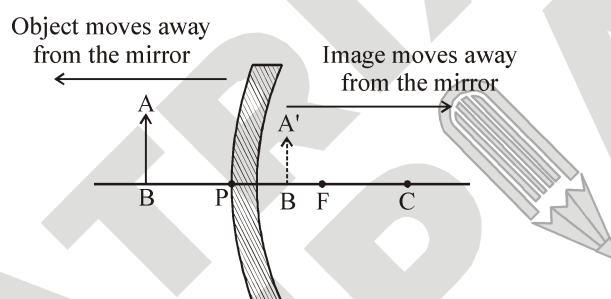


Figure : Effect on the position of the image formed when an object is moved away from a convex mirror.

6. REFRACTIVE INDEX

Light travels the fastest in vacuum with the highest speed of $3 \times 10^8 \text{ m s}^{-1}$. In air, the speed of light is only marginally less, compared to that in vacuum. But for all practical purposes, we consider the speed of light in air equal to the speed of light in vacuum. However speed of light decreases in denser media like water, glass etc. It means when light goes from air to some other medium like water and glass, its speed decreases. The amount of change in the speed of light in a medium depends upon the property of the medium. This property is known as refractive index of the medium. Refractive index is a measure of how much the speed of light changes when it enters a medium from air.

Absolute Refractive index :

Absolute refractive index of a medium is defined as the ratio of the speed of light in vacuum or air to the speed of light in the medium. It is denoted by n .

$$\text{Then, } n = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}} = \frac{c}{v}$$

It has no unit.

Relative refractive index :

When light passes from medium 1 to another medium 2, the refractive index of medium 2 with respect to medium 1 is written as ${}_2n_1$ and is called relative refractive index.

$${}_2n_1 = \frac{\text{Speed of light in air}}{\text{Speed of light in medium}} = \frac{v_1}{v_2} \dots\dots(i)$$

Multiply and divide R.H.S. of eqn. (i) by c (speed of light in air), we get

$${}_2n_1 = \frac{cv_1}{cv_2} = \left(\frac{c}{v_2}\right) \times \left(\frac{v_1}{c}\right) = \left(\frac{c/v_2}{c/v_1}\right) \dots\dots(ii)$$

But $\frac{c}{v_1} = n_1$ (absolute refractive index of medium 1) and $\frac{c}{v_2} = n_2$ (absolute refractive index of medium 2)

Hence, eqn. (ii) can be written as ${}_2n_1 = \frac{n_2}{n_1} \dots\dots(iii)$

Thus, relative refractive index of medium 2 with respect to medium 1 is defined as the ratio of absolute refractive index of medium 2 to the absolute refractive index of medium 1.

We know, refractive index of medium 2 with respect to medium 1 is given by, ${}_2n_1 = \frac{v_1}{v_2} \dots\dots(iv)$

Similarly, refractive index of medium 1 with respect to 2 is given by, ${}_1n_2 = \frac{v_2}{v_1} \dots\dots(v)$

Multiplying eqn. (iv) and (v), we get ${}_2n_1 \times {}_1n_2 = \frac{v_1}{v_2} \times \frac{v_2}{v_1} = 1$ or ${}_2n_1 = \frac{1}{{}_1n_2}$

i.e. refractive index of medium 2 with respect to medium 1 is the reciprocal of refractive index of medium 1 with respect to medium 2.

Example 12

Find the refractive index of glass with respect to water, the refractive index of glass with respect to air is 3/2 and refractive index of water with respect to air is 4/3.

Solution :

For water, ${}_w n_a = \frac{4}{3}$ or 1.33, For glass, ${}_g n_a = 1.5$

Refractive index of glass with respect to water, ${}_g n_w = \frac{{}_g n_a}{{}_w n_a} = \frac{3/2}{4/3} = \frac{9}{8} = 1.125$

Example 13

The speed of light in air is $3 \times 10^8 \text{ ms}^{-1}$ and the speed of light in water is $2.26 \times 10^8 \text{ m s}^{-1}$. Find the refractive index of water.

Solution :

Given, $c = 3 \times 10^8 \text{ m s}^{-1}$, $v = 2.26 \times 10^8 \text{ m s}^{-1}$

Using, $n = \frac{c}{v}$, we have $n = \frac{3 \times 10^8 \text{ ms}^{-1}}{2.26 \times 10^8 \text{ ms}^{-1}} = 1.33$

Thus, refractive index of water = 1.33

7. REFRACTION OF LIGHT

(a) Definition :

When light travels in the same homogeneous medium. It travels along a straight path. However, when it passes from one transparent medium to another, the direction of its path changes at the interface of the two media. This is called refraction of light.

The phenomenon of the change in the path of the light as it passes from one transparent medium to another is called refraction of light. The path along which the light travels in the first medium is called incident ray and that in the second medium is called refracted ray. The angles which the incident ray and the refracted ray make with the normal at the surface of separation are called angle of incidence (i) and angle of refraction (r) respectively.

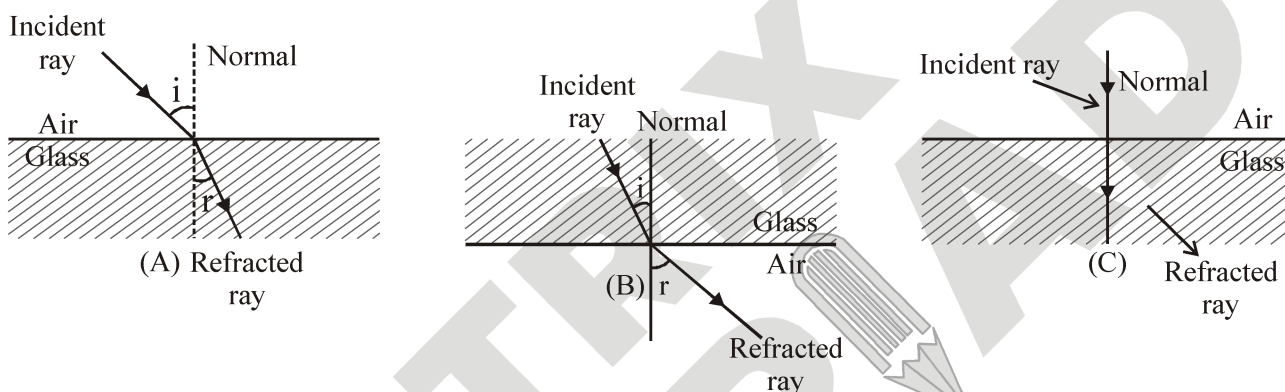


Figure : Showing different cases of refraction

It is observed that :

- (i) When a ray of light passes from an optically rarer medium to a denser medium, it bends towards the normal ($\angle r < \angle i$), as shown in figure (A).
- (ii) When a ray of light passes from an optically denser to a rarer medium, it bends away from the normal ($\angle r > \angle i$) as shown in figure (B).
- (iii) A ray of light travelling along the normal passes undeflected, as shown in figure (C). Here $\angle i = \angle r = 0^\circ$.

(b) Cause of refraction :

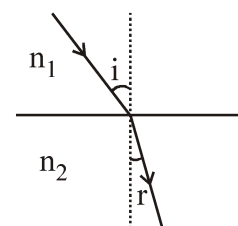
Light rays get deviated from their original path, while entering from one transparent medium to another medium of different density. This deviation (change in direction) in the path of light is due to the change in velocity of light in the different medium. The velocity of light depends on the nature of the medium in which it travels. Velocity of light in a rarer medium (low optical density) is more than in the denser medium (high optical density).

7.1 LAWS OF REFRACTION

Refraction of light follows the following two laws :

First Law : The incident ray, the normal to the transparent surface at the point of incidence and the refracted ray, all lie in the same plane.

Second Law : The ratio of sine of the incidence angle ($\angle i$) to the sine of the refracted angle ($\angle r$) is constant. It is denoted by ${}_2n_1$.



i.e., $\frac{\sin i}{\sin r} = {}_2n_1$

This constant is called refractive index of the second medium with respect to the first medium. Refractive index of second medium with respect to the first medium is denoted by ${}_2n_1$.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$n_1 \sin i = n_2 \sin r$$

8. REFRACTION THROUGH GLASS SLAB

Consider a rectangular glass slab, as shown in figure. A ray AE is incident on the face PQ at an angle of incidence i . On entering the glass slab, it bends towards normal and travel along EF at an angle of refraction r . The refracted ray EF is incident on face SR at an angle of incidence r' . The emergent ray FD bends away from the normal at an angle of refraction e .

Thus the emergent ray FD is parallel to the incident ray AE, but it has been laterally displaced with respect to the incident ray. There is shift in the path of light on emerging from a refracting medium with parallel faces.

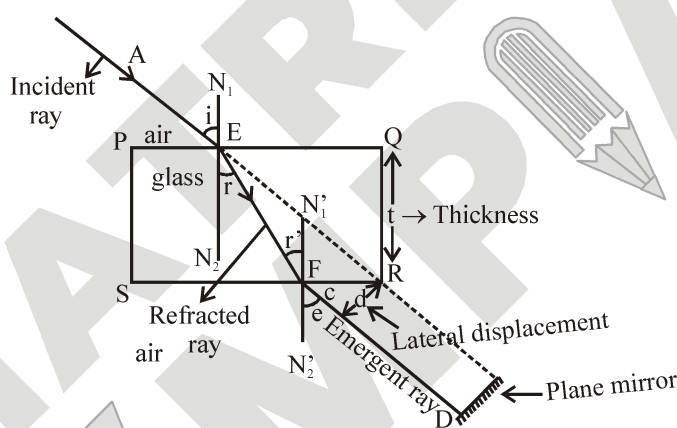


Figure : Bending of light in glass slab

If a plane mirror is placed in the path of emergent ray FD then the path of the emergent ray along FD is reversed back, it follows the same path along which it was incident i.e. the incidence ray becomes the emergent ray & emergent ray becomes the incident ray. It is known as principle of reversibility of light.

Case I : For light going from air to glass at point E.

$\angle i$ = angle of incidence, $\angle r$ = angle of refraction.

$${}_a\mu_g = \frac{\sin i}{\sin r} \dots\dots\dots(1)$$

(${}_a\mu_g$ = absolute refractive index of glass)

Case II : For light going from glass to air at point F.

$$\Rightarrow {}_g\mu_a = \frac{\sin r'}{\sin e} \text{ where } \left\{ \begin{array}{l} \angle r' = \text{angle of incidence} \\ \angle e = \text{angle of emergence} \end{array} \right\} \because \angle r = \angle r'$$

$$\Rightarrow {}_g\mu_a = (\text{as } \angle e = \angle i)$$

$$\therefore \frac{1}{\mu_a} = \frac{\sin i}{\sin r} \dots\dots\dots(2)$$

\therefore From (1) & (2) \Rightarrow

$\angle e = \angle i$, hence incident ray and emergent ray are parallel.

$$\mu_g = \frac{1}{\mu_a} \Rightarrow \mu_g \times \mu_a = 1$$

Lateral shift : Lateral shift is the perpendicular distance between the incident and emergent rays when light is incident obliquely on a refracting slab with parallel faces. if thickness of glass slab is t then lateral

$$\text{shift } d = \frac{t \sin(i-r)}{\cos r}$$

Factors on which lateral shift depends are :

- (i) Lateral shift is directly proportional to the thickness of glass slab.
- (ii) Lateral shift is directly proportional to the incident angle.
- (iii) Lateral shift is directly proportional to the refractive index of glass slab.
- (iv) Lateral shift is inversely proportional to the wavelength of incident light.

9. APPARENT DEPTH

When an object lying inside an optically denser medium is seen from a rarer medium, its depth appears to be less than its real depth. This depth is called ‘apparent depth’ (see figure). Apparent depth = A_1I ; real (actual) depth = OA . This happens because rays of light from denser medium (like water) when enter into rarer medium (like air), they bend away from the normal and thus, they appear to diverge from a point above the object where the image of the object is formed. Thus, we see the image of the object (not the actual object) in water which is at lesser depth than the real depth.

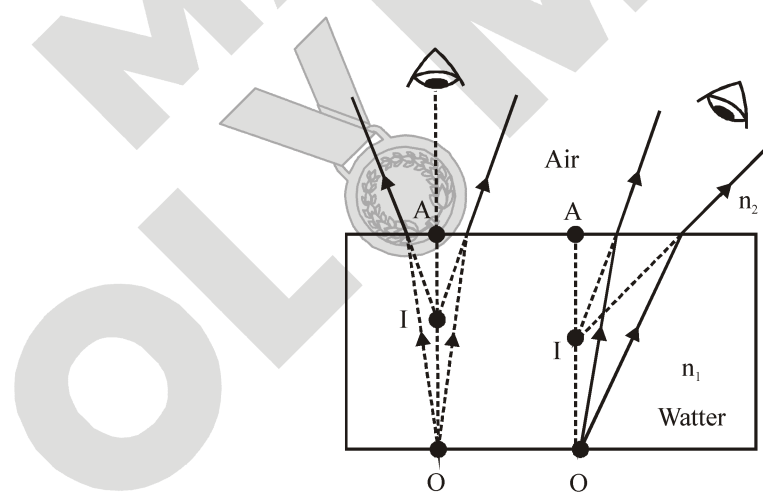


Figure : Apparent depth of an object is less than the actual depth when seen from air

9.1 EFFECT OF REFRACTION OF LIGHT

(i) A pencil appears bent and short in water :

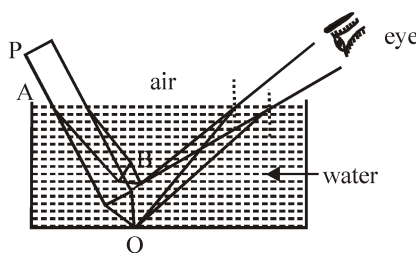


Figure : Bending of pencil in water

Consider a pencil PQ. Let AQ portion of the pencil be dipped in water as shown in figure. Rays of light from the tip (Q) of the pencil bend away from the normal as they go from water to air i.e. denser to rarer medium. These rays appear to come from a point B. Thus, the dipped portion of the pencil appears as AB. Hence a pencil appears bent and short when immersed in water.

(ii) A water tank appears shallow i.e. less deep than its actual depth :

Consider an object O say a stone lying on the bed of a water tank as shown in figure. A ray (OB) of light from the object suffers refraction at the free surface of water in the tank and bends away from the normal along BC. The refracted ray BC appears to come from point I which is above the object O. Thus, the bed of the tank appears at the level of point. In other words, water tank appears shallow.

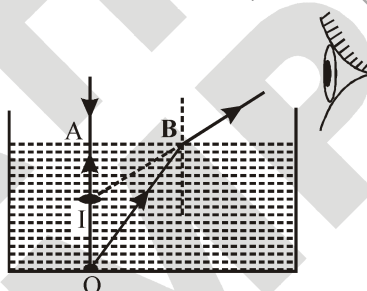


Figure : Appearance of object in watertant

10. TOTAL INTERNAL REFLECTION

The phenomenon by virtue of which a beam of light travelling from a denser medium to a rarer medium gets reflected back in the same denser medium at the interface of two media, obeying laws of reflection is called “total internal reflection”.

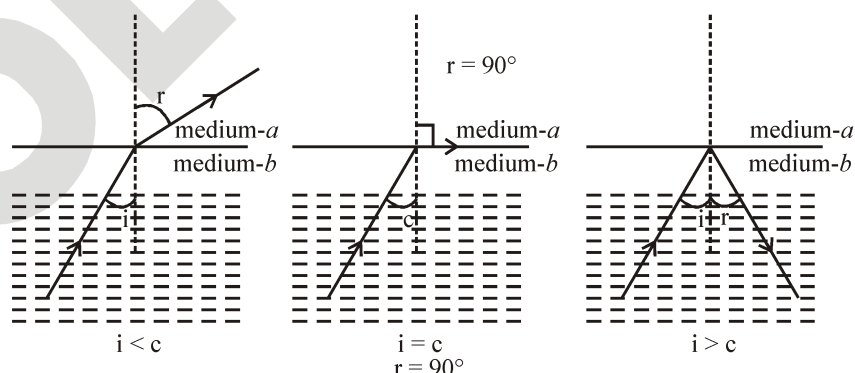


Figure : Total internal Reflection

- The critical angle for a pair of media is the angle of incidence of light in the denser medium, for which the angle of refraction in the rarer medium is 90° , i.e., when $i = c$ then $r = 90^\circ$

So by Snell's law

$${}^b\mu_a = \frac{\sin c}{\sin 90^\circ} = \frac{\sin c}{1} \text{ or } {}^a\mu_b = \frac{1}{\sin c}$$

For total internal reflection to take place, necessary conditions are

- The ray of light should be travelling from optically denser medium towards optically rarer medium.
- The angle of incidence should be greater than the critical angle for the given pair of media.

11. SPHERICAL LENSES

(A) Definition :

A lens is a piece of transparent refracting material bounded by two spherical surfaces or one spherical and other plane surface.

A lens is the most important optical component used in microscopes, telescopes, cameras, projectors etc. Basically lenses are of two types :

- (i) Convex lens or converging lens (ii) Concave lens or diverging lens

Convex lens and its types :

A lens which is thick at the centre and thin at the edges is called a convex lens. The most common form of a convex lens has both the surfaces bulging out at the middle. Some forms of convex lens are shown in the figure.

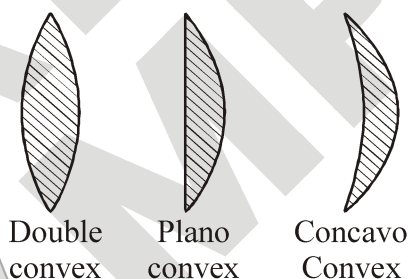


Figure : different types of convex lens

Concave lens and its types :

A lens which is thin at the middle and thick at the edges is called a concave lens. The most common form of a concave lens has both the surfaces depressed inward at the middle. Some forms of concave lenses are shown in the figure.

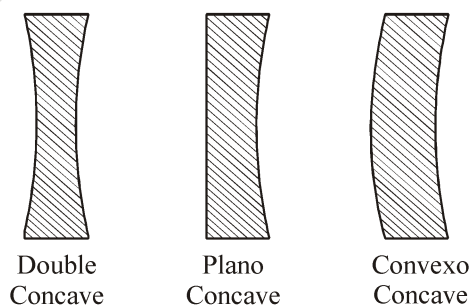


Figure : Different types of concave lens

(B) Definitions in connection with spherical lens :

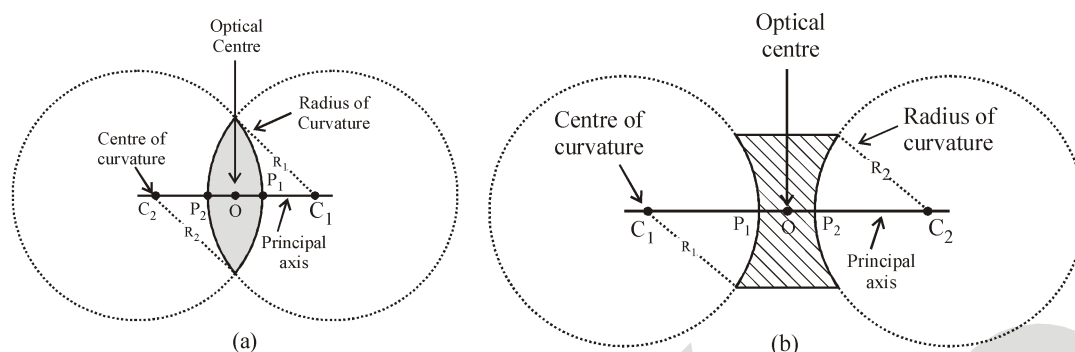


Figure : Characteristics of convex and concave lenses

(i) Optical centre : If a ray of light is incident on a lens such that after refraction through the lens the emergent ray is parallel to the incident ray, then the point at which the refracted ray intersects, the principal axis is called the optical centre of the lens. In the figure O is the optical centre of the lens. It divides the thickness of the lens in the ratio of the radii of curvature of its two surfaces. If the radii of curvature of the two surfaces are equal then the optical centre coincides with the geometric centre of the lens.

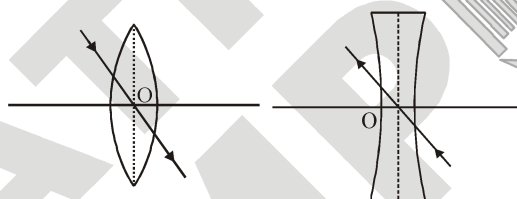


Figure : Optical centre in convex and concave lenses

For a ray passing through the optical centre, the incident and emergent rays are parallel. However, the emergent ray suffers some lateral displacement relative to the incident ray. The lateral displacement decreases with the decreases in thickness of the lens. Hence a ray passing through the optical centre of a thin lens does not suffer any lateral deviation, as shown in the figure above.

(ii) Principal foci and focal length :

(a) First principal focus and first focal length : It is a fixed point on the principal axis such that rays starting from this point (in convex lens) or appearing to go towards this point (concave lens), after refraction through the lens, become parallel to the principal axis. It is represented by F_1 of f' . The plane passing through this point and perpendicular to the principal axis is called the first focal plane. The distance between first principal focus and the optical centre is called the first focal length. It is denoted by f_1 of f' .

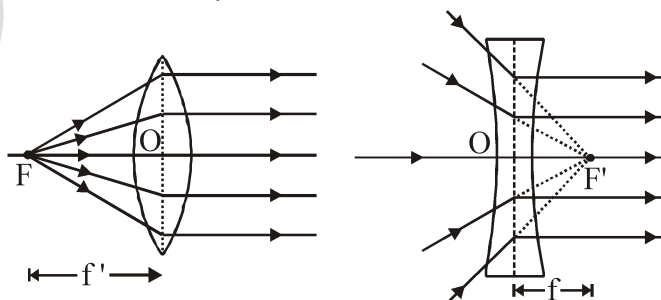


Figure : Ray diagram showing First principal focus

(b) Second principal focus and second focal length : It is a fixed point on the principal axis such that the light rays incident parallel to the principal axis, after refraction through the lens, either converge to this point (in convex lens) or appear to diverge from this point (in concave lens). The plane passing through this point and perpendicular to principal axis is called the second focal plane. The distance between the second principal focus and the optical centre is called the second focal length. It is denoted by f_2 or f .

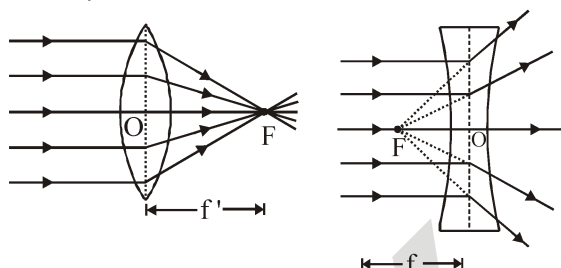


Figure : Ray diagram showing Second principal focus

Generally, the focal length of a lens refers to its second focal length. It is obvious from the above figures, that the foci of a convex lens are real and those of a concave lens are virtual. Thus the focal length of a convex lens is taken positive and the focal length of a concave lens is taken negative.

If the medium on both sides of a lens is same, then the numerical values of the first and second focal lengths are equal. Thus $f = f'$

(C) Rules for image formation by convex lens :

The position of the image formed by a convex lens can be found by considering two of the following rays (as explained below).

(i) A ray of light coming parallel to principal axis, after refraction through the lens, passes through the principal focus (F) as shown in the figure.

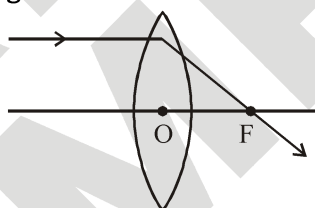


Figure : Convex lens

(ii) A ray of light passing through the optical centre O of the lens goes straight without suffering any deviation as shown in the figure.

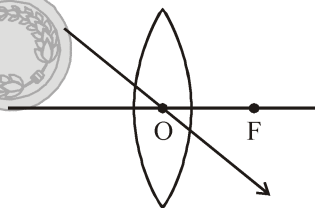


Figure : Convex lens

(iii) A ray of light coming from the object and passing through the principal focus of the lens after refraction through the lens, becomes parallel to the principal axis.

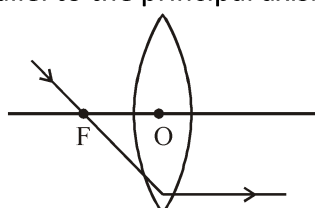


Figure : Convex lens

(D) Image formed by Convex lens :

The position, size and nature of the image formed by a convex lens depends upon the distance of the object from the optical centre of the lens. For a thin convex lens, the position and nature of image formed is summarised in the table :

(i) When object lies at infinity : When an object lies at infinity, a real, inverted and highly diminished image is formed on the other side of the lens in its focal plane.

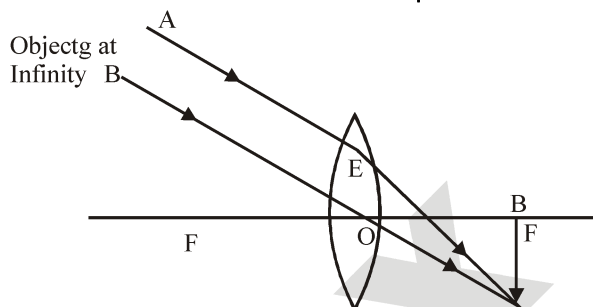


Figure : Convex lens

(ii) When object lies beyond $2F$: When an object lies beyond $2F$, its real, inverted and diminished image is formed between F and $2F$ on the other side of the lens.

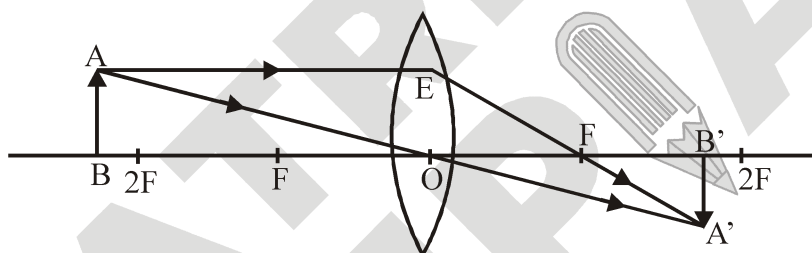


Figure : Convex lens

(iii) When object lies at $2F$: When an object lies at $2F$, its real inverted image having same size as that of the object is formed on the other side of the convex lens.

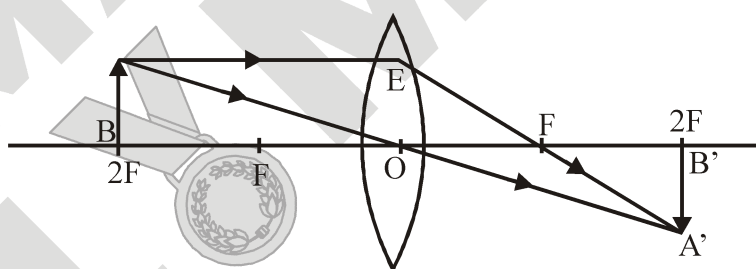


Figure : Convex lens

(iv) When object lies between F and $2F$: When an object lies between F and $2F$ in front of a convex lens, its real, inverted and magnified image is formed beyond $2F$ on the other side of the lens.

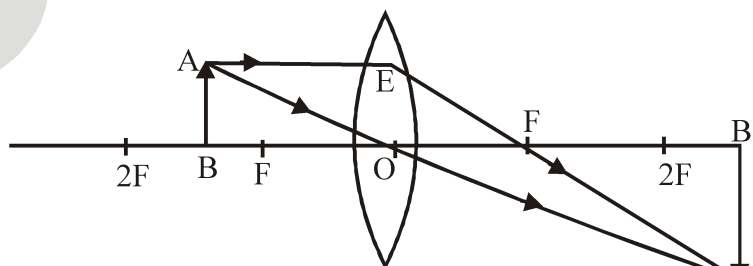


Figure : Convex lens

(v) When object lies at F : When an object lies at the principal focus F of a convex lens, then its real, inverted and highly magnified image is formed at infinity on the other side of the lens.

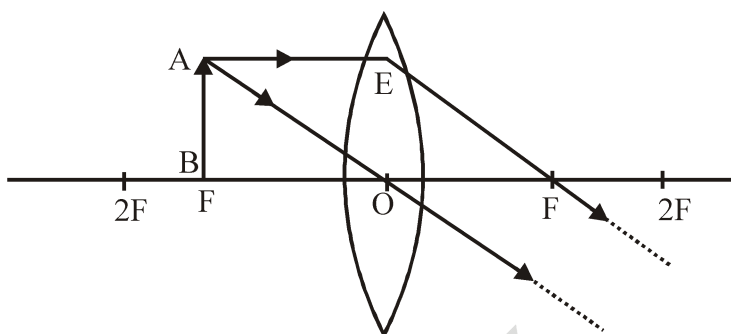


Figure : Convex lens

(vi) When object lies between O and F : When an object lies between the optical centre O and the principal focus F of a convex lens, then its virtual, erect and magnified image is formed on the same side as that of the object.

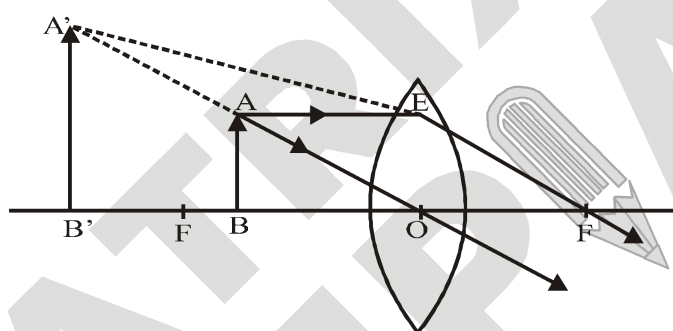


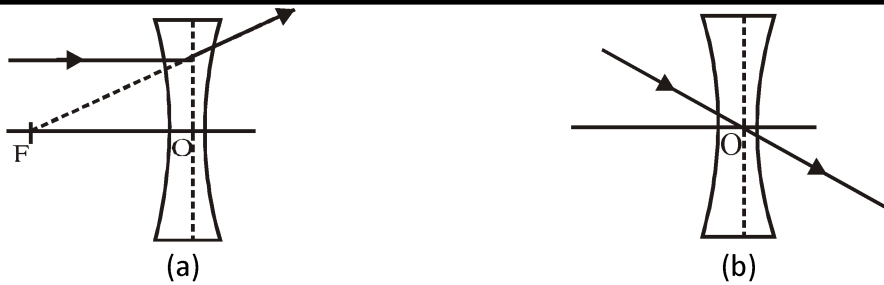
Figure : Convex lens

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished	Real and inverted
Beyond 2F	Between F and 2F	Diminished	Real and inverted
At 2F	At 2F	Same size	Real and inverted
Between F and 2F	Beyond 2F	Magnified	Real and inverted
At F	At infinity	Highly Magnified	Real and inverted
Between O and F	On the side of the object	Magnified	Virtual and erect

(E) Rules for image formation by Concave lens :

The position of the image formed by a concave lens can be found by considering following two rays coming from a point object (as explained below).

- (i) A ray of light coming parallel to the principal axis, after refraction, appears to pass through the principal focus F of the lens, when produced backward as shown in figure (a).
- (ii) A ray of light passing through the optical centre O of the lens goes straight without suffering any deviation as shown in figure (b)



(F) Image formed by Concave lens :

The image formed by a concave lens is always virtual, erect and diminished and is formed between the optical centre O and the principal focus F of the lens.

(i) When the object lies at infinity :

When object lies at infinity in front of a concave lens, a virtual, erect, highly diminished image is formed at the principal focus F.

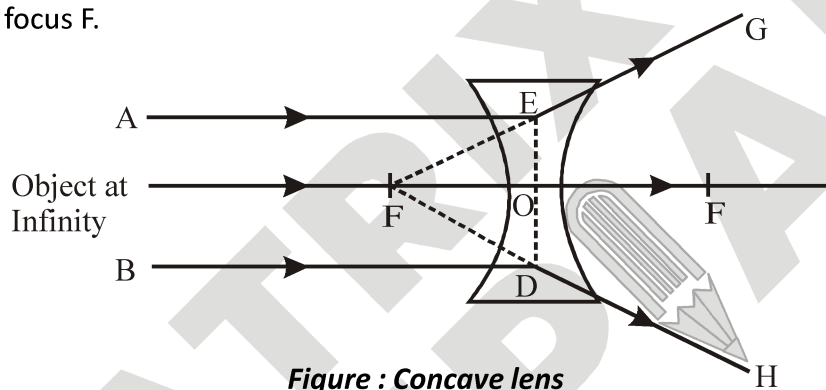


Figure : Concave lens

(ii) When the object lies between O and ∞ .

When an object lies at any position between the optical centre O and infinity in front of a concave lens, the image formed is virtual, erect, diminished and is formed between the optical centre O and the principal focus F.

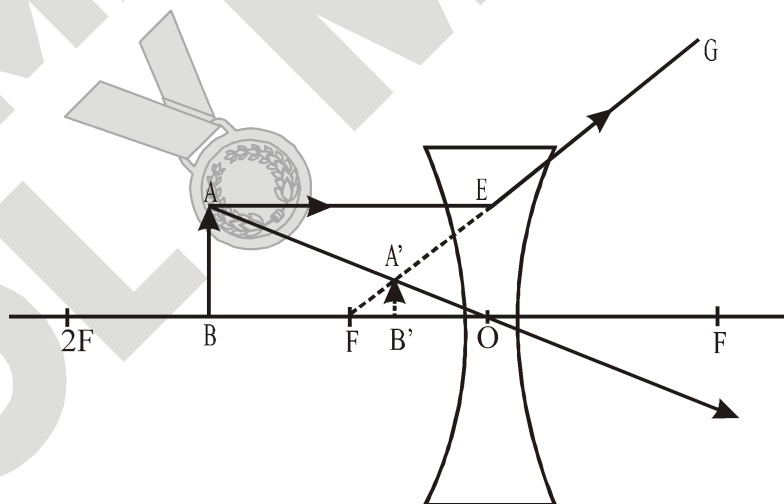


Figure : Concave lens

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished	Virtual and erect
Between O and infinity	Between O and F	Diminished	Virtual and erect

(G) Lens formula :

Relation between object distance u , image distance v and focal length f is :

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

(H) Linear magnification :

Linear magnification (m) is defined as the ratio of the size of the image to the size of the object.

$$m = \frac{A'B'}{AB} = \frac{h_2}{h_1} = \frac{\text{height of image}}{\text{height of object}}$$

also $m = \frac{v}{u}$

if m is +ve (image is virtual & erect)
 if m is -ve (image is real & inverted) or $\left(m = \frac{f-v}{f} \right)$

(I) Power of lens :

It is the measure of deviation produced by a lens. It is defined as the reciprocal of its focal length in metres. Its unit is Diopter (D) (f should always be in metres).

$$\text{Power (P)} = \frac{1}{\text{focal length (in m)}}$$

Power of a convex lens is +ve (As it has a real focus and its focal length measured is +ve)

Power of a concave lens is -ve (As it has a virtual focus and its focal length measured is -ve).



Focus Point

If two thin lenses are placed in contact, the combination has a power equal to the algebraic sum of the power of two lenses, $P = P_1 + P_2$

$$\Rightarrow \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

Here, f_1 and f_2 are the focal length of lenses and f is focal length of combination of lenses.

Example 14

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

Solution :

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

Image distance $v = -10\text{cm}$; focal length $f = -15\text{ cm}$;

object distance $u = ?$

Lens equation,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{(-10)} - \frac{1}{u} = \frac{1}{(-15)}$$

$$\text{or } \frac{1}{u} = \frac{1}{15} - \frac{1}{10} = \frac{2-3}{30} = \frac{-1}{30} \text{ or } u = -30\text{ cm}$$

$$\text{Magnification, } m = \frac{v}{u} = \frac{(-10)}{(-30)} = \frac{1}{3} = +0.33$$

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

Example 15

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

Solution :

Given, height of the object $h_1 = 2.0\text{ cm}$; focal length $f = +10\text{ cm}$; object distance $u = -15\text{ cm}$;

image distance $v = ?$; height of the image $h_2 = ?$

Lens equation,

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{ or } \frac{1}{v} - \frac{1}{(-15)} = \frac{1}{(+10)}$$

$$\text{or } \frac{1}{v} = \frac{1}{10} - \frac{1}{15} = \frac{3-2}{30} = \frac{+1}{30} \text{ or } v = +30\text{ cm}$$

$$\text{Magnification, } m = \frac{h_2}{h_1} = \frac{v}{u} \text{ or } h_2 = \frac{v}{u} \times h_1 = \frac{+30}{-15} \times (+2) = -4\text{cm}$$

The negative sign of h_2 shows that the image is inverted and real. A real, inverted image, 4 cm tall, is formed at a distance of 30 cm on the other side of the lens.

Example 16

What distance should an object be placed in front of a convex lens of focal length 0.4 m so that the virtual image is thrice the size of the object ?

Solution :

Given $f = 0.4\text{ m}$, $h_i = 3h_o$, $u = ?$

$$\text{We know that, } m = \frac{h_i}{h_o} = \frac{v}{u} = 3 \text{ (virtual)}$$

$$\frac{h_i}{h_o} = \frac{3h_o}{h_o} = \frac{v}{u} \Rightarrow v = 3u \text{ (virtual image)}$$

Also from lens formula,

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} = (1/3u) - (1/u) = (2/3 u)$$

$$f = -\frac{3u}{2} \Rightarrow u = -\frac{2f}{3} = -\frac{2 \times 0.4}{3} = -0.267 \text{ m}$$

i.e. object distance, $u = -0.267 \text{ m}$

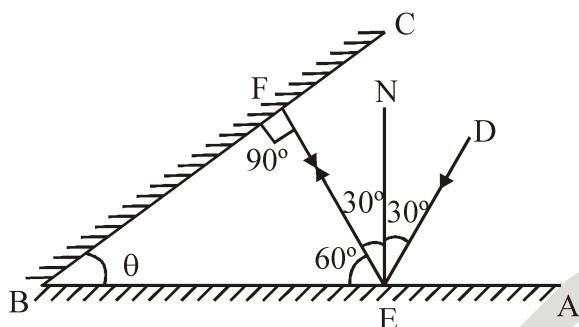
The object must be placed at 0.267 m from the lens.

SOLVED EXAMPLES

SE. 1

Two plane mirrors are inclined to each other at some angle. A ray of light is incident on one of them at an angle of 30° . The light after reflection falls on the second mirror and finally gets reversed. Find the angle between the mirrors.

Ans.



Let the mirrors AB and BC be inclined at angle θ in adjoining figure. Let DE be the incident ray which after reflection from mirror AB goes along EF. Draw NE normal on mirror AB. Then according to laws of reflection, $\angle DEN = \angle NEF = 30^\circ$

As the ray EF gets reversed, so it must be falling normally on the second mirror BC. As NE is normal to AB, $\angle NEB = 90^\circ$

In $\triangle FBE$, $\angle EFB = 90^\circ$

$\therefore \angle FEB = 90^\circ - 30^\circ = 60^\circ$

As the sum of the three angles of a triangle is two right angles or 180° , so

$90^\circ + 60^\circ + \angle\theta = 180^\circ \Rightarrow \angle\theta = 30^\circ$

So, the two mirrors are inclined to each other at an angle of 30° .

SE. 2

An object 4.0 cm in size is placed at a distance of 25.0 cm in front of a convex mirror of radius of curvature 40 cm. Find (i) the position, (ii) the size and (iii) nature of the image.

Ans. Here, $h = +4.0$ cm

$u = -25.0$ cm (sign conventions)

$R = +40$ cm

$$\therefore f = \frac{R}{2} = \frac{40}{2} = 20.0 \text{ cm}$$

(i) Determination of the position of the image

Using $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ we get

$$\frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{20} - \frac{1}{(-25)} = \frac{1}{20} + \frac{1}{25} = \frac{9}{100}$$

$$\text{or } v = \frac{100}{9} = 11.11 \text{ cm}$$

Thus, the image is at 11.11 cm behind the convex mirror.

(ii) Determination of size

Using, $m = \frac{h'}{h} = -\frac{v}{u}$ or $h' = -\frac{v}{u}h$

$$\text{or } h' = -\frac{(100/9)(4)}{-25} = \frac{16}{9} = 1.78 \text{ cm}$$

Thus, size of image = 1.78 cm

(iii) Since h' is positive, so the image is erect

SE. 3

An object 3cm high is placed at a distance of 10 cm in front of a concave mirror of focal length 20 cm. Find the position, nature and size of the image formed

Ans. Here, size of object, $h = 3$ cm

$u = -10$ cm (sign convention)

$f = -20$ cm (sign convention)

Using $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$, we have

$$-\frac{1}{10} + \frac{1}{v} = -\frac{1}{20} \text{ or } \frac{1}{v} = -\frac{1}{20} + \frac{1}{10} = \frac{1}{20}$$

$$\therefore v = 20 \text{ cm}$$

Thus, image is formed at a distance of 20 cm from the concave mirror. Since v is positive, so image is formed behind the concave mirror. It means the image is virtual (nature).

Using $m = \frac{h'}{h} = -\frac{v}{u}$, we get

$$\frac{h'}{h} = -\frac{20\text{cm}}{-10\text{cm}} = 2$$

or $h' = 2 \times h = 2 \times 3 \text{ cm} = 6 \text{ cm}$

Thus, size of the image is 6 cm.

SE. 4

An object is placed at a distance of 8 cm from a concave mirror of focal length 10 cm. Find the nature of the image formed by drawing the ray diagram.

Ans. Here, (using sign convention)

Focal length, $f = -10 \text{ cm}$

Object distance, $u = -8 \text{ cm}$

Image distance, $v = ?$

From mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

Putting values, we get

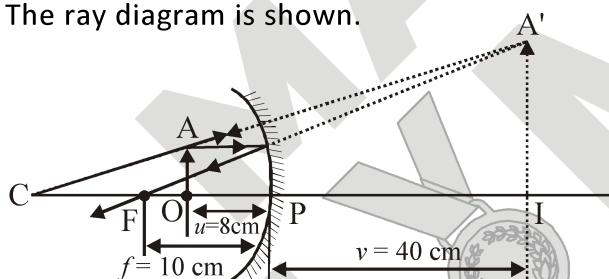
$$\frac{1}{v} = \frac{1}{-10} - \frac{1}{-8} = \frac{-4 + 5}{40} = \frac{1}{40}$$

$v = +40 \text{ cm}$

The image is formed at distance 40 cm behind the mirror.

It is virtual, erect and enlarged.

The ray diagram is shown.



Incident rays taken are one parallel to principal axis and the other appearing to come from side of centre. Reflected rays appear to come from A', forming virtual image of A. IA' is erect, virtual image of real object OA.

SE. 5

An object 2cm high is placed at a distance of 16cm from a concave mirror which produce a real image 3 cm high. What is the focal length of the mirror and position of the image ?

Ans. Here, (using sign convention)

Object height, $h_1 = +2 \text{ cm}$

Image height, $h_2 = -3 \text{ cm}$

Object distance, $u = -16 \text{ cm}$

(object on left of mirror)

Focal length, $f = ?$

Image distance, $u = ?$

From relation, $\frac{h_2}{h_1} = -\frac{v}{u}$

We have, $v = -u \frac{h_2}{h_1}$

Putting values, we get, $v = -(-16) \times \frac{-3}{2}$
 $v = -24 \text{ cm}.$

The image is formed at distance of 24 cm in front of the mirror (negative sign means on the left side).

To find focal length of mirror

From mirror formula, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

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

Putting values, we get

$$\frac{1}{f} = \frac{1}{-16} + \frac{1}{(-24)} = \frac{-3 - 2}{48} = -\frac{5}{48}$$

or $f = -\frac{48}{5} = -9.6 \text{ cm}$

The focal length of the mirror is 9.6 cm (negative sign means concave mirror)

SE. 6

When an object is placed at a distance of 25 cm from a mirror, the magnification is m_1 . The object is moved 15 cm farther away with respect to the earlier position and the magnification becomes m_2 .

If $\frac{m_1}{m_2} = 4$, then calculate the focal length of the mirror.

Ans. We know that, $m = \frac{v}{u} = \frac{f}{f - u}$

$$\text{Here } m_1 = \frac{f}{f - (-25)} = \frac{f}{f + 25}$$

$$\text{and } m_2 = \frac{f}{f - (-25 - 15)} = \frac{f}{f + 40}$$

$$\text{Since } \frac{m_1}{m_2} = 4,$$

$$\text{therefore, } \frac{f + 40}{f + 25} = 4;$$

$$\text{Thus } f + 40 = 4f + 100 \text{ or } f = -20 \text{ cm}$$

The negative sign show that the mirror is concave.

SE. 7

How far should an object be held from a concave mirror of focal length 40 cm so as to get an image magnified three times ?

Ans. Given : Focal length (f) = -40 cm

Magnification (m) = 3

Distance of the object (u) = ?

Since the nature of the image so formed is not specified, so two cases arise here.

$$\text{Formula to be used : } \frac{1}{v} + \frac{1}{u} = \frac{1}{f}$$

Since only f and m are given, therefore, we cannot use this formula directly and instead first use the formula,

$$m = -\frac{v}{u} \Rightarrow 3 = -\frac{v}{u}, v = -3u$$

Case I : When image formed is real, $v = +3 u$ cm

Substituting the given values, we get

$$\frac{1}{3u} + \frac{1}{u} = \frac{1}{-40} \Rightarrow \frac{1+3}{3u} = \frac{1}{-40} \Rightarrow \frac{3u}{4} = -40$$

$$\therefore u = -53.33 \text{ cm}$$

Case II : When image formed is virtual, $v = -3u$ cm

Substituting the given values, we get

$$-\frac{1}{3u} + \frac{1}{u} = -\frac{1}{40} \Rightarrow \frac{-1+3}{3u} = -\frac{1}{40}$$

$$\Rightarrow \frac{2}{3u} = -\frac{1}{40} \Rightarrow u = \frac{-80}{3}$$

$$\therefore u = -26.67 \text{ cm}$$

Hence, if the object is held at a distance of 53.33 cm, a real image thrice in size is obtained. Also, a virtual image of thrice the size is obtained if the distance of the object is 26.67 cm.

SE. 8

Size of image of an object by a mirror having focal length of 20 cm is observed to be reduced to $1/3^{\text{rd}}$ to its size. At what distance, the object has been placed from the mirror ? What is the nature of the image and the mirror ?

Ans. Here, considering (the case for both type of possible spherical mirrors)

For concave mirror

Focal length, $f = -20$ cm

$$\text{Magnification, } m = -\frac{1}{3}$$

$$\text{Since, magnification, } m = -\frac{v}{u}$$

$$\text{Magnification, } m = -\frac{1}{3} = -\frac{v}{u}$$

$$v = \frac{u}{3}$$

Using mirror formula, we have

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f} \Rightarrow \frac{1}{f} = \frac{1}{u} + \frac{3}{u} = \frac{4}{u}$$

$$\Rightarrow u = 4f = 4(-20) = -80 \text{ cm}$$

The object should be placed at a distance 80 cm from the concave mirror.

For convex mirror,

Focal length, $f = +20$ cm

$$\text{Magnification, } m = +\frac{1}{3}$$

Since, magnification, $m = -\frac{v}{u}$

$$\therefore \text{Magnification, } m = \frac{1}{3} = -\frac{v}{u}$$

$$v = -\frac{u}{3}$$

Using mirror formula, we have

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

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

$$u = -2f = -2(20) = -40 \text{ cm}$$

The object should be placed at a distance 40 cm from the convex mirror to form virtual, erect and diminished image.

SE. 9

A car is fitted with a convex mirror of focal length 20 cm. A second car 2m broad and 1.6m high is 6m away from the first car.

- (a) Find position of the second car as seen in the mirror of the first and
- (b) Find the breadth and height of the second car seen in the mirror of the first car, are respectively.

Ans. $u = -6\text{m} = -600\text{cm}$, $f = +20\text{cm}$

$$(a) \frac{1}{v} + \frac{1}{-600} = \frac{1}{20} \text{ or } \frac{1}{v} = \frac{31}{600}$$

$$\text{or } v = \frac{600}{31} \text{ cm} = 19.35 \text{ cm}$$

$$(b) m = -\frac{v}{u} = -\frac{600}{31} \times \frac{1}{-600} = \frac{1}{31}$$

$$\text{Breadth of image} = \frac{1}{31} \times 200 \text{ cm} = 6.45 \text{ cm}$$

$$\text{Height of image} = \frac{1}{31} \times 160 \text{ cm} = 5.16 \text{ cm}$$

SE. 10

A dentist uses a small concave mirror of focal length 3.0 cm and holds it at a distance of 2 cm from the tooth. what is the magnification of the image.

Ans. Given

Focal length of the mirror (f) = -3.0 cm

Distance of the object (u) = -2.0 cm

Magnification (m) = ?

Formula to be used : $m = -\frac{v}{u}$

Since in this case we do not know the value of v ,

so first of all we will use the formula, $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$, to calculate v and then we will find out m .

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

Substituting the given values, we get

$$\frac{1}{v} = -\frac{1}{3} - \left(-\frac{1}{2}\right) = -\frac{1}{3} + \frac{1}{2} = \frac{-2+3}{6} = \frac{1}{6}$$

$$\therefore v = 6 \text{ cm}$$

Since v is positive, the image is virtual

$$\text{Now, } m = -\frac{v}{u} = -\frac{6}{-2} = 3$$

i.e., the image is three times the size of the object.

SE. 11

The refractive index of water is $\frac{4}{3}$ and for glass it is $\frac{3}{2}$ with respect to air. What is the refractive index of glass with respect to water ?

Ans. Here,

Refractive index of water with respect to air,

$${}_w n_a = \frac{4}{3}$$

R.I. of glass with respect to air, ${}_g n_a = \frac{3}{2}$

R.I. of glass with respect to water, ${}_g n_w = ?$

From relation,

For successive refraction, ${}_w n_a \times {}_g n_w \times {}_a n_g = 1$

$$\left(\text{As } \frac{{}_w n_a}{n_a} \times \frac{{}_g n_w}{n_w} \times \frac{{}_a n_g}{n_g} = 1 \right)$$

We have, ${}_g n_w = \frac{1}{{}_w n_a \times {}_a n_g} = \frac{{}_g n_a}{{}_w n_a}$

Putting value, we get,

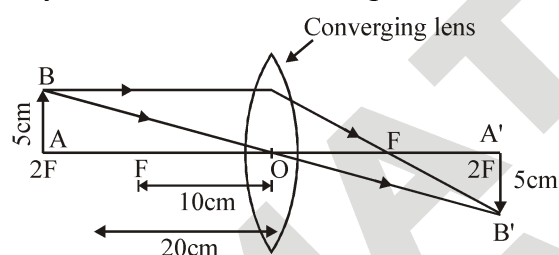
$${}_g n_w = \frac{3/2}{4/3} = \frac{3}{2} \times \frac{3}{4} = \frac{9}{8} = 1.125$$

SE. 12

An object of 5cm is placed 20 cm away from a converging lens of focal length 10 cm. Draw the ray diagram to produce the image and find the position, size and the nature of the image formed.

Ans. In this case, $f = +10$ cm, $u = -20$ cm, $h_1 = 5$ cm

Here, object is placed 20 cm away from the lens of focal length 10 cm, so object is at 2F. So the image of the object will be formed at 2F on right side of the lens. The image formed will be real, inverted and of the same size as that of the object as shown in the diagram.



Step I : Using $-\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$, we have

$$-\frac{1}{(-20)} + \frac{1}{v} = \frac{1}{10} \text{ or } \frac{1}{v} = \frac{1}{10} - \frac{1}{20} = \frac{1}{20}$$

$$\therefore v = +20 \text{ cm}$$

Positive sign shows that a real image is formed

Step II : Using, $\frac{h_2}{h_1} = \frac{v}{u}$, we have $h_2 = \frac{v}{u} h_1$

$$= \frac{20}{-20} \times 5 = -5 \text{ cm}$$

Negative sign shows that the image formed is inverted.

Thus, image formed is real, inverted and of the same size as that of the object.

SE. 13

A convex lens forms a real and inverted image of a needle at a distance of 25 cm from the lens. If the image is of the same size as that of the needle, then where should the needle be placed in front of the lens. Also calculate the power of the lens.

Ans. Step 1. We know, if the size of the real and inverted image is same as that of the object, then the object is at 2F and image is also formed at 2F on the other side of the convex lens.

$$\therefore u = -25 \text{ cm, } v = 25 \text{ cm } (\because u = v)$$

Using $-\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$, we get

$$\frac{1}{f} = \frac{1}{25} + \frac{1}{25} = \frac{2}{25} \text{ or } f = \frac{25}{2} = 12.5 \text{ cm}$$

In this case, $2f = 25$ cm or $f = 12.5$ cm

Thus, needle must be placed at a distance of 25cm in front of the convex lens.

Step 2 : Now, power of lens, $P = \frac{100}{f(\text{in cm})}$

$$= \frac{100}{12.5} = +0.8 \text{ D}$$

SE. 14

A diverging lens or a concave lens of focal length, $f = 15$ cm forms an image 10 cm from the lens. Draw a ray diagram and prove that the object is placed 30 cm away from the lens. Use a scale of 1 : 5.

Ans. In figure, A'B' is the image AB is the real object. Also by measurements.

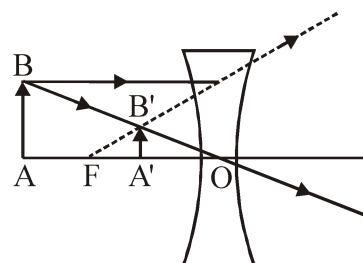


Image distance $CA' = 2$ cm

i.e., $v = 10$ cm

Focal length, $CF = 3$ cm i.e., $f = 15$ cm

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

or $\frac{1}{u} - \frac{1}{v} = \frac{1}{f} = \frac{1}{10} - \frac{1}{15} = \frac{3-2}{30} = \frac{1}{30}$

or $u = 30$ cm CA comes to be 6 cm.

Hence, object distance = 30 cm

SE. 15

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

Ans. Here, (using sign convention)

Focal length, $f = -15$ cm (focus on left of the lens)
Image distance, $v = -10$ cm (image on left of the lens)

(i) Object position

From lens formula, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

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

Putting values, we get, $-\frac{1}{u} = \frac{1}{-15} - \frac{1}{-10}$

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

Object must be placed at distance 30 cm on the left of the lens.

(2) Magnification

From relation, $m = \frac{h_2}{h_1} = \frac{v}{u}$

Putting value, we get, $m = \frac{-10 \text{ cm}}{-30 \text{ cm}} = \frac{1}{3}$

The virtual image has $\left(\frac{1}{3}\right)^{\text{rd}}$ size as that of the object.

SE. 16

The image of candle flame formed by a lens is obtained on a screen placed on the other side of the lens. If the image is three times the size of the flame and the distance between lens and image is 80 cm, at what distance should the candle be placed from the lens ? what is the nature of the imge at a distance of 80 cm and the lens ?

Ans. The image is real as only the real image can be taken on the screen.

Here, image distance $v = + 80$ cm

Magnification, $m = - 3$

Object distance, $u = ?$

Since, magnification, $m = \frac{v}{u} \Rightarrow -3 = \frac{80}{u}$

$u = \frac{-80}{3}$ cm

Nature of image

→ Real, inverted

→ magnified

→ formed beyond 2F

Using lens formula, we have

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

$\frac{1}{f} = \frac{1}{80} - \frac{3}{-80} = \frac{4}{80} = \frac{1}{20}$

$\Rightarrow f = 20$ cm

Positive focal length denoted that lens is convex.

NS. 1

Define the principal focus of a concave mirror.

Ans. A point on the principal axis where the parallel rays of light after reflecting from a concave mirror meet.

NS. 2

The radius of curvature of a spherical mirror is 20 cm. What is its focal length ?

Ans. Radius of curvature, $R = 20$ cm

$$\therefore \text{Focal length, } f = \frac{R}{2} = \frac{20}{2} = 10 \text{ cm}$$

NS. 3

Name a mirror that can give an erect and enlarged image of an object.

Ans. A concave mirror gives an erect and enlarged image of an object between pole and principal focus of the mirror.

NS. 4

Why do we prefer a convex mirror as a rear-view mirror in vehicles ?

Ans. This is because a convex mirror forms an erect and diminished (small in size) images of the objects behind the vehicle and hence the field of view behind the vehicle is increased.

NS. 5

Find the focal length of a convex mirror whose radius of curvature is 32cm.

Ans. Given, $R = +32$ cm

$$\therefore f = \frac{R}{2} = \frac{32}{2} = +16 \text{ cm}$$

Thus, the focal length of the convex mirror is 16 cm.

NS. 6

A concave mirror produces three times magnified real image of an object placed at 10 cm in front of it. Where is the image located ?

Ans. Here, linear magnification (m) = 3
(Negative sign for real image, which is inverted)
Object distance (u) = -10 cm
Image distance (v) = ?

$$\text{As } m = -\frac{v}{u} \Rightarrow -3 = \frac{-v}{-10} \therefore v = -30 \text{ cm}$$

The image is located at 30 cm in front of the mirror

NS. 7

The image formed by a concave mirror is observed to be virtual, erect and larger than the object. Where should be the position of the object ?

- (a) Between the focus and the centre of curvature
- (b) At the centre of curvature
- (c) Beyond the centre of curvature
- (d) Between the pole of the mirror and its focus.

Ans. (d) For virtual, erect and larger image, the object must lie between the pole of the mirror and its focus.

NS. 8

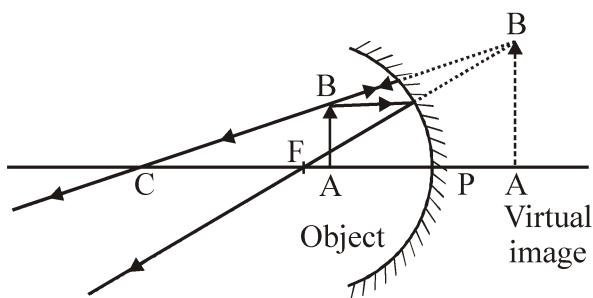
No matter how far you stand from a mirror, your image appears erect. The mirror is likely to be (a) plane (b) concave (c) convex (d) either plane or convex

Ans. (d) The image is erect in a plane mirror and also in a convex mirror, for all positions of the object.

NS. 9

We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror ? What is the nature of the image ? Is the image larger or smaller than the object ? Draw a ray diagram to show the image formation in this case.

Ans. A concave mirror produces an erect image if the object is placed between the pole and the focus of the concave mirror. Thus, object may be placed at any position whose distance is less than 15cm from the concave mirror. The image is virtual and erect. The image is larger than the object. The ray diagram is shown below



NS. 10

Name the type of mirror used in the following situations.

- (a) Headlights of a car
- (b) Side/rear-view mirror of a vehicle
- (c) Solar furnace

Support your answer with reason.

Ans. (a) For head lights of a car, we use a concave mirror. The light source is held at the focus of the mirror. On reflection, a strong parallel beam of light emerges.

(b) A convex mirror is used as side rear view mirror, because its field of view is larger and it forms virtual, erect and diminished images of objects behind.

(c) For solar furnace, we use a concave mirror. Light from the sun, on reflection from the mirror, is concentrated at the focus of the mirror, producing heat.

NS. 11

An object is placed at a distance of 10 cm from a convex mirror of focal length 15 cm. Find the position and nature of the image.

Ans. Here, object distance (u) = -10 cm, focal length (f) = 15 cm, image distance (v) = ?

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

$$\Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = \frac{1}{15} - \frac{1}{(-10)} = \frac{1}{15} + \frac{1}{10} = \frac{5}{30} = \frac{1}{6}$$

$$\therefore v = 6 \text{ cm}$$

Here, + sign of v indicated that image is at the back of the mirror. It must be virtual, erect and smaller in size than the object.

NS. 12

The magnification produced by a plane mirror is $m = +1$. What does this mean ?

$$\text{Ans. As } m = \frac{h_2}{h_1} = +1$$

$$\Rightarrow h_2 = h_1$$

i.e., size of image is equal to size of the object. Further, +sign of m indicates that the image is erect and hence virtual.

NS. 13

An object 5.0 cm in length is placed at a distance of 20 cm in front of a convex mirror of radius of curvature 30 cm. Find the position of the image, its nature and size.

Ans. Here, object size (h_1) = 5.0 cm, object distance (u) = -20 cm, Radius of curvature (R) = 30 cm, image distance (v) = ?

$$\text{As } \frac{1}{v} + \frac{1}{u} = \frac{1}{f} = \frac{2}{R}$$

$$\Rightarrow \frac{1}{v} = \frac{2}{R} - \frac{1}{u} = \frac{2}{30} + \frac{1}{20} = \frac{4+3}{60} = \frac{7}{60}$$

$$\therefore v = \frac{60}{7} = 8.57 \text{ cm}$$

Positive sign of v indicates that image is at the back of the mirror. It must be virtual and erect.

$$\text{As } m = \frac{h_2}{h_1} = -\frac{v}{u}$$

$$\Rightarrow \frac{h_2}{5.0} = \frac{-60/7}{-20} = \frac{3}{7}$$

$$\Rightarrow h_2 = \frac{3}{7} \times 5.0 = \frac{15.0}{7} = 2.1 \text{ cm} \therefore h_2 = 2.1 \text{ cm}$$

This is the size of the erect image.

NS. 14

An object of size 7.0 cm is placed at 27 cm in front of a concave mirror of focal length 18 cm. At what distance from the mirror should a screen be placed, so that a sharp focussed image can be obtained ? Find the size and the nature of the image.

Ans. Here, object size (h_1) = 7.0 cm,
object distance (u) = -27cm
focal length (f) = -18cm,
image distance(v) = ?

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

$$\Rightarrow \frac{1}{v} = \frac{1}{f} - \frac{1}{u} = -\frac{1}{18} + \frac{1}{27} = \frac{-3+2}{54} = -\frac{1}{54}$$

$$\therefore v = -54 \text{ cm}$$

Therefore, the screen should be held in front of the mirror at a distance of 54 cm from the mirror. The image obtained on the screen will be real.

$$\text{As } m = \frac{h_2}{h_1} = -\frac{v}{u} \Rightarrow \frac{h_2}{7.0} = -\frac{(-54)}{(-27)}$$

$$\therefore h_2 = -14.0 \text{ cm}$$

Negative sign of h_2 shows that the image is inverted.

NS. 15

A ray of light travelling in air enters obliquely into water. Does the light ray bend towards the normal or away from the normal ? Why ?

Ans. When a ray of light travels from air into water obliquely, it bends towards the normal. This is because water is optically denser than air. On entering water, speed of light decreases and the light bends towards normal.

NS. 16

Light enters from air to glass having refractive index 1.5. What is the speed of light in glass ? The speed of light in vacuum is $3 \times 10^8 \text{ m s}^{-1}$.

Ans. Here, refractive index, $n = 1.5$,
speed of light in vacuum = $c = 3 \times 10^8 \text{ m s}^{-1}$
speed of light in glass, $v = ?$

$$\text{From, } n = \frac{c}{v} \Rightarrow v = \frac{c}{n} = \frac{3 \times 10^8}{1.5}$$

$$= 2 \times 10^8 \text{ ms}^{-1}$$

NS. 17

Give the medium having highest optical density. Also, give the medium with lowest optical density.

Ans. The medium with highest optical density is diamond and its refractive index is maximum (=2.42), also, the medium with lowest optical density is air and its refractive index is minimum (=1.0003).

NS. 18

You are given kerosene, turpentine and water. In which of these does the light travel fastest ?

Ans. We know from the definition of refractive index, that the speed of light is higher in a medium with lower refractive index. So, the light travels fastest in water relative to kerosene and turpentine.

NS. 19

The refractive index of diamond is 2.42. What is the meaning of this statement ?

Ans. This statement means that the speed of light in diamond is lower by a factor of 2.42

NS. 20

Define 1 dioptre of power of a lens.

Ans. The power of a lens whose focal length is one metre (1m) is one dioptre.

NS. 21

A convex lens forms a real and inverted image of a needle at a distance of 50 cm from it. Where is the needle placed in front of the convex lens if the image is equal to the size of the object ? Also, find the power of the lens.

Ans. Distance of the image from the lens, $v = 50 \text{ cm}$
Distance of the object from the lens, $u = ?$
Size of the image, $I =$ size of the object, O
From the definition, if h is the height of the image and that of the object,

$$\text{magnification} = \frac{I}{O} = \frac{-h}{h} = -1$$

[\therefore The image is inverted]

For a lens, magnification = $\frac{v}{u}$

So, $\frac{v}{u} = -1 \Rightarrow u = -v = -50\text{cm}$

So, the needle (the object) is placed at a distance of 50cm in front of the lens.

Using the lens formula, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$

$$\Rightarrow \frac{1}{f} = \frac{1}{50\text{cm}} - \frac{1}{(-50\text{cm})} = \frac{1}{50\text{cm}} + \frac{1}{50\text{cm}}$$

$$\frac{2}{50\text{cm}} = \frac{1}{25\text{cm}}$$

$$\therefore f = 25\text{ cm}$$

$$\begin{aligned} \text{Then, power of the lens} &= \frac{100}{f(\text{cm})} \text{ D} \\ &= \frac{100}{25} \text{ D} = 4\text{D} \\ \therefore P &= 4\text{D} \end{aligned}$$

NS. 22

Find the power of a concave lens of focal length 2m.

Ans. Focal length of the concave lens = -2m

So, power of the concave lens = $\frac{1}{-2} \text{ D} = -0.5 \text{ D}$

NS. 23

Which one of the following materials cannot be used to make a lens ?

- (a) Water (b) Glass (c) Plastic (d) Clay

Ans. (d) because clay is opaque.

NS. 24

Which of the following lenses would you prefer to use while reading small letters found in a dictionary?

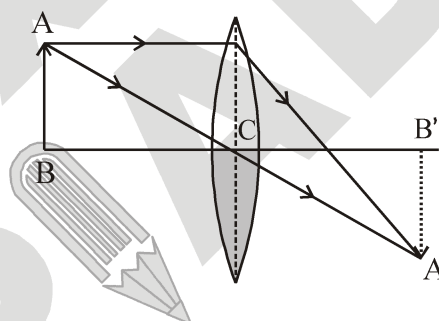
- (a) Convex lens of focal length 50 cm
 (b) A concave lens of focal length 50 cm
 (c) A convex lens of focal length 5 cm
 (d) A concave lens of focal length 5 cm

Ans. (c) For reading small letters in a dictionary, we need to use a convex lens of smaller focal length.

NS. 25

One half of a convex lens is covered with a black paper. Will this lens produce a complete image of the object ? Verify your answer experimentally. Explain your observations.

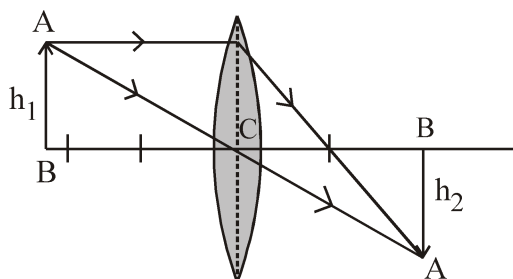
Ans. Yes, it will produce a complete image of the object, as shown in figure. This can be verified experimentally by observing the image of a distant object like tree on a screen, when lower half of the lens is covered with a black paper. However, the intensity or brightness of image will reduce.



NS. 26

An object 5cm in length is held 25 cm away from a converging lens of focal length 10cm. Draw the ray diagram and find the position, size and the nature of the image formed.

Ans. Here, object size, $h_1 = 5\text{ cm}$
 object distance, $u = -25\text{ cm}$
 focal length of lens, $f = 10\text{ cm}$
 image distance, $v = ?$
 image size, $h_2 = ?$



$$\text{As } \frac{1}{v} - \frac{1}{u} = \frac{1}{f} \therefore \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{10} - \frac{1}{25} = \frac{5-2}{50}$$

$$\Rightarrow v = \frac{50}{3} = 16.67\text{cm}$$

As v is positive, the image formed is real; on the right side of the lens, as shown in figure.

$$\text{As } m = \frac{h_2}{h_1} = \frac{v}{u}$$

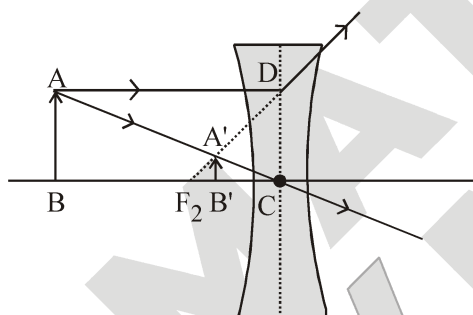
$$\therefore \frac{h_2}{5} = \frac{50/3}{-25} = \frac{-2}{3}$$

$$\Rightarrow h_2 = -\frac{10}{3} = -3.3\text{cm}$$

NS. 27

A concave lens of focal length 15 cm forms an image 10 cm from the lens. How far is the object placed from the lens? Draw the ray diagram.

Ans. Here, focal length of lens, $f = -15\text{cm}$
 image distance, $v = -10\text{cm}$
 object distance
 $u = ?$



$$\text{As } \frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\Rightarrow \frac{1}{u} = \frac{1}{v} - \frac{1}{f} = \frac{1}{-10} + \frac{1}{15}$$

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

$$\therefore u = -30\text{cm}$$

NS. 28

Find the focal length of a lens of power -2.0D . What type of lens is this?

Ans. Here, focal length, $f = ?$, power, $P = -2.0\text{D}$

$$\text{As } f = \frac{100}{P} \Rightarrow f = \frac{100}{-2.0} = -50\text{cm}$$

As power of lens is negative, the lens must be concave.

NS. 29

A doctor has prescribed a corrective lens of power $+1.5\text{D}$. Find the focal length of the lens. Is the prescribed lens diverging or converging?

Ans. Power of the lens, $P = +1.5\text{D} = +1.5 \text{ m}^{-1}$

$$\therefore \text{Focal length of the lens, } f = \frac{1}{+1.5\text{m}^{-1}}$$

$$= 0.667\text{m} = 66.7 \text{ cm}$$

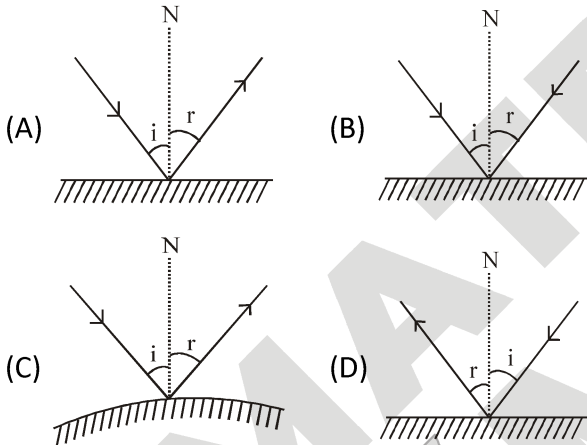
Thus, the focal length of the lens is 66.7 cm

Since the focal length of the lens is positive, hence the given lens is a converging lens.

EXERCISE – I

ONLY ONE CORRECT TYPE

- Which of the following is not a natural source of light ?
 (A) Sun (B) Oil-lamps
 (C) Moon (D) Stars
- Air is not visible because it :
 (A) is nearly a perfectly transparent substance
 (B) neither absorbs nor reflects light
 (C) transmits whole of light
 (D) all of the above are correct
- A light ray falls on a plane mirror and deviates by 60° , then the angle of reflection will be :
 (A) 30° (B) 90° (C) 60° (D) 180°
- Choose the wrong option :



- A boy is standing in front of a plane mirror at a distance of 3m from it. What is the distance between the boy and his image ?
 (A) 3m (B) 4.5m
 (C) 6m (D) None of these
- A mirror forms a virtual image of a real object :
 (A) It must be a convex mirror
 (B) It must be a concave mirror
 (C) It must be a plane mirror
 (D) It may be any of the mirrors mentioned above.
- An object is placed at the centre of curvature of a concave mirror. The distance between its image and the pole is :
 (A) equal to f
 (B) between f and 2f
 (C) equal to 2f
 (D) greater than 2f

- An object of size 2.0 cm is placed perpendicular to the principal axis of a concave mirror. The distance of the object from the mirror equals the radius of curvature. The size of the image will be :
 (A) 0.5 cm (B) 1.0 cm
 (C) 1.5 cm (D) 2.0 cm
- The magnification m of an image formed by a spherical mirror is negative. It means, the image is :
 (A) smaller than the object
 (B) larger than the object
 (C) erect
 (D) inverted
- A ray of light is incident on a concave mirror. If it is parallel to the principal axis, the reflected ray will :
 (A) pass through the focus
 (B) pass through the centre of curvature
 (C) pass through the pole
 (D) retrace its path
- If an incident ray passes through the centre of curvature of a spherical mirror, the reflected ray will
 (A) pass through the pole
 (B) pass through the focus
 (C) retrace its path
 (D) be parallel to the principal axis
- To get an image larger than the object, one can use :
 (A) a convex mirror but not a concave mirror
 (B) a concave mirror but not a convex mirror
 (C) either a convex mirror or a concave mirror
 (D) a plane mirror
- The image is always erect in :
 (A) Plane mirror (B) Concave mirror
 (C) Convex mirror (D) Both (A) & (C)
- Choose the correct relation between u, v and R for spherical mirror :

$$(A) R = \frac{2uv}{u+v}$$

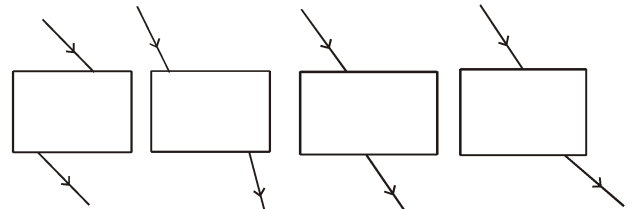
$$(B) R = \frac{2}{u+v}$$

$$(C) R = \frac{2(u+v)}{(uv)}$$

$$(D) \text{ None of these}$$

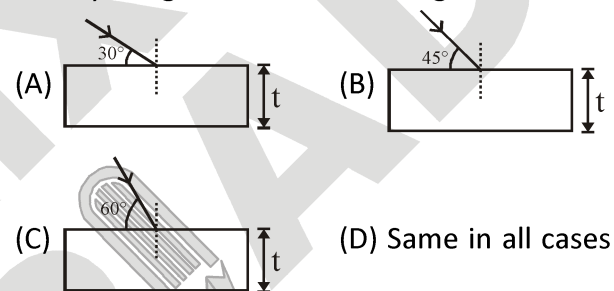
15. A dentist has a small mirror of focal length 16 mm. He views the cavity in the tooth of a patient by holding the mirror at a distance of 8 mm from the cavity. The magnification is :
- (A) 1 (B) 1.5
(C) 2 (D) 3
16. The focal length of a concave mirror is f and the distance of the object from the principal focus is a . The magnitude of magnification obtained will be :
- (A) $(f + a)/f$ (B) f/a
(C) \sqrt{f} / \sqrt{a} (D) f^2/a^2
17. The image formed by a concave mirror is observed to be virtual, erect and larger than the object, then the position of the object should be :
- (A) between the focus and the centre of curvature
(B) at the centre of curvature
(C) beyond the centre of curvature
(D) between the pole of the mirror and the focus
18. Which of the following can make a parallel beam of light when light from a point source is incident on it ?
- (A) Concave mirror as well as convex lens
(B) Convex mirror as well as concave lens
(C) Two plane mirrors placed at 90° to each other
(D) Concave mirror as well as concave lens
19. A ray of light travelling in air falls obliquely on the surface of a calm pond. It will :
- (A) go into the water without deviating from its path
(B) deviate away from the normal
(C) deviate towards the normal
(D) turn back on its original path
20. A ray of light goes from a medium of refractive index n_1 to a medium of refractive index n_2 . The angle of incidence is i and the angle of refraction is r . Then, $\sin i / \sin r$ is equal to :
- (A) n_1 (B) n_2
(C) n_1/n_2 (D) n_2/n_1

21. Four students showed the following traces of the path of a ray of light passing through a rectangular glass slab.



The trace most likely to be correct is that of student (A) I (B) II (C) III (D) IV

22. In which figure lateral displacement will be larger if a ray of light of same wavelength



23. A convex lens forms a virtual image when an object is placed at a distance of 18 cm from it. The focal length must be :
- (A) greater than 36 cm (B) greater than 18 cm
(C) less than 36 cm (D) less than 18 cm
24. An object is placed before a concave lens. The image formed :
- (A) is always erect (B) may be real or virtual
(C) is always virtual (D) both (A) and (C)

PARAGRAPH TYPE

PARAGRAPH # 1

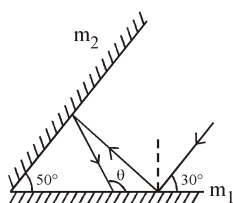
The radius of curvature of a convex mirror used on a moving automobile is 2.0 m. A truck is coming behind it at a constant distance of 3.5 m.

25. The image is at a distance of behind the mirror.
(A) 0.58 m (B) 0.68 m
(C) 0.78 m (D) 0.88 m
26. The nature of the image is
(A) Diminished and inverted
(B) Virtual and erect
(C) Virtual and inverted
(D) Real and erect

EXERCISE – II

VERY SHORT ANSWER TYPE

1. What is homogeneous medium, explain.
2. What is heterogeneous medium, explain.
3. According to given figure what angle(θ) does the reflected ray from mirror m_2 , make with mirror m_1 ?



4. Give differences between real image and virtual image.
5. What focal length can be assigned to a plane mirror?
6. What are the values of the angle of incidence and the angle of reflection for normal incidence on a plane mirror?
7. Define the principal focus of a concave mirror.
8. The radius of curvature of spherical mirror is 20 cm. What is its focal length?
9. Name a mirror that can give an erect and enlarged image of an object.
10. The image formed by a concave mirror is observed to be virtual, erect and large than the object. State the position where the object has been placed?

SHORT ANSWER TYPE

1. If angle of incident is 30° for a ray of light, find the angle of deviation after reflection
2. Write the two laws of reflection of light.
3. With the help of a ray diagram, state and explain the laws of reflection of light at a plane mirror. Mark the angle of incidence and reflection clearly on the diagram.
4. If magnification of an image formed by a spherical mirror comes out to be negative, what does it implies?
5. What is the difference between the virtual images produced by concave, plane and convex mirrors?

LONG ANSWER TYPE

1. Write the sign convention used for spherical mirrors.
2. By drawing a neat ray diagram, show the formation of the image of a point object placed above the principal axis of a convex mirror. Explain the construction.
3. We wish to obtain an erect image of an object, using a concave mirror of focal length 15 cm. What should be the range of distance of the object from the mirror? What is the nature of the image? Is the image larger or smaller than the object? Draw a ray diagram to show the image formation in this case.
4. Name the type of mirror used in the following situations
 - (a) Headlights of a car
 - (b) Side/rear-view mirror of a vehicle
 - (c) Solar furnace
5. Explain the principle of reversibility of light and prove that ${}_1\mu_2 = \frac{1}{{}_2\mu_1}$.

TRUE / FALSE TYPE

1. Light cannot travel in vacuum.
2. The angle of incidence is equal to the angle of reflection. This is true for reflection from plane mirrors, but is not true for reflection from spherical mirrors.
3. A spherical mirror never forms an image whose size is the same as that of the object.
4. A ray starting from the focus of a concave mirror becomes parallel to the principal axis after reflection.
5. A ray of light incident parallel to the principal axis of a spherical mirror retraces its path after reflection.

Answer Key

EXERCISE–I

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	D	C	B	C	D	C	D	D	A	C	B	D	A	C
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B	D	A	C	D	C	A	B	D	C	B	A	A	B	A
31	32													
A	B													

EXERCISE – II

VERY SHORT ANSWER TYPE

3. 130° 8. 10cm

SHORT ANSWER TYPE

1. 120°

TRUE / FALSE

1. F 2. F 3. F 4. T 5. F

FILL IN THE BLANKS

1. vacuum ; 3×10^8 2. away 3. constant
 4. speed 5. parallel

NUMERICAL PROBLEMS

1. 24 cm from the mirror, on the same side as the object
 2. 4 cm
 3. 30 cm
 4. 18 cm, 1 cm, real and inverted
 5. 48 cm

SELF PROGRESS ASSESSMENT FRAMEWORK

(CHAPTER : LIGHT : REFLECTION AND REFRACTION)

CONTENT	STATUS	DATE OF COMPLETION	SELF SIGNATURE
Theory			
In-Text Examples			
Solved Examples			
NCERT Exercises			
Exercise I			
Exercise II			
Short Note-1			
Revision - 1			
Revision - 2			
Revision - 3			
Remark			

NOTES :

1. In the status, put “completed” only when you have thoroughly worked through this particular section.
2. Always remember to put down the date of completion correctly. It will help you in future at the time of revision.



Space for Notes :

A large rectangular area filled with horizontal dotted lines, intended for writing notes.

