Unit - 15
Current Electricity

Students Learning Outcomes (SLOs)

After learning this unit students should be able to

- Define electric current.
- Describe the concept of conventional current
- Understand the potential difference across a circuit component and name its unit
- Describe Ohm's law and its limitations
- Define resistance and its unit.
- Explain the under lying principles in the working of volume controls of radio and T.V
- Calculate the effective resistance of a number of resistances connected in series and also in parallel.
- Describe the factors affecting the resistances of a metallic conductor
- Distinguish between conductors and insulators
- Sketch and interpret the V-I characteristics graph for a metallic conductor, a filament lamp and a thermistor
- Describe how energy is dissipated in a resistance and explain Joule's law.
- Apply the equation $E = IVt = I^2Rt = \frac{V^2t}{R}$ to solve numerical problem.
- Calculate the cost of energy when given the cost perkWh.
- Identify circuit components such as switches, resistors batteries transducers, LDRs, Thermistors and capacitors, Relays and diodes, LEDs.
- Identify the symbols of circuit components and colour codes on resistors
- Construct simple series (single path) and parallel circuits (multiple paths).
- State the functions of the live, neutral and earth wires in the domestic main supply.
- Predict the behavior of light bulbs in series and parallel circuit such as for celebration lights.
- Describe the use of electrical measuring devices like galvanometer, ammeter and voltmeter (construction and working principles not required).
- Explain Alternating Current AC
- Describe hazards of electricity (damage insulation, overheating of cables, damp conditions).
- Explain the use of safety measures in household electricity, (fuse, circuit breaker, earth wire).
- Describe the damages of an electric shock from appliances on the human body.

wireless electricity. Wireless electricity is the transfer of power from one device to another, air being the medium of transmission. First attempt of wireless power transmission was made by Nikola Tesla. In the year 1899, Nikola Tesla first made practical demonstrations of wireless power transmission. He powered a field of fluorescent lamps which were located twenty-five miles away from their power source and that too without using wires.

Explanation of principles involved

This demonstrates the idea of a magnetic field being used as a source of electricity for a light bulb. The tesla coil serves as the electric source. The magnetic field that is being emitted from the tesla coil causes the electrons to move inside the bulb, eventually splitting releasing energy causing the bulb to be lit.

Do You Know!

Current is a tensor quantity because its having direction but not obeys law of vector addition.

Do You Know!

André-Marie Ampère (20 January 1775 – 10 June 1836) was a French physicist, mathematician.

Electricity is one of the most important branch of physics. Electricity has many uses in our daily life. It is used for lighting rooms, working fans and domestic appliances like using electric stoves, air condition and more. All these provide comfort to people. In factories, large machines are worked with the help of electricity.

Modern means of transportation and communication have been revolutionised by it. Electric trains and electric cars are quick means of travel. Electricity plays a pivotal role in the fields of medicines and surgery too such as X-ray, ECG. The use of electricity is increasing day by day.

15.1 ELECTRIC CURRENT

A current is motion of any charge moving from one point to another point. An electric current is always considered as flow of negative charges of the conductor. An electric current is symbolized by **I** .The symbol **I** was used by the French physicist "Andre-Marie Ampere". The unit of electric current (ampere) is named after him. Current always flow in circuit or electrical system.

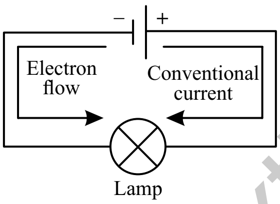


Figure 15.1

Electronic current: When current flow from the negative terminal to the positive terminal of battery.

Conventional current: When current flows from the positive terminal to the negative terminal of battery.

Equation: $I = \frac{q}{t}$ $\therefore [q = ne]$

There are two types of electric current

i. Direct current (DC)

ii. Alternating current (AC)

i. Direct Current (DC)

A current that always flows in one direction only is called direct current. The current we get from a battery is a direct current.

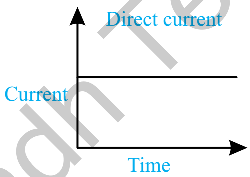


Figure 15.2

ii. Alternating Current (AC)

A current that reverses its direction periodically is called alternating current. Most power stations in our country produce alternating current. AC changes direction every 1/50 second and its frequency is 50 Hertz (Hz).

One advantage of AC over DC is that it can be transmitted over long distances without much loss of energy.

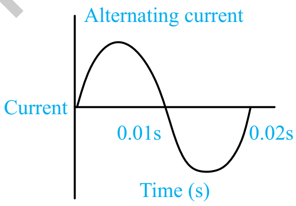


Figure 15.3

SELF ASSESSMENT QUESTIONS

Q1: Calculate the current if 20C charges passing through a conductor in 5 Sec?

Q2: What is Analogue of flow of current?

Q3: What is the frequency of DC?

15.2 POTENTIAL DIFFERENCE

When a charge moves through a potential difference, electrical work is done and energy transferred. The Potential difference is the difference in the amount of energy that charge carriers have between two points in a field. The potential difference can be calculated by using the equation:

Equation of electric potential difference:

$$\Delta V = \frac{W}{q_o}$$

$$\therefore \quad \Delta V = V_B - V_A$$

$$V_B - V_A = \frac{W}{q_o}$$

It can also be calculated by the equation

Potential difference is measured in volt. Volts is denoted by V.

$$\text{Volt} = \frac{\text{Joule (J)}}{\text{Columb (C)}} = \frac{J}{C} = V$$

15.2 ELECTROMOTIVE FORCE

The amount of energy required to move the charge from lower potential to higher potential of the battery is called EMF.

$$\text{Equation: } \text{EMF}(\varepsilon) = \frac{\text{energy supplies (W)}}{\text{unit charge (q)}}$$

S.I unit of EMF is volt.

In centimeter-gram-second system the unit of EMF is the Statvolt or one erg per electrostatic unit of charge.

15.3 OHM'S LAW.

In 1826, George Simon Ohm made an investigation of the relation between potential difference across a conductor and the current flowing through it.

Do You Know!

The magnitude of AC and DC if same so, DC is more dangerous..

Do You Know!

Potential difference is also called voltage.

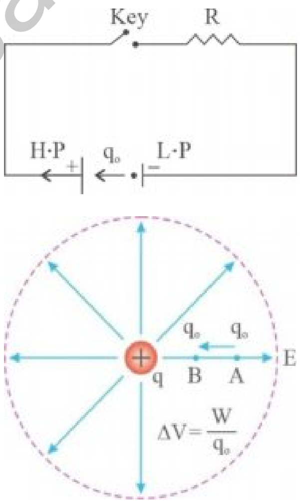


Fig: 15.4
Potential difference

Do You Know!

Production of DC is more expensive then AC

Do You Know!

The (K) in the ohm's law indicated the conductance and its unit is mho
Symbol: Ω^{-1}

Do You Know!

In graph a independent term always on x – axis and dependent term on y – axis.

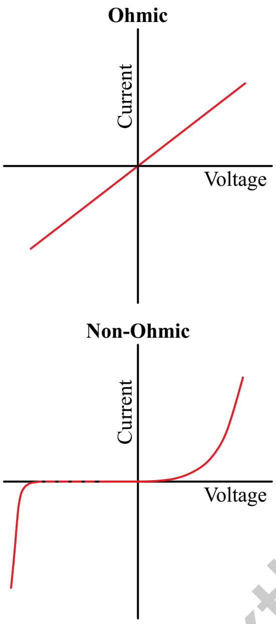


Fig: 15.5
V-I Graph of Ohmic and non-ohmic conductors

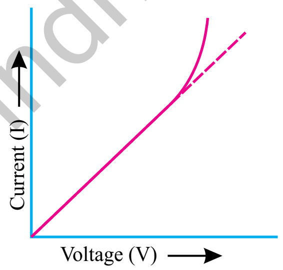


Fig: 15.6
IV characteristics

"The current flowing through the conductor is directly proportional to the potential difference (V) across the two ends of a conductor, provided the physical state (Dimension, Temperature, etc) of the conductor remain same.

Mathematically can be written as $I \propto V$

I=KV where K is constant of proportionality called conductance or physical state of conductor. Conductance is opposite to resistance. Thus (K=1/R).

I=V/R rearranging the equation

V=IR

Ohm's Law is valid only for ohmic substance at a given temperature and for steady currents.

V = IR where R is a constant called resistance R depends on the dimensions of the conductor and also on the material of the conductor. Its SI unit is Ohm (Ω).

Ohm's law was found out by various experiments, somewhat similar to the thermodynamic laws. As far as its significance is concerned, this law is used within all branches of electronic studies or science. The law is useful in carrying out calculations such as in determining the value of resistors or the current in a circuit and in measuring the voltage.

Ohm's law Limitations

There are some limitations to Ohm's law. They are as follows:

- Ohm's law is an empirical law which is found true for maximum experiments but not for all.
- Some materials are non-ohmic under a weak electric field.
- Ohm's law holds true only for a conductor at a constant temperature because resistivity changes with temperature.
- As long as the current flows, greater will be the temperature of the conductor.
- Heat produced in a conductor can be calculated by Joule's heat law $H = I^2Rt$ where I is current, R is resistance and t is time.
- Ohm's law is not applicable to in-network circuits.

- Ohm's does not apply directly to capacitor circuits and Inductor circuits.
- V-I graph of ohmic conductors is not really a straight graph. It does show some variation.
- The V-I characteristics of diodes are much different from ohmic conductors V-I graph.

Worked Example 1

How much voltage will be dropped across a 50 kΩ resistance whose current is 300 μA?

Solution:

Step 1: Write down the known quantities and quantities to

R = 50 kΩ = 50 × 103Ω

I = 300 μA = 300 × 10-6 A

V = ?

Step 2: Write down the formula and rearrange if necessary.

V = I × R

Step 3: Put the values and calculate.

V = I × R

V = (300 × 10-6) × (50 × 103)

V = 15 V

Result: V = 15 V

SELF ASSESSMENT QUESTIONS

Q1: The Product of resistance and capacitance equal to?

15.4 RESISTANCE

The electrical resistance of a circuit is the ratio between the voltage applied to the current flowing through it. According to Ohm's law, there is a relation between the current flowing through a conductor and the potential difference across it. It is given by,

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

Where V is the potential difference measured across the conductor (in volt), I is the current (ampere), R is the constant of proportionality, is called resistance (ohms)

The unit of electrical resistance is ohms.

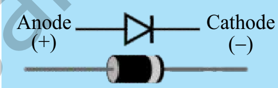
$$R = \frac{V}{I} = \text{ohm} = \frac{1\ \text{volt}}{1\ \text{ampere}}$$

Electric charge flows easily through some materials

Do You Know!

The device that does not follow ohm's law is known as a **non - ohmic device**

Examples of non-ohmic devices are **thermistors, crystal rectifiers, vacuum tube, diode** etc.



Diode

Thermistor

Vaccum tube

Fig: 15.7
Resistor

than others. The electrical resistance measures how much the flow of this electric charge is restricted within the circuit.

Factor affecting the resistance

Electrical resistance is directly proportional to length (L) of the conductor and inversely proportional to the cross-sectional area (A). It is given by the following relation.

$$R = \rho L/A$$

where ρ is the resistivity of the material measured in Ωm, (ohm-meter)

Resistivity is a qualitative measurement of a material's ability to resist flowing electric current. Obviously, insulators will have a higher value of resistivity than that of conductors.

Electrical resistance is inversely proportional to the temperature of metallic conductor because the random motion of free electron increased and offers more resistance in a metallic conductor.

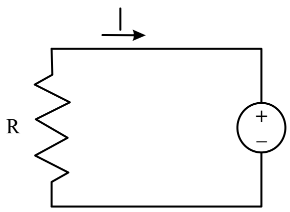
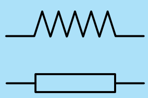


Fig: 15.8

Do You Know!

Symbol of resistor



Uses of Resistance

Resistance is also useful in things like transistor radios and TV sets. Suppose you want to lower the volume on your TV. You turn the volume knob and the sound gets quieter but how does that happen? The volume knob is actually part of an electronic component called a variable resistor. If you turn the volume down, you're actually turning up the resistance in an electrical circuit that drives the TV's loudspeaker. When you turn up the resistance, the electric current flowing through the circuit is reduced. With less current, there's less energy to power the loudspeaker—so it sounds much quieter.

Do You Know!

Series Combinition of resistors called voltage divider

15.5 SERIES AND PARALLEL COMBINATIONS OF RESISTORS IN A CIRCUIT

The method of connect the electric components is called circuit.

There are two types of circuits

(1) Series Combination circuit

(2) Parallel Combinations circuit

Series combination circuits:

When resistors are connected end to end such that there is only one path for the current to flow then the combination is called series combination.

Let suppose three resistors R_1, R_2 and R_3 are connected in Series, when this combination is connected to a battery of V volts, it draws current I from the battery. Re is a single resistor. This resistor is such that when it is connected to the same battery of V volts, it also draws current I from the battery. This resistor is therefore called equivalent resistor and its resistance is called equivalent resistance.

$V = V_1 + V_2 + V_3$

By applying Ohm's Law to each resistor. We have:

$V_1 = IR_1$, $V_2 = IR_2$, $V_3 = IR_3$, $V = IR_e$.

Using them in equation we get:

$IR_e = IR_1 + IR_2 + IR_3$.

$IR_e = I\ (R_1 + R_2 + R_3)$.

$R_e = R_1 + R_2 + R_3$

Thus equivalent resistance is equal to the sum of individual resistance.

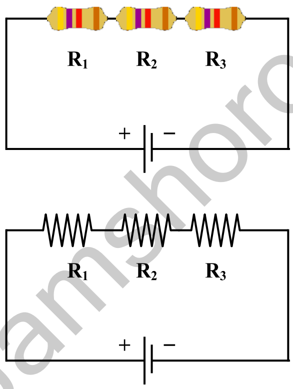


Fig: 15.9 Diagram showing three resistors connected in series

Advantages:

1. It's employed when a large number of bulbs or lights need to be used at the same time.
2. Because the circuit receives less current, it is safer.
3. Because all the bulbs, lights, and appliances are connected together, it's easier to turn them on or off.

Disadvantages:

1. Because all electrical appliances have only one switch, no single appliance may be turned off separately.
2. The second component of the circuit will not function if one component is fused or quits operating.
3. Because the voltage is distributed in series or combinations, not all of the components receive the same voltage.

Weblinks

Encourage students to visit below link for Resistor in series combination circuit

https://www.youtube.com/watch?v=pd3RkGs1Tsg&ab_channel=Don%27tMemorise

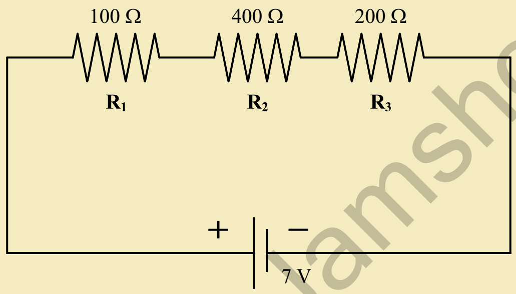
Weblinks

Encourage students to visit below link for How to find current and voltage of resistor in series

https://www.youtube.com/watch?v=EsNsAZ8PR4E&ab_channel=VAM%21Physics%26Engineering

Worked Example 2

Find the current I passing through circuit and the voltage across each of the resistors in the circuit below. Resistors in series.



Solution:

Step 1: Write down the known quantities and quantities to The three resistors in series have a resistance Re given by the sum of the three resistances. Hence

$$Re = 100 + 400 + 200 = 700\ \Omega$$

Step 2: Write down the formula and rearrange if necessary.

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

Step 3: Put the values and calculate.

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

$$I = \frac{7V}{700\Omega} = 0.01A$$

The voltage across each resistance is calculated using Ohm's law as follows:

$$V = IR_1 = 100 \times 0.01 = 1\ V$$
$$V = IR_2 = 400 \times 0.01 = 4\ V$$
$$V = IR_3 = 200 \times 0.01 = 2\ V$$

Result: I = 0.01 V=1 V, 4 V, 2 V

Weblinks

Encourage students to visit below link for Parallel arrangement of resistors

https://www.youtube.com/watch?v=BbYtMQ8EYBg&ab_channel=7activestudio

Parallel combination circuits:

When there are multiple paths for current flow in a circuit (as indicated in the diagram), the combination of resistances is referred to as parallel combination. Each resistance's potential is the same and equal to the applied potential.

Each resistor has a steady current flowing through it. In homes, the parallel combination is used for various domestic appliances, each of which has its own switch that may be turned on or off as needed.

Let suppose three resistors R_1, R_2 and R_3 are connected in Parallel. When the combination is connected to a battery of V volts, it draws a current I from the battery.

Re is a single resistor. This resistor is such that when it is connected to the same battery of V volts, it also draws current I from the battery. This resistor is therefore called equivalent resistor and its resistance is called equivalent resistance.

$I = I_1 + I_2 + I_3$

By applying Ohm's Law to each resistor. We have:

$$V = I_1R_1, V = I_2R_2, V = I_3R_3, V = IR_e$$

$$I_1 = \frac{V}{R_1}, I_2 = \frac{V}{R_2}, I_3 = \frac{V}{R_3}, I = \frac{V}{R_e}$$

Using them in equation, we get:

$$\frac{V}{R_e} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R_e} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

Thus the reciprocal of equivalent resistance is equal to the sums of reciprocals of individual resistances.

If one component of the circuit or a resistor is destroyed in parallel combinations of resistors, the remaining components of the circuit will continue to function normally. It's due to the fact that there are multiple paths for electric current to go through.

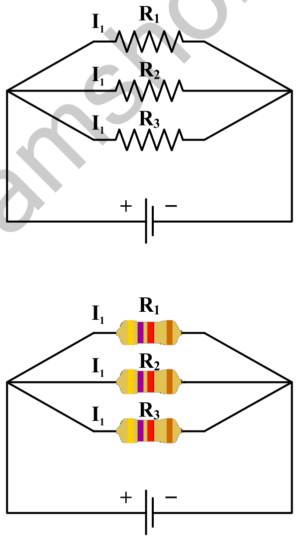


Fig: 15.10
Three resistors connected in parallel

Worked Example 3

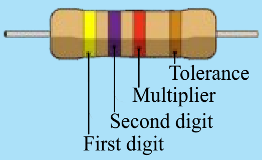
Find current I in the circuit below and the current passing through each of the resistors in the circuit. Resistors in parallel in example 2.

Solution:

The three resistors are in parallel and behave like a resistor with resistance Req given by

Do You Know!

Colours coding of resistors



1st digit	2nd digit	Multiplier	Tolerance
0	0	×1	Silver±10%
1	1	×10	Gold ±5%
2	2	×100	
3	3	×1000	
4	4	×1000	
5	5	×100000	
6	6	×1000000	
7	7		
8	8		
9	9		

Yellow	Violet	Orange	Gold
4	7	⊗ 1000	±5%

47KΩ ±5%

Do You Know!

To calculate the kWh for a specific appliance, multiply the power rating (watts) of the appliance by the amount of time (hrs) you use the appliance and divide by 1000.

$$\text{Kwh} = \frac{\text{Watts} \times \text{times (hrs)}}{1000}$$

Watts: Usually listed on the power cord, this is the rated power your appliance uses when turned on

times (hrs): Time appliances in "on" if minutes or seconds, convert to hours first

Kwh: Kilo-Watt-hour is what you are billed for by the utility company.

1000: Need to divide the total by 1000 otherwise it would wh, not 'Kil-Wh'

1 / Re = 1 / 100 + 1 / 400 + 1 / 200
Multiply all terms by 400 and simplify to obtain
400 / Re = 4 + 1 + 2
Solve for Re to obtain
Re = 400 / 7 Ω
The main current I is given by
I = 7 / Re = 7 / (400 / 7) = 49 / 400 A
We now use Ohm's law to find the current passing through each resistor.
The current through the resistor of 100 Ω: I_1 = 7 / 100 A
The current through the resistor of 400 Ω: I_2 = 7 / 400 A
The current through the resistor of 200 Ω: I_3 = 7 / 200 A
As an exercise; check that the sum of the three currents above is equal to the current I = 49 / 400 A.

Advantages:

1. Each appliance can be turned on or off independently.
2. The voltage of each electrical appliance is the same as the power supply line.
3. If one electrical appliance stops working due to a problem, the other appliances will continue to function.

Disadvantages:

1. Because the circuit can carry higher current, it is less safe.
2. If hundreds of appliances or lamps need to be turned on or off at the same time, this method is difficult to apply.

15.7 ELECTRICAL POWER AND JOULE'S LAW

Electric Power

The rate at which the work is being done in an electrical circuit is called an electric power.
or
The rate of the transfer of energy.

When a current flows through a resistor, electrical energy is converted into HEAT energy. The heat generated in the components of a circuit, all of which possess at least some resistance, is dissipated into the air around the components.

The rate at which the heat is dissipated is called **power dissipation**

It is denoted by P and measured in units of Watts (W)
Mathematically equation of power dissipation and resistors.

$$P = IV = I^2R = \frac{V^2}{R}$$

Energy in Resistors

ENERGY is dissipated when a particular amount of power is dissipated over a period of time. Energy (power × time) is measured in Joules, and the energy dissipated by a component or circuit can be estimated by including time (t) in the power formulas.

Energy dissipated = Pt or VIt or V^2t/R or even I^2Rt Joules

Joule's law

When an electric current flows through a circuit, it increases the internal energy of the conductor, which gives rise to the collision of electrons with atoms of the conductor, and which results in heat generation. To measure the amount of heat generated due to these collisions, Joule, an English physicist, gave the Joule's law.

when an electric current passes through a conductor, heat H is produced, which is directly proportional to the resistance R of the conductor, the time t for which the current flows, and to the square of the magnitude of current I.

Mathematically it is represented as $H \propto I^2 .Rt$.

The joule's first law shows the relationship between heat produced by flowing electric current through a conductor.

$$H = I^2 Rt$$

Where, **H** indicates the amount of heat, **I** show electric current, **R** is the amount of electric resistance in the conductor, **t** denotes time

The amount of generated heat is proportional to the wire's electrical resistance when the current in the circuit and the flow of current is not changed.

The amount of generated heat in a conductor carrying current is proportional to the square of the current flow through the circuit when the electrical resistance and current supply is constant.

The amount of heat produced because of the current flow is proportional to the time of flow when the resistance and current flow is kept constant.

Do You Know!

Applications of Joule's law

The heating effect of electric current is used in some electrical equipment such as the electric iron, electric toaster, and electric heater. In many electrical devices, Nichrome (an alloy of nickel and chromium) is employed as a heating element. This is due to the following factors:

Nichrome possesses a high level of specific resistance.

The melting point of nichrome is extremely high.

Nichrome is resistant to oxidation.

Weblinks

Encourage students to visit below link for Verification of Joule's law

https://www.youtube.com/watch?v=93AVPN747O8&ab_channel=Physics4students

Weblinks

Encourage students to visit below link for Current and potential difference

https://www.youtube.com/watch?v=cYifAaTFe8A&ab_channel=FuseSchool-GlobalEducation

Worked Example 4

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

Solution:

Step 1: Write down the known quantities and quantities to be found

$H = 100J$

$t = 1s$

$R = 4\ \Omega$

$V = ?$

Step 2: Write down the formula and rearrange if necessary.

$$H = I^2Rt$$

$$V = IR$$

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

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

$$H = \left(\frac{V}{R}\right)^2 \times Rt$$

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

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

Step 3: Put the values and calculate.

$$100 = \frac{V^2}{4} \times 1$$

$$100 \times 4 = V^2$$

$$400 = V^2$$

$$V^2 = 400$$

$$V = \sqrt{400}$$

$$V = 20V$$

Result: Potential difference is 20V.

15.8 USE OF CIRCUIT COMPONENTS

Electrical components and their uses

The devices that make up an electronic circuit are known as electronic components. They're made to be joined together, usually by welding, to form a circuit on a circuit system. Semiconductors, active, passive, optoelectronic, electromagnetic, and other types of components can be classified.

Switches or key: It is one of the most fundamental electrical components, it is used to turn electric circuits ON and OFF. This simply implies that when you press or flick a switch, current is allowed to pass through to the rest of the circuit.

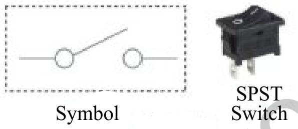


Fig: 15.11
Switch or key

Resistor: It is a two-terminal electrical component that implements electrical resistance as a circuit element.

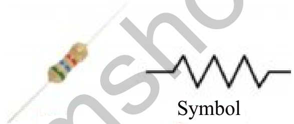


Fig: 15.12
Resistor

Battery: It is electrical source that store the chemical energy and converts the chemical energy into electrical energy.

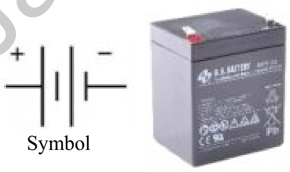


Fig: 15.13
Battery

Transducer: It is an electrical component that converts one form of energy into another form of energy like microphone converts sound energy into electrical energy/ signal as shown in figure 15.14.

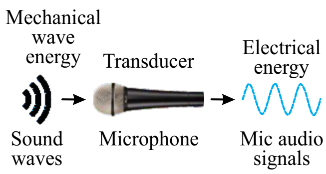


Fig: 15.14
Transducer

LDRs (Light Dependent Resistors):

A photoresistor or light dependent resistor is an electronic component that is sensitive to light.

For example, in automatic security lights. Their resistance decreases as the light intensity increases

- In low light levels, the resistance of an LDR is high and little current can flow through it.
- In bright light, the resistance of an LDR is low and more current can flow through it.

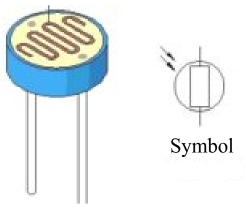


Fig: 15.15
Light dependent resistor (LDR)

Thermistors

It is thermally sensitive resistors whose resistance is strongly dependent on temperature. It is used to measure the temperature very accurately.

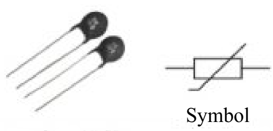


Fig: 15.16 Thermistor

Relay: It switches which aim at OFF and ON the circuits electronically as well as electromechanically.

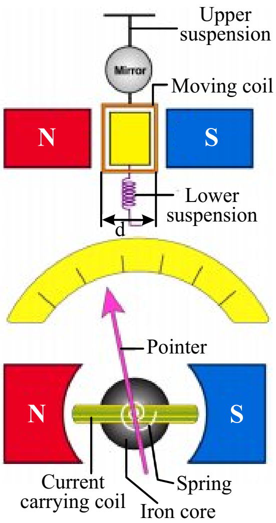
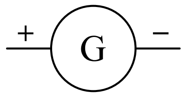


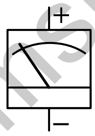
Fig: 15.17
Galvanometer

Moving coil galvanometer:

It is an electromechanical instrument used to detect and measures small amount of current which is in the range between milli amperes or micro amperes.
Luigi Galvano invented this device so it belongs to his name. this is a current detecting meter based on magnetic dipole torque.



OR



Ammeter:

An Ammeter is an Electromechanical instrument used to measure electric current. It is a modified form of Galvanometer. A Galvanometer can be converted into an Ammeter by connecting a low shunt resistance in parallel to the Galvanometer. A Ammeter using in a circuit always in "Series" Its symbol is **(A)**

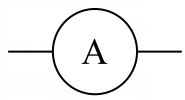
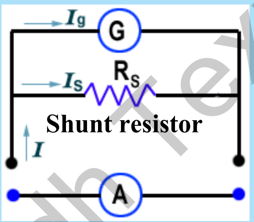


Fig: 15.18 Ammeter

Do You Know!

A resistor having a very low value of resistance such type of resistor is called **shunt resistance.**



Voltmeter:

Voltmeter is an Electromechanical Instrument sued to measure potential difference. A Galvanometer can be converted into a Voltmeter if a high resistance is connected in Series with Galvanometer.

Do You Know!

A voltmeter using in a circuit parallel.
Symbol of voltmeter is

Fig: 15.19
Voltmeter

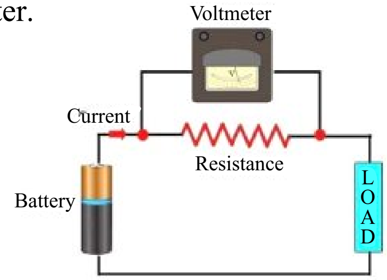


Fig: 15.20 circuit diagram of voltmeter

Electrical Power transmission to a house

There are three cables that provide electricity into the building. One is referred to as a **ground wire** or **earth wire (E)**. There is no current through this. The house's earth wire is connected to a buried metal plate. The other cable, known as a **neutral wire**, is grounded to the Earth within the power plant itself to keep its voltage constant (N). The current flows back through this wire. The third wire, which has a high potential and is called the **livewire**, is connected to the battery (L). Difference in voltage between the live and neutral wires is 220V.

The human body is a good conductor of electricity. If a person holds livewire, current will flow to the ground through his body, which could be dangerous. The live and neutral wires are used to connect all of the equipment in a home. All have the same potential difference, thus they're joined in parallel to the power source.

A connection has been made between the cables coming from the mains and the electricity meter that has been installed in the residence as shown in the figure 15.9 The electric meter's output goes to the main distribution board and subsequently the home electric circuit.

The main box has fuses with ratings of about 30 A. Each appliance has its own connection made directly to the live wire. A fuse and a switch are used to connect the appliance terminal to the livewire. In the event that the fuse of one appliance blows, it will not have any impact on the functioning of the other appliances.

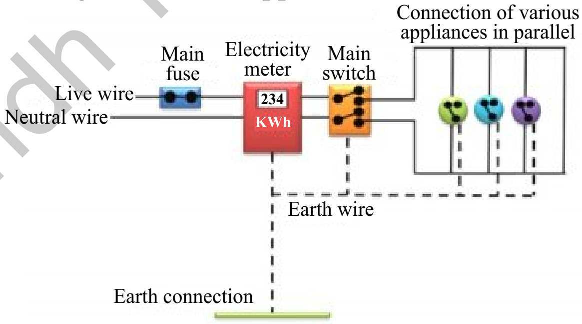


Fig: 15.21
Illustrate the distribution of electrical power from main to the home appliances

Weblinks

Encourage students to visit below link for Live, neutral and earth wire
https://www.youtube.com/watch?v=0OKTejgaWTY&ab_channel=FuseSchool-GlobalEducation

Weblinks

Encourage students to visit below link for How electricity reaches out home
https://www.youtube.com/watch?v=nBM1kd_ECog&ab_channel=GauravJ-TheElectricalGuy

Hazards of electricity

Electrical shock, fire, and arc flashes are the primary hazards that are present when working with electricity. When the human body comes into contact with either or both of the wires in an electrical circuit or with one wire of an energized circuit and the ground, or with a metallic part that has become energized by contact with an electrical conductor, the result is an electric shock.

Electrical shock severity depends on the pathway through the body, the amount of current, the length of exposure, and whether the skin is wet or dry. Wet skin and wet conditions are good conductors of electricity.

Fig: 15.22
Damaged Insulation

Damaged Insulation:

Insulation refers to the sheath made of plastic that is wrapped around wires in a circuit. If the insulation on a cable is damaged, the metal conductors inside will be exposed.

It is possible for a person to receive an electric shock if they come into contact with the exposed wires, which could result in their death. Before replacing any damaged insulation attempting to cover any damaged insulation with electrical tape, make sure that all power sources have been turned off and then replace the damaged insulation.

Fig: 15.23
Over heating of a cable

Overheating of cables:

When a very high current is passed through a cable, there is a possibility that the wire will overheat as a result of the excessive amount of energy. Because of the overheating, there is a risk of electrical fires.

Fig: 15.24
Electrical extension placed damped environment

Damp conditions:

People who are in close proximity to an electrical appliance that is being used in a damp environment, such as a bathroom, have an increased risk of being electrocuted by the electricity that is being conducted through the water because water is a conductor. If a person touches a socket while their skin is wet in any way, they run the risk of being electrocuted.

Safety measures in household electricity

Electricity as a power source has become very crucial to the functioning of modern society. Despite its usefulness, there are a number of potential electrical hazards and mishaps that must not be ignored. If not handled carefully, this constant stream of electrons can destroy any living tissue it comes into contact with. To avoid any unwanted incident few measures must be taken which are given below:

Fuses and Breakers

Circuit breakers, or fuses, prevent damage to electronics components caused by overheating. When there is a significant amount of current running through the circuit, the wires that are contained within the circuit will begin to overheat. A metal wire fuse with a low melting point will become molten, breaking the circuit.

The Circuit-Breaker

In the majority of applications found in the home, circuit breakers are used to restrict the amount of current flowing through a single circuit. Although circuit breakers are available in a wide range of sizes, the maximum current that can flow through a single circuit is typically 20 amps. 20 amps of current will heat the bimetallic strip, bending it downward and releasing the trip-lever. To manage the large surges that result from a short circuit, a different mechanism is utilized due to the relatively slow heating. In the case of a high-current spike, the bimetallic strip will be rapidly retracted by a small electromagnet made from wire loops wrapped around a piece of iron.

The Ground Wire

The word "ground" means that something is connected to the earth, which stores charge. A ground wire gives an electrical appliance a path to the earth that is separate from the normal path that current takes. As a practical matter, it is connected to the electrical neutral at the service panel so that if there is an electrical fault, there is a path with low enough resistance to trip the circuit breaker as illustrated in figure 15.23. Attached to an appliance's case, it keeps the case's voltage at ground potential (usually taken as the zero of voltage). In this way, electric shock is prevented. Standard electric circuits have a ground wire and either a fuse or a circuit breaker for safety.

Fig: 15.25
Different type of fuse used in electronic component

Fig: 15.26 (a)
Circuit breaker

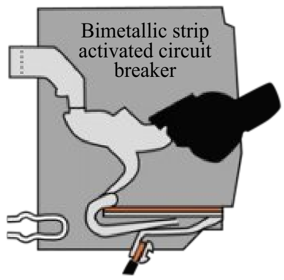


Fig: 15.27 (b)
Schematic diagram of circuit breaker

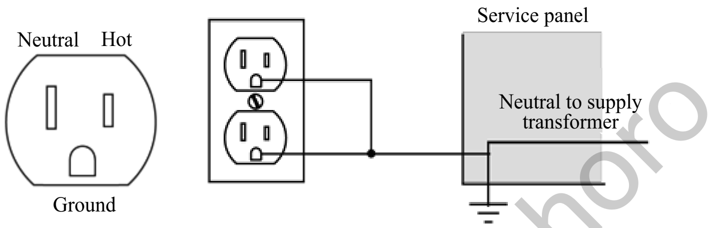


Fig: 15.28 Electric circuit having ground wire

Effects of electric shock on human body

- Electric current of 0.001 A can be felt
- Electric current of 0.005 A, can be painful for human body.
- If electric current is of 0.010 A, resulting in the contraction of muscles in an uncontrollable manner (spasms)
- Electric shock of 0.015 A can leads to a lack of control over the muscles.
- The electric current of 0.070 A passes through the heart; creates a significant disturbance; and is almost certainly fatal if the current continues for more than one second.

Weblinks

Encourage students to visit below link for Why don't birds get electrocuted on power lines?

https://www.youtube.com/watch?v=rtnmCf2QFTc&ab_channel=InterestingEngineering

SELF ASSESSMENT QUESTIONS

Q1: Explain briefly the dangers of electricity in the home.

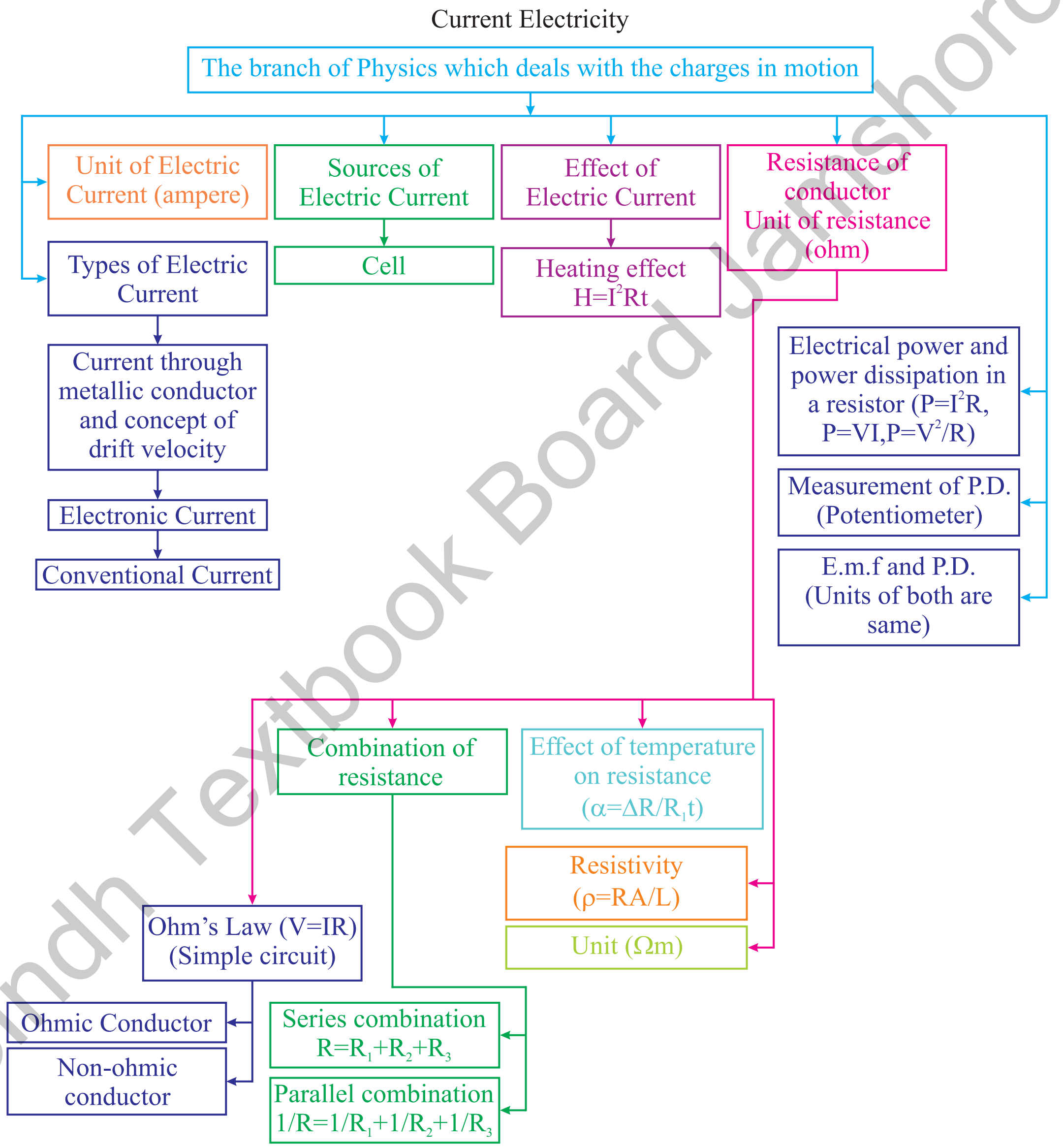
Q2: Give four safety precautions that should be taken with the household circuit.

Q3: In a circuit, does the fuse regulate the voltage or the current?

SUMMARY

- Steady current: The continuous flow of free electrons.
- Electric current is the net charge flowing through the cross-section area A per unit time. I=Q/t
- Direct Current (DC) is current flows in one direction with constant magnitude.
- Alternating Current (AC) is an electric current that reverses its direction many times a second at regular intervals.
- The difference of electrical potential between two points is known as Potential Difference.
- Electromotive force (Emf) is the energy per unit electric charge that is imparted by an energy source, such as an electric generator or a battery
- Ohm's law states that the magnitude of the current flowing through conductor is directly proportional to the potential drop across the ends of conductor as long as the physical state of the conductor is kept constant. (V = IR)
- Conductance is the reciprocal of resistance of a conductor.
- In series combination of resistors, the Equivalent resistance is equal to sum of individual resistors.
- In Parallel Combination of resistors, the reciprocal of resistance is equal to the sum reciprocals of individual resistances.
- Electric power is the rate at which work is done in an electric circuit.
- Joule's Law state that The rate at which heat is produced by a steady current in any part of an electric circuit is jointly proportional to the resistance and the square of the current
- Thermistor is a heat sensitive device usually made of a semiconductor material whose resistance changes very rapidly with change of temperature.
- Relay is a device that opens or closes the contacts to cause the operation of the other electric control.
- Light-Emitting Diode (LED) is a semiconductor light source that emits light when current flows through it.
- Light dependent resistors (LDRs) or photo-resistors are electronic components that are often used in electronic circuit designs where it is necessary to detect the presence or the level of light.
- Galvanometer is an electrical instrument used to measure and detect small current.
- Ammeter is an electrical device used to measure the electric current in Amperes (A) or mili-ampere (mA).
- Voltmeter is an electrical device used to measure the potential across the two ends.

CONCEPT MAP


Current Electricity
The branch of Physics which deals with the charges in motion
Unit of Electric Current (ampere)
Sources of Electric Current
Effect of Electric Current
Resistance of conductor Unit of resistance (ohm)
Types of Electric Current
Cell
Heating effect $H=I^2Rt$
Current through metallic conductor and concept of drift velocity
Electronic Current
Conventional Current
Electrical power and power dissipation in a resistor ($P=I^2R$, $P=VI$, $P=V^2/R$)
Measurement of P.D. (Potentiometer)
E.m.f and P.D. (Units of both are same)
Combination of resistance
Effect of temperature on resistance ($\alpha=\Delta R/R_1t$)
Resistivity ($\rho=RA/L$)
Unit (Ωm)
Ohm's Law (V=IR) (Simple circuit)
Ohmic Conductor
Non-ohmic conductor
Series combination $R=R_1+R_2+R_3$
Parallel combination $1/R=1/R_1+1/R_2+1/R_3$

Section (A) Multiple Choice Questions (MCQs)

1. In an Electric circuit when Electrons move from low to high potential they will:
   (a) Gain Energy (b) Lose their identity
   (c) Lose Energy (d) Gain Potential
2. In an electric circuit an ammeter is always connected in
   (a) Series (b) parallel
   (c) mixed (d) none of the above
3. Resistance of a conductor does not depend on
   (a) Length of the conductor (b) Area of crossection
   (c) Density (d) Resistivity
4. Ohm's law states that:
   (a) Resistance increases as current increases
   (b) Resistance decreases as current increases
   (c) Resistance increases as voltage increases
   (d) Current increases as voltage increases
5. The condition when the resistance of a circuit is zero is known as
   (a) Closed-circuit (b) Open circuit
   (c) Short circuit (d) Zero circuit
6. The condition for the validity of Ohm's law is that the
   (a) Temperature should remain constant
   (b) Current should be proportional to voltage
   (c) Resistance must be wire wound type
   (d) All of the above
7. Ohm's law is not applicable to
   (a) Semiconductors (b) D.C. circuits (c) Small resistors (d) High currents
8. Two resistances of 6 Ω and 12 Ω are connected in parallel. Their net resistance is ____.
   (a) 7Ω (b) 6 Ω (c) 4 Ω (d) 5 Ω
9. The property of a body to oppose the flow of electric charge through it is called electric ________________.
   (a) Capacitance (b) potential
   (c) resistance (d) conductance
10. Which of the following is the purpose of connecting a battery in an electric circuit?
    (a) To maintain resistance across the conductor.
    (b) To vary resistance across the conductors.
    (c) To maintain constant potential difference across the conductor.
    (d) To maintain varying potential difference across the conductor.

Section (B) Structured Questions

1. Is it always the case that a series connection between capacitors will result in an equal amount of charge being stored in each capacitor?
2. Why should we connect the equipment in parallel rather than in series, and what are the benefits of this configuration?
3. Does a circuit need a potential difference in order for current to flow through it?
4. It is impracticable to connect an electric blub and an electric heater in series. Why?
5. When a fuse is used in a circuit, does it control the current or the potential difference?
6. Explain what you mean by the term "conventional current"
7. Describe Ohm's law and its limitations
8. Determine the effective resistance of a number of resistances that are connected in either series or parallel by doing the appropriate calculations.
9. Explain what influences the resistance of a metal conductor and how you measured it.
10. Explain Joule's law and the process of energy dissipation in a resistance.
11. Explain the roles of the live, neutral and earth wires in a standard home electrical system.
12. How Does AC Work?
13. Explain the risks associated with electrical current (damage insulation, overheating of cables, damp conditions).
14. Explain how safety precautions are used in home electricity.
15. Describe the effects of an appliance-caused electrical shock on the human body.
16. Why the voltage used for the domestic supply much lower than the voltage at which the power is transmitted?

Section (C) Numericals

1. When the current in a pocket calculator is 0.0002 A, how much charge flows every minute? **(12mC)**
2. Calculate the amount of current that an electric heater uses to heat a room in 5 minutes if the charge is 2100 C. **(7 A)**
3. A potential difference of 90 V exists between two points. The amount of work done when an unknown charge is moved between the points is 450J. Determine the charge amount **(5 C)**
4. Calculate the potential difference between two points A and B if it takes 9×10^{-4} J of external work to move a charge of +9 μC from A to B. **(100 V)**
5. The potential difference applied to a portable radio terminal is 6.0 Volts. Determine the resistance of the radio when a current of 20 mA flows through it. **(300 Ω)**
6. Resistances of 4 Ω, 6 Ω, and 12 Ω are connected in parallel and then connected to a 6V emf source. Determine the value of
   i. The circuit's equivalent resistance. **(2 Ω)**
   ii. The total current flowing through the circuit. **(3 A)**
   iii. The current that flows through each resistance. **(1.5 A, 1 A, 0.5 A)**
7. A 220 V circuit is used to power two 120 watt and 80 watt light bulbs. Which bulb has the greater resistance and which one has the higher current?
   (80 W bulb, 120 W bulb)

•••••••