Chapter 14

Current Electricity

ELECTRIC CURRENT

STATEMENT :-

"The rate of flow of electric charge through any cross sectional area is called current."

MATHEMATICAL EXPLANATION :-

If the charge Q is passing through any area in time t, then current I flowing through it will be given by :

$$\text{Current} = \frac{\text{Charge}}{\text{Time}}$$

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

IMPORTANT FEATURES :-

- SI Unit of current is ampere (A)
- 1A = When 1C charge passes through a cross sectional area in 1s, then I is one ampere. $1A = \frac{1C}{1S} = CS^{-1}$
- Smaller unit of current are milli ampere (mA), micro ampere (μA).

$1\, mA = 10^{-3}\, A$

$1\, \mu A = 10^{-6}\, A$

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Insulators: Force of attraction is strong. Electrons are tightly bound to the nucleus.

Conductors: Force of attraction is weak. Electrons are losely bound. They are mobile electrons. Charge carriers in conductors are electrons.

Solutions: +ive and -ive charges randomly move. Charge carriers are ions. When such charges exposed to an electric field, they move in a specific direction and that constitute electric current

TYPES OF CURRENT

(i) **Electronic Current:** due to the flow of electrons (-ive charges)

(ii) **Conventional current:** due to the flow of +ive charges.

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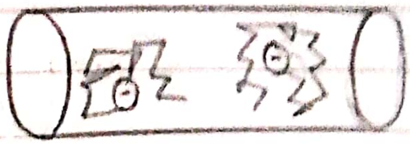
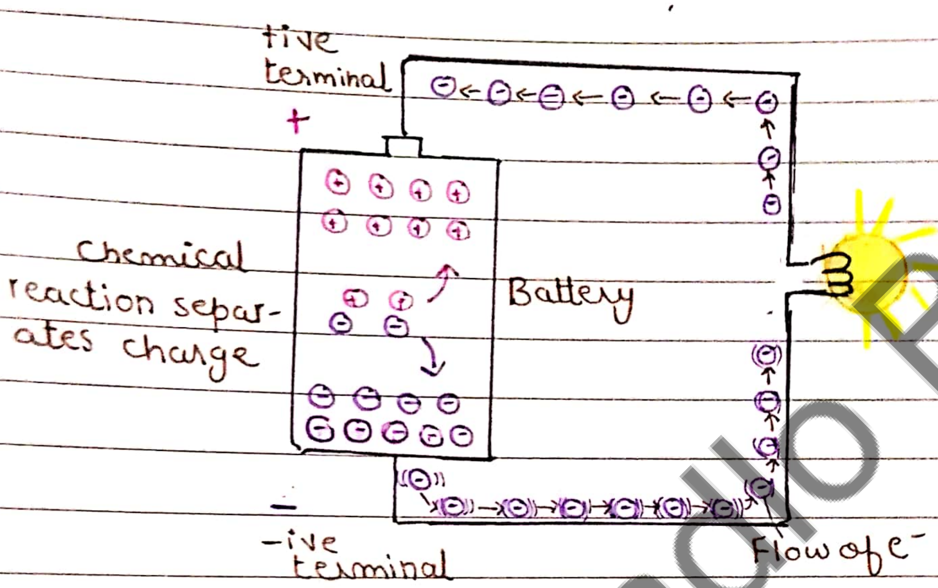
BATTERY AS A SOURCE OF ENERGY



When conductor is not connected with battery charges flow but current has no specific direction that's why net current is zero. $I = I_1 + I_2 = 0$



=> The electrochemical reaction inside a battery separates +ive and -ive charges

=> The separation of charges causes potential difference

=> When conducting wire is connected across the terminals of battery, charges move due to potential

=> The chemical energy changes to electrical energy.

=> The electrical energy is converted light and heat energy.

=> The V energy decreases as charges move around circuit.

=> Charge carriers and charge remain same.

=> Only energy change to electric potential.

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CONVENTIONAL CURRENT

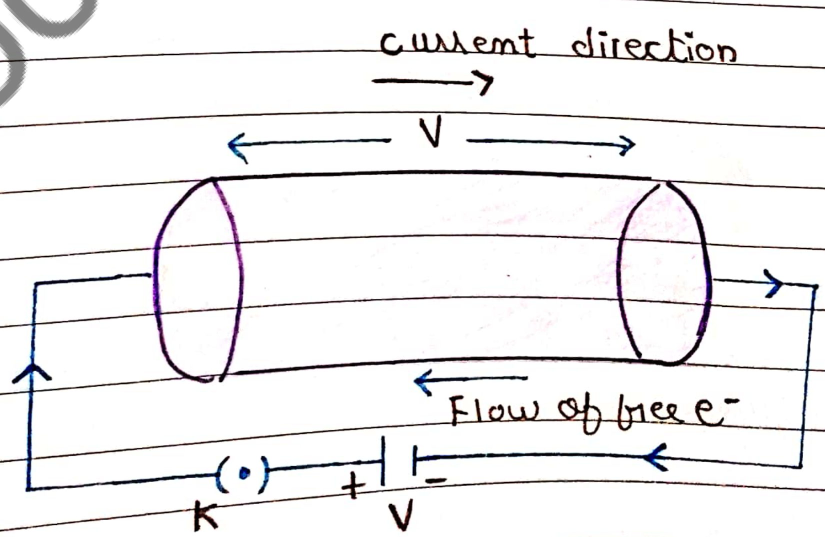
DEFINITION

"Current flowing from +ive to −ive terminal of a battery due to the flow of +ive charges is called conventional current."

ANALOGIES

- Heat energy flows from higher temperature to lower temperature. (The flow stop when both ends reach same T)
- Water flow from higher level to lower level.
- Similarly current flow from higher potential to lower potential.

> ⇒ Current flow when potential is provided.
>
> ⇒ Conventional current produces the same effect as the electronic current.



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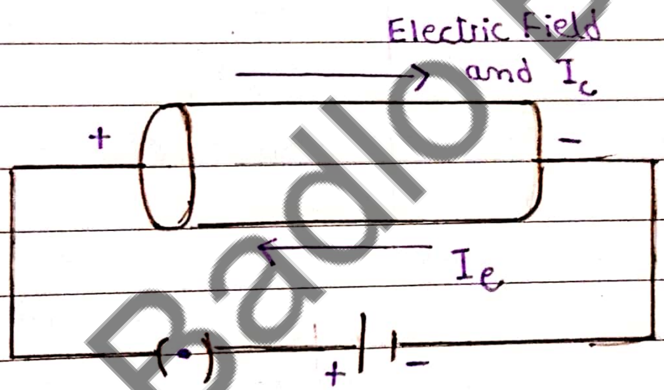
Conventional Current	Electronic Current
• I_c is due to +ive charges.	• I_e is due to the electrons.
• I_c move from +ive terminal to -ive terminal.	• I_e move from -ive terminal to +ive terminal.
• Direction of I_c and electric field is same.	• Direction of I_e and electric field is opposite.



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MEASUREMENT OF CURRENT

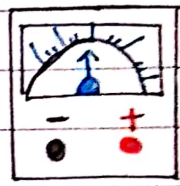
INSTREMENTS :—

1. Galvanometer
2. Ammeter.

We donot connect galvanometer in parallel because there will be more than 1 path for the flow of I that's why we connect in series to get accurate measurement.

GALVANOMETER 

- Galvanometer is a sensitive instrument as it can detect a small current in a circuit.
- A current of few milliamperes is sufficient to cause full scale deflection in it.



POLARITY OF GALVANOMETER

Generally, the terminal of galvanometer with red color shows the +ive polarity while that with **black** color shows **-ive polarity.**

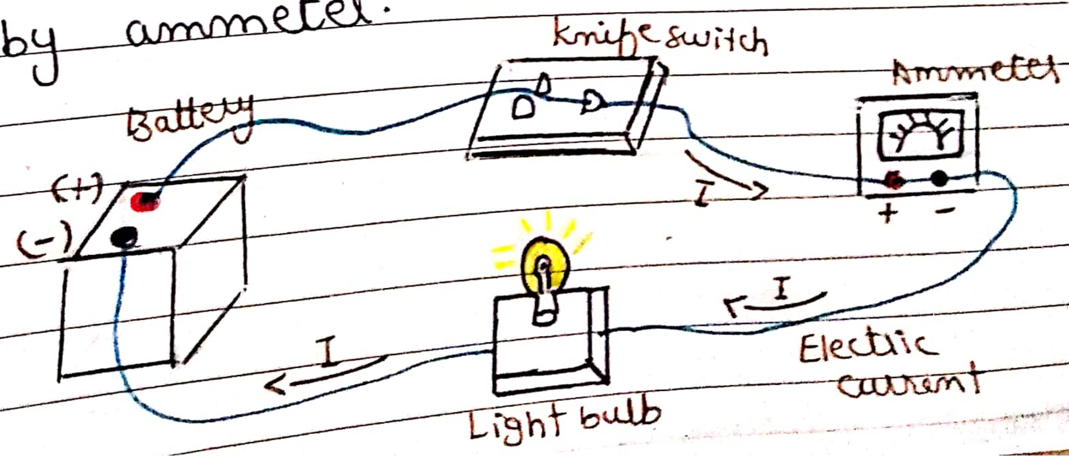
IDEAL GALVANOMETER

An ideal galvanometer should have very small resistance to pass the maximum current in the circuit

MODIFIED FORMS (AMMETER)

- Galvanometer can be converted into ammeter by connecting a low resistance which is called shunt resistance in parallel with galvanometer.

large current of the range such as 1A or 10A can be measured by ammeter.



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POTENTIAL DIFFERENCE

- Potential difference across two ends of conductor causes the dissipation of electrical energy into other forms of energy.
- Mathematically can be written as:

Potential difference $= \dfrac{\text{work done by charge}}{\text{charge}}$

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

- Electrical energy changes into different form of energy.

Electrical Energy ⟹ chemical/heat/mechanical.

- The unit of potential difference is volt.

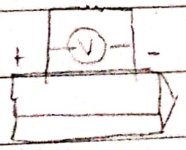
$$\Delta V = \frac{W}{Q}$$

$$= \frac{J}{C} \quad \text{energy given by } Q$$

$$= JC^{-1}$$

$$= \text{Volt}$$

current pass



ELECTROMOTIVE FORCE (e.m.f)

- e.m.f is the potential given to charge or energy supplied by a battery to a unit +ive charge
- Mathematically can be written as:

e.m.f $= \dfrac{\text{energy supplied to charge}}{\text{charge}}$

$$E = \frac{W}{Q}$$

- Energy converted from non-electrical forms to electrical forms.

Non Electrical Forms ⟹ Electrical Forms

- e.m.f stands for electromotive force but its unit is volt.

$$E = \frac{W}{Q}$$

$$= \frac{J}{C} \quad \text{energy given to } Q$$

$$= JC^{-1}$$

$$= \text{volt}.$$

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• When current flows to conductor, it experiences resistance due to collisions with the atoms of conductor, so energy is dissipated. Dissipation of this energy is considered for potential difference.	• +ive charges leaves the +ive terminal of the battery, passes through the conductor and reaches the -ive terminal of the battery. As +ive charges enter the battery at Low Potential, battery must supply energy to +ive charges, then they will move from Low potential to high potential again.
Example: When one ampere of current passes through the bulb. When one volt potential difference is applied across its ends, bulb uses 1 J of energy.	**Example:** If e.m.f of the battery is 2V then total energy given by the battery is 2J, when 1C charge flow through closed circuit.
Energy given by the charge.	Energy supplied to the charge.
voltage when circuit is closed	voltage of battery when circuit is open.
at any two points	voltage is across the battery terminals
Provide energy to Q from H.P to L.P.	give energy to Q from L.P to H.P

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~OHM'S LAW~

STATEMENT

The amount of current passing through a conductor is directly proportional to potential difference applied across its end.

MATHEMATICAL EXPLANATION

$$I \propto V$$

$$V \propto I$$

$$V = RI$$

RESISTANCE

'R' is the proportionality constant.

"The property of a substance which offers opposition to the flow of current through it is called resistance."

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

UNIT OF RESISTANCE

→ SI unit of resistance is ohm

→ Ohm is denoted by Ω

ONE OHM

"When potential difference of one volt is applied across the ends of a conductor and one ampere of current passes through it, then its resistance will be one ohm"

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

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CONDITIONS FOR OHM LAW

1. Temperature should remain constant.
2. Physical state of the conductor should not change.

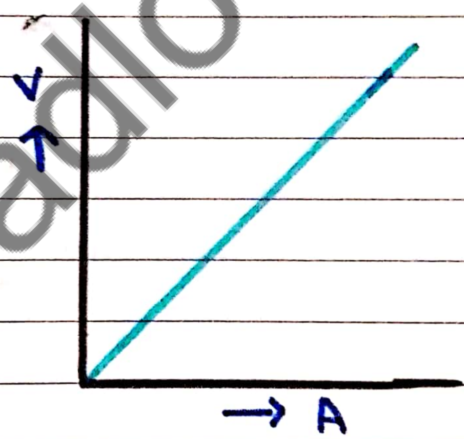
GRAPHICAL EXPLANATION

The graph between the current and the voltage (potential difference) will be a **straight line**.

➡ $V \propto I$

➡ Relation between V and I is linear.

➡ Relation between V and I is uniform.



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Characteristics Of Ohmic And Non-Ohmic Conductors

Ohmic Conductors	Non Ohmic Conductors
• Materials that obey Ohm's law and have constant resistance over a wide range of voltages are said to be ohmic.	• Materials that don't obey Ohm's law and have resistance that changes with voltage or current are non-ohmic.
• They obey ohm's law. ($V \propto I$)	• They don't obey ohm's law
• They have linear V-I relationship.	• They have non-linear V-I relationship.
• The ratio between V and I is constant.	• The ratio between V and I is not constant.
• The graph between V and I is a straight line.	• The graph between V and I is not a straight line.
Example Metals.	**Examples** × Filament lamp × thermister.

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QUESTION: Describe the behaviour of thermister when potential is provided to it according to ohm's haw.

ANSWER:—

➡ A thermister is a device that resist heat.

➡ When 'I' is increased the 'R' is decreased.

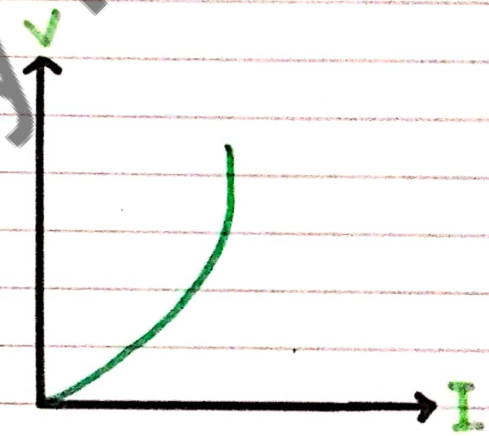
➡ More free elections become available for conduction of current because of heating.

FILAMENT LAMP

When heated:

R increases

I decreases

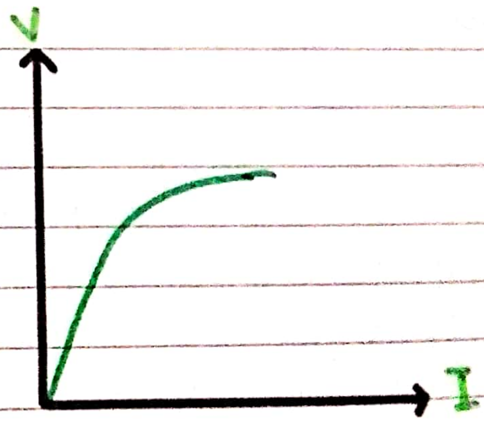


THERMISTER

When heated:

R decreases

I increases



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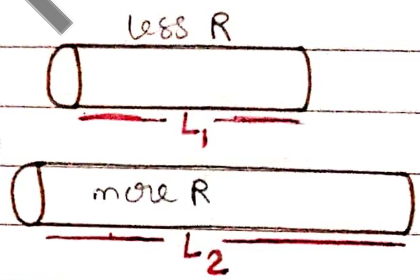
~ FACTORS AFFECTING RESISTANC ~

The resistance depends on:

1. Length of wire
2. cross sectional area of wire
3. Nature of wire
4. Temperature of wire.

Length of Wire

Resistance 'R' is directly proportional to the length 'L'.



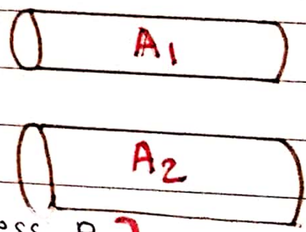
$$R \propto L$$

$$R_2 > R_1$$

$$L_2 > L_1$$

Cross Sectional area of Wire

Resistance 'R' is inversely proportional to the area of cross section A.



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

$$A_1 < A_2$$

$$R_1 > R_2$$

[thick wire has less R
thin wire has more R]

Nature of Wire

* Cu wire has less resistance
* steel wire has more resistance.

Temperature of Wire

As the temperature of wire increases, the motion of atoms increases and this cause a large resistance.

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As,

$R \propto L$ — (i)

$R \propto \frac{1}{A}$ — (ii)

Combining eq (i) and (ii)

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

$$\boxed{R = \rho \frac{L}{A}}$$

PROPORTIONALITY CONSTANT

ρ is the proportionality constant known as specific resistance OR resistivity.

UNIT OF SPECIFIC RESISTANCE

$$\rho = \frac{RA}{L}$$

$$\rho = \frac{\Omega m^2}{m}$$

$$\rho = \Omega m \text{ (ohm meter)}$$

WHEN $R = \rho$

$L = 1m$ $A = 1m^2$

$$R = \rho \frac{L}{A}$$

$$R = \rho \frac{1}{1}$$

$$R = \rho$$

The value of ρ depends upon the nature of conductor

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Conductors	Insulators
The materials through which electricity can pass are called conductors	The material through which electricity cannot pass are called insulators
Conductors have free electrons	insulators donot have free e^-
Have low resistance	Have high resitance
Electrons are loosely bound	Electrons are tightly bound
Most of the metals are conductors	Most of the non-metals are insulators.
Heat can be transmitted through conductors.	Heat cannot be transmitted through insulators
Examples: Copper, Iron, Aluminium	Examples: wood, rubber, plastic

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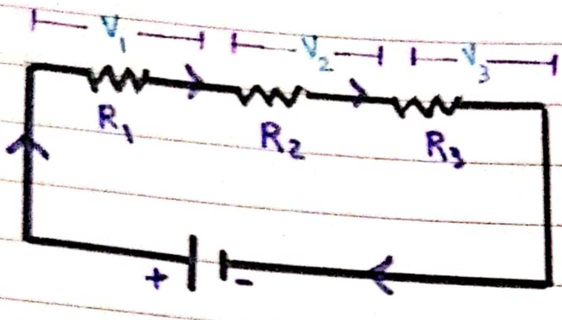
COMINATION OF RESISTORS

Series Combination



Resistors are connected end to end

There is single path for the flow of current.

The resistors are not directly connected with the source.

Current is same for each resistor

$$I = I_1 = I_2 = I_3$$

Voltage divides among individual resistor

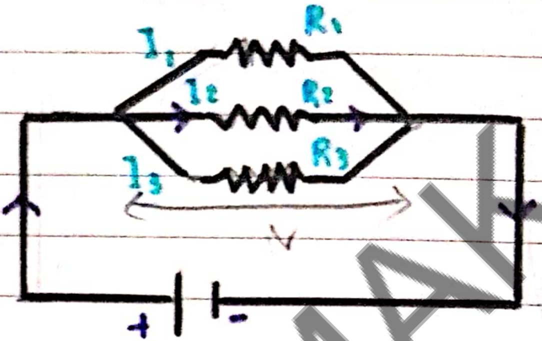
$$V = V_1 + V_2 + V_3$$

$$V = IR_1 + IR_2 + IR_3$$

$$V = I(R_1 + R_2 + R_3)$$

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

Parallel Combination



1 end of each resistor is connected with 1 terminal of battery, other end of each resistor is connected with other terminal

There are many paths for the flow of current.

The resistors are directly connected with the source.

Voltage is same for each resistor

$$V = V_1 = V_2 = V_3$$

Current divides among resistors.

$$I = I_1 + I_2 + I_3$$

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

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

$$\frac{I}{V} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

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Equivalent Resitance can be written as $R_{eq} = R_1 + R_2 + R_3$	Equivalent Resistance can be written as $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
If n- resistors are connected then Req can be written as $R_{eq} = R_1 + R_2 + R_3 \cdots\cdots R_n$ $R_{eq} = \sum_{i=1}^{n} R_i$	If n- resistors are connected then $\frac{1}{R_{eq}}$ can be written as $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots\cdots \frac{1}{R_n}$ $\frac{1}{R_{eq}} = \sum_{i=1}^{n} \frac{1}{R_i}$
$R_{eq} >$ Individual value of any R	$\frac{1}{R_{eq}} <$ indvidual value of any R

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ELECTRICAL ENERGY AND JOULE'S LAW

↳ Turbines run generator to produce electrical energy when water falls on it from higher gravitational to lower gravitational potential.

↳ When charge moves from a higher electric potential to lower potential, **it delivers electric current.**

↳ The process during which charges continuously move from a higher potential to a lower potential becomes a continuous **source of electrical energy.**

Consider 2 points with ΔV of V volts. When 1C charge moves b/w these points charges will deliver energy.

According to the concept of electric potential:

$$V = \frac{W}{q}$$

$$qV = W$$

$$QV = W$$

'W' is the electrical Energy

As we know,

$$ItV = W \quad (\because Q = It)$$

$$ItV = W \quad (W \text{ in terms of } V, I, t)$$

→ The energy supplied by the charge in time 't'.

HEAT ENERGY

Electrical energy can be converted into heat and other forms **So** the amount of heat in resistance 'R':

$$W = ItV$$

$$W = It(IR) \quad (\because V = IR)$$

$$W = I^2Rt \quad (W \text{ in terms of } I, R, t)$$

OR

$$W = ItV$$

$$W = \left(\frac{V}{R}\right)tV \quad (\because I = \frac{V}{R})$$

$$W = \frac{V^2}{R}t \quad (W \text{ in terms of } V, R, t)$$

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STATEMENT

Joul's heating law can be defined as:

"The amount of heat generated in a Resistance due to flow of charge is equal to the product of square of current 'I', resistance 'R' and time 't'."

$$[W = I^2 R t]$$

CONCLUSION

Energy can be utilized for useful purposes:-

1. Bulb converts this energy (I^2Rt) into light and heat.
2. Heater and Iron convert that energy into heat.
3. Fans convert that energy into Mechanical Energy.

If potential of two terminals become same, there will be no flow of current.	battery provides constant continuously potential difference.

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ELECTRIC POWER

STATEMENT

"The amount of energy supplied by current in unit time is known as ELECTRIC POWER."

MATHEMATICAL EXPLANATION

As we know,

$$V = \frac{W}{Q}$$

$$W = QV$$

$$P = \frac{W}{t}$$

$$P = \frac{QV}{t}$$

$$P = IV \quad \left(\because I = \frac{Q}{t}\right) \quad \text{— (i)}$$

From eq (i)

$$P = IV$$

$$P = I(IR) \quad (\because V = IR)$$

$$P = I^2 R$$

Again from eq (i)

$$P = IV$$

$$P = \left(\frac{V}{R}\right) V \quad \left(\because I = \frac{V}{R}\right)$$

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

IMPORTANT FEATURES

1. When current is passing through a resistor R, the electric power in the resistance is given by I^2R
2. The unit of electric power is watt (Js^{-1}).
3. It is represented by the symbol W.

KILOWATT-HOUR

→ Electric energy is consumed in very large quantity for measurement.

→ Very large unit of electric energy is needed which is called kilowatt-hour.

STATEMENT

'The amount of energy delivered by a power of one kilowatt in one hour is called kilo-watt hour

$$1\,kWh = 1000\,W \times 3600\,s$$
$$= 10^3 \times 3.6 \times 10^3$$
$$= 3.6 \times 10^6\,J$$
$$= 3.6\,MJ$$

$$P = \frac{W}{t}$$

$$W = \frac{J}{s}$$

$$Ws = J$$

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To Calculate kWh

The energy in kWh can be calculated by:

$$\text{Energy in kWh} = \frac{\text{watt} \times \text{time of use in hours}}{1000}$$

$$= \frac{W \times t}{1000}$$

→ The electric meter installed in our homes measures the consumption of electric energy in the units of kWh.

1 kWh = 1 unit.

To Calculate The Bill Of Electricity

The amount of electricity bill can be calculated by:

cost of electricity = No. of units consumed × cost of 1 unit

$$= \frac{W \times t}{1000} \times \text{cost of one unit.}$$

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	DIRECT CURRENT	ALTERNATING CURRENT
DIFINITION	Electrical charges flow in one direction (unidirectional) is known as DC current.	Electrical charges changes its direction (bidirectional) is known as AC current (periodically).
POLARITY	Polarity of source remain same (fixed).	Polarity of source changes with every cycle.
SOURCES	Battery OR cell	AC generators.
FREQUENCY	0 Hz	50 Hz
LONG DISTANCE	Cannot travel (because DC flows in one direction, it produce large amount of heat and can melt the insulation)	Can travel (its half cycle is +ive and half cycle -ive, there is increase and decrease in current, it produce less heat.
MAGNITUDE OF CURRENT	Magnitude of current is constant with time.	magnitude of current changes with time.
USE	Electronic devices use D.C for their working.	Used as transmission from grid to home.

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Physics-X

Q.1 Write the important features of wires which bring electric power in our houses?

(i) Earth wire (E):- green/ yellow

A) It is known as groundwire.

b)It is connected to a large metal. plate buried deep in ground wire .

c) It carries ....no........ electricity.

(ii) Neutral (N) :-S black / blue

A) Neutral wire is maintained at zero potential.

b) It is connected to the Earth at the power station itself and is called neutral wire. c) This wire provides .return. path..for the current.

iii) Live wire:- Red / Brown

a) It is at ..high..potential. and is called livewire (L).
b) The ΔV between the livewire and the neutral wire is ..220.V......
c) This wire provides ..incoming.path..for the current.
d) . All electrical appliances are connected across the neutral and .livewires..

Q # 2 How are main techniques applied in house wiring?

1) The wires coming from the mains are connected to ....electricity meter installed in the house.
2) The ...output power from electric meter... is taken to the main distribution board and then to the domestic electric circuit.
3) The main box contains fuses of rating about ..30..A
4) A .separate. connection is taken from the livewire of each appliance.
5) The terminal of the appliance is connected to the livewire through..separate fuse and a switch.

Q # 3What happens if fuse of one appliance burn out?

Miss Asiya nazar
Soch Badlo By MAK

Q # 4 Which combination is helpful in house wiring & why. Give a proper reason.

Q#5 What range of voltage & current can be fatal?

Q #6 How an insulation can be helpful?

Q # 7 under which conditions short circuit takes place? According which law condition is discussed express mathematically?

Q # 8 How can we avoid thermal energy due to excessive or additional current.

Q # 9 Differentiate cable & common current carrying wire?

Q # 10 Calculate current for under common conditions.

(i) dry human skin

(ii) (ii) under damp condition

Q#11 Write the name of few safety devices? How are they helpful?

Q# 12 How is fuse applied in circuit & explain its function?

Q # 13 What are safety measure taken when fuse are applied in circuit.

Q # 14 What will be rating of a fuse if 10 lamps of 100W are applied in circuit?

Q # 15 Draw circuit diagram of circuit breaker & express its function in steps?

Q # 16 I f fuse didn't capture additional currents from live wire , then which protection conditions help & how?

Q # 17 Write one word answer.

i) A high current can pass through earth wire because its R=..low
ii) Earth terminal is connected to device part =..metal..case
iii) Electromagnet Attract iron strip to separate the contacts & circuit will=..break .
iv) Three resistors are connected in series, all of same value, then current will be=..Same
v) Dc source gives constant potential and constant=..magnitude of current .
vi) I f the current value is less than 0.001A, Can we feel?....no.
vii) I=0.015A causes loss of muscular control. Yes/no.

Soch Bisaat By MAK

Asiyah Zia

PHYSICS ASSIGNMENT

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Q.3 What happens if fuse of one appliance burn out?

If the fuse of one appliance burns out, it does not affect the other appliances. Fuse is connected in series because if a problem develops in one room the fuse will melt and disconnect the current but the other rooms will get electricity. That's why, for each room, there is separate fuse.

Q.4 Which combination is helpful in house wiring and why?

Parallel combination is helpful in hous wiring because the devices get full voltage and each device can be turned ON and OFF indvidually. In series, if we want to turn OFF one device then all the devices will turn OFF, and for example, If we turn ON the fan, the bulb will start to dim because the ΔV in series is different.

Q.5 What range of voltage and current can be fatal?

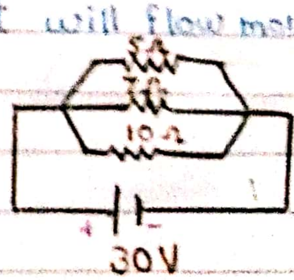
Voltage of 50V and current of 50mA ($50\times10^{-3}A$) can be fatal.

Q.6 How can insulation be helpful?

The electrical wires are coated with plastic covers, that is called insulation. They are covered with plastic because plastic is insulator which means electricity cannot pass through it and so current cannot pass to our body.

Q.7 Under which condition short circuit takes place? According which law condition is discussed. Express mathematically.

Short circuit occurs when a circuit with a very low resistance is formed. low 'R' means current will flow more.



$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{7} + \frac{1}{10} = \frac{14 + 10 + 7}{70}$$

$$R_{eq} = \frac{31}{70} \Rightarrow 2.25\Omega$$

$$I = \frac{30}{2.25} \Rightarrow 13.3A$$

When more devices are connected, $\frac{1}{R_{eq}}$ is less and more current will flow.

Q.8 How can we avoid thermal energy due to excessive current?

1. Wires carrying current should never be naked.
2. No friction should be there between wires.
3. There should be less moisture in the wires.
4. Using a cable with 2 layers of insulation.

Q.9 Differentiate b/w cable and common current carrying wire.

WIRE	CABLE
considered a single conductor	Group of conductors.
has thin layer of insulation.	has thick layer of insulation
Less protective	more protective
Cheap	expensive.

Q.10 Calculate current for under common condition.
(i) dry human skin
(ii) under damp condition.

(i) $I = \frac{V}{R} \Rightarrow \frac{220}{100,000} \Rightarrow 2.2 \times 10^{-3}$ A

(ii) $I = \frac{V}{R} \Rightarrow \frac{220}{1000} \Rightarrow 0.22$ A

Q.11 Write the names of few safety devices. How are they helpful?

To prevent from hazards of electricity, safety devices are used:
* Fuse
* Circuit Breaker
* Earth Wire.

These devices prevent circuit overloads that can occur when too many appliances are turned ON at the same time OR when short circuit occurs in one appliance.

Q.12 How is fuse applied in circuit. Explain its function. Fuse is connected in series with livewire in the circuit

Function: It protects the equipments when excess current flows.
If the current exceeds from rated value, the fuse melts & break circuit before wire become hot and cause fire.

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Q.13 What are the safety measures taken when fuse applied in circuit?

Following safety measures should be taken while using fuses:

1. Fuses to be used should be slightly more than the normal current.
2. Fuses should be connected in livewire.
3. Swithch OFF the main before changing any fuse.

Q.14 What will be the rating of fuse if 10 lamps of 100W are applied in circuit?

$$P = IV$$

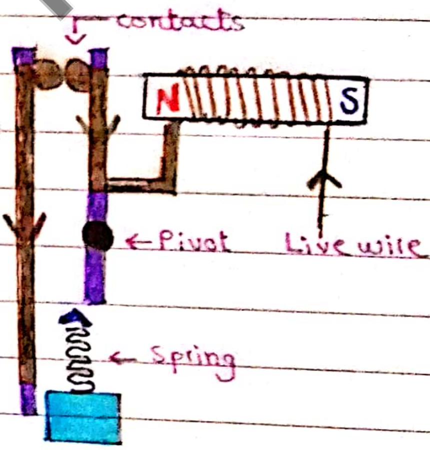
$$I = \frac{P}{V}$$

$$I = \frac{100}{220} \Rightarrow 0.45A$$

Q.15 Draw the circuit diagram of circuit breaker and express its function in steps.

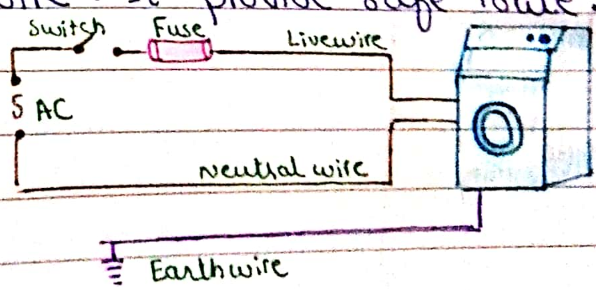
→ It disconnects the supply when current exceeds the normal value.

1. When normal current passes through the livewire, its electromagnet is not strong enough to separate the contacts.
2. When current exceeds the rated current of circuit breaker, the electromagnet will attract iron strip to separate the contacts and break the circuit.
3. The spring then keeps the contact apart.
4. After the fault is repaired, the contacts can be pushed back together by pressing a button on the outside of circuit breaker box.



Q.16 If fuse didn't capture additional currents from livewire then which protection conditions help and how?

Earth wire is used to capture additional current from livewire. Connect the metal case of appliance with earthwire and ground it, the current will pass through the earth wire. It provide safe route.



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