Electricity

Electric Charges

1. ▷ Inherent property of matter that feels a force of attraction / repulsion due to excess or defeciency of charges.

▷ (+)ve Charge = e^- defeciency (glass rod rubs silk)
(−)ve Charge = e^- excess (ebonite rod rubs fur)

2. ▷ S.I. Unit = C Coulamb
1 Coulomb = 6.241×10^{18} e = 6.241×10^{18} e^- is equal to 1 (−)ve Coul

3. ▷ $q = ne$

$$n = \frac{q}{e} = \frac{1}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$$

$$\frac{10}{1.6} \times 10^{18}$$

$1 e^- = -1.6 \times 10^{-19}$ C

Electric Current

▷ Rate of flow of charges / e^- through a conducter.

▷ Result of potential difference across a conducter.

▷ $$i = \frac{Q}{t} = \frac{ne}{t}$$

$$= \frac{\text{Charge}}{\text{time}}$$

▷ S.I. Unit = A = $\frac{C}{s}$ = Ampere

▷ Ampere = one ampere is current flowing a conducter if 1C of charge flows through it in 1 sec.

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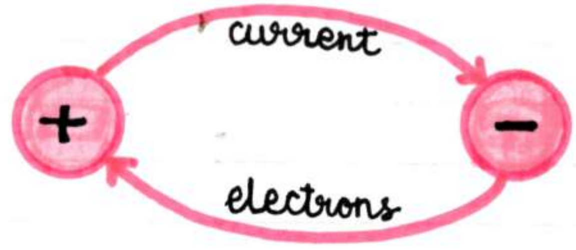
- scalar quantity
- AMMETER (A) - series - ↓R
- milliampere = 1mA = 10^{-3} A
  microampere = 1μA = 10^{-6} A

Direction

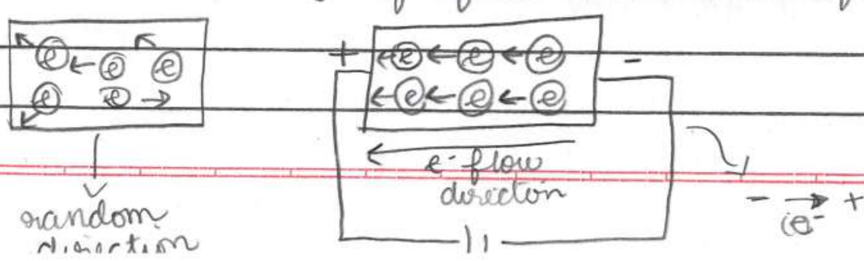


- Conventional Current:
  - flow of electric current from (+)ve terminal to (−)ve terminal.
  - flow of (+)ve charges in a given direction is electrically opposite direction of electric current. or flow of electrons e⁻ [(−)ve].

Flow in wire

- Solids - tightly packed = STILL
  travel ~ vaccum = smoothly
- Steady current
  ⇓ flows
  Average Drift Speed ← effect of External Electric Supply
  10^{-3} m/s
  drift v < thermal v
- ∴ Flow of charges / electrons produces current in a wire

metal wire - plenty of free e⁻ - electric force acts on e⁻



Electric Potential

- amount of work done in moving a unit (+)ve charge from infinity to that point.

  $\infty \xrightarrow{(+)ve} \bullet$

- Si. Unit = 'V' Voltage $= \frac{J}{C}$
- $V = \frac{W}{Q} = \frac{\text{Workdone}}{\text{Charge}} = \frac{J}{C}$

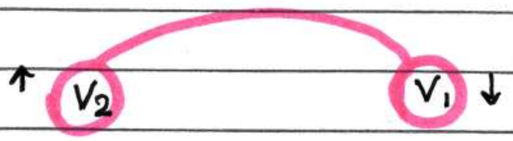
Potential Difference

- amount of work done in moveing a unit positive charge from 1 point to another.

  $\bullet① \longrightarrow \bullet②$

- $1\,\text{Volt} = \frac{1J}{1C}$
- 1 joule of work is done in moving 1 coulumb of charge from 1 point to another.
- VOLTMETER - (V) - Parallel - ↑R
- Smaller units - $1\,mV = 10^{-3}\,V$
  - $1\,\mu V = 10^{-6}\,V$

  Larger units - $1\,KV = 10^{3}\,V$
  - $1\,MV = 10^{6}\,V$



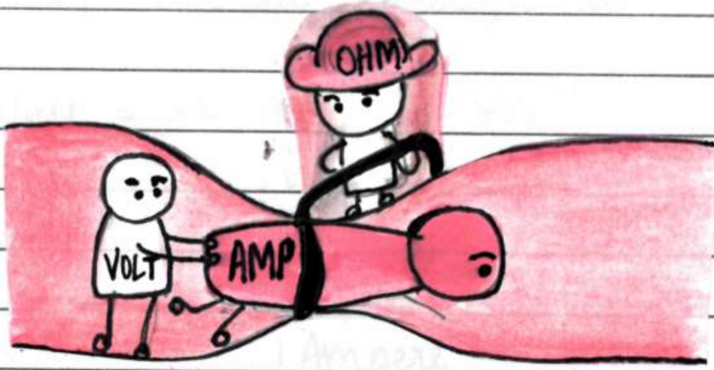
$V = V_2 - V_1$

Circuit

Closed & continuous path through which electric current flows

Ohm's Law

- Georg Simon Ohm



- "Current flowing through a conducter is directly propotional to the potential difference between ints ends provided its temperature remains same."

- $V \propto I$

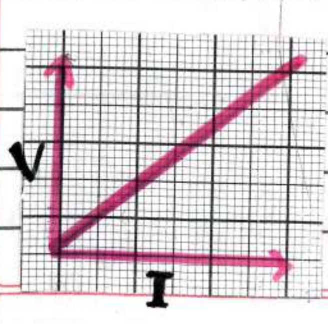
R = constant of propotionality = Resistance

$V = IR$

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

$V \propto I \propto \frac{1}{R}$

- Conducters → OHMIC, NON-OHMIC



$\therefore \frac{V}{I}$ = constant

Resistance

- property of conducter to oppose or resist flow of current through it.

- S.I. Unit = Ω Ohm = VA^{-1}

  If a p.d of 1V across the ends of conducter makes a current of 1A to flow through it.

  $$1\,\text{Ohm} = \frac{1\,\text{Volt}}{1\,\text{Ampere}}$$

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

- $R = \frac{V}{i}$

  $R = \frac{V}{A}$ in terms of SI Unit

- **RESISTOR :**
  - A component in electric circuit which offers resistance to the flow of e^- constituting electric current.
  - uses - electrical deivces - ↑R needed
    - ↓i in circuit
    - Alloys - NICHROME , CONSTANTAN

- **RHEOSAT / VARIABLE RESISTANCE**

  variable resistor - control flow of electric current by manually increasing or decreasing the resistance

- **GOOD CONDUCTER** ↓R

  A material which offers ↓R to flow of e^- or electric current in an electric circuit.

POOR CONDUCTER ↑↓R

A material which offer higher R than conducters to flow of e^- or electric current in an electric circuit.

INSULATOR ↑R

A material which offers very high resistance to the flow of e^- or electric current in an electric circuit.

GC > PC > I

Factors

- Length $L \propto R$
- Area of coss Section $\frac{1}{A} \propto R$
- ∞ Resistivity (need not
- Nature of material
- Temperature [MOSTLY] $T \propto R$

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

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

Rho
Propotion

Resistivity

Specefic Resistance

natural resistance of conducter

- Characteristic property of material by which it resists amount of current through it.

  ∴ specefic for a specefic substance

- Factors [~~dimensions~~]
  - Material
  - temperature

- S.I. Unit = Ωm Ohm meter
  = ρ (Rho)

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

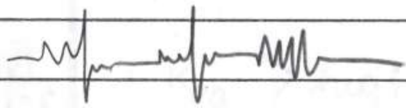
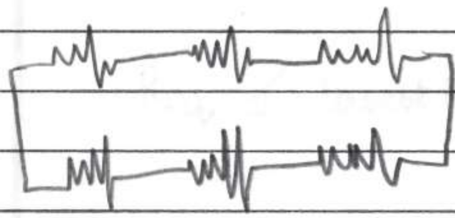
!! VOLUME is constant = $V = Al$

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

▶ Metal $\overset{\rho}{<}$ Alloys = INSULATOR = $10^{-8}\,\Omega m - 10^{-6}\,\Omega M$

Rubber, Glass = CONDUCTER = $10^{12}\,\Omega m - 10^{17}\,\Omega M$

SYSTEM OF RESISTORS

Series	Parallel
	

CRITERIA	Series	Parallel
1.		
2. CONNECTION	end to end connection	start & end together
3. CURRENT (i)	same	differs
4. VOLTAGE (V)	differs	same
5. EQUIVALENT RESISTANCE	↑ R_{eq} > highest R	↓ $R_{eq} \leq$ lowest R
6. AMOUNT OF CURRENT	↓ i $I \propto \frac{1}{R}$	↑ i
7. SWITCH	If 1 switched OFF, others also	If 1 switched OFF, others work independently
8. APPLIANCE FAILIURE	If 1 appliance stops working, others also stop.	If 1 appliance stops working, other indepent.
9. POTENTIAL DIFFERENCE	each resistor gets LESS ~~resistance~~ P.D since they are divided	each resistor receives MAXIMUM potential difference

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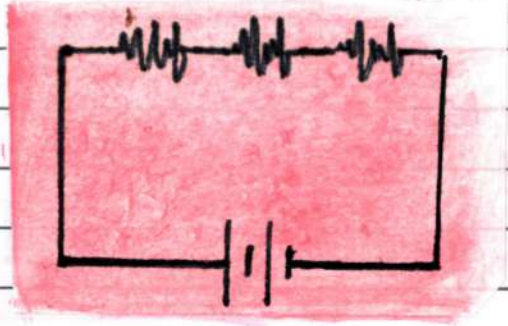
Series

① The figure shows 3 resistances R_1, R_2, & R_3. If potential difference across R_1 is V_1 & R_2 is V_2, R_3 is V_3.



② If the total potential difference across the battery is V.

③ The potential difference across combination of resistors connected in series is equal to sum of potential difference of individual resistors.

$$V = V_1 + V_2 + V_3 \quad \text{—— ①}$$

④ Applying Ohm's law to the whole circuit,

$$V = IR$$

⑤ Applying ohms law to all 3 resistors,

$$V_1 = IR_1 \quad \text{—— ②}$$

$$V_2 = IR_2 \quad \text{—— ③}$$

$$V_3 = IR_3 \quad \text{—— ④}$$

⑥ Substituting ②, ③ & ④ in ①.

$$IR = IR_1 + IR_2 + IR_3$$

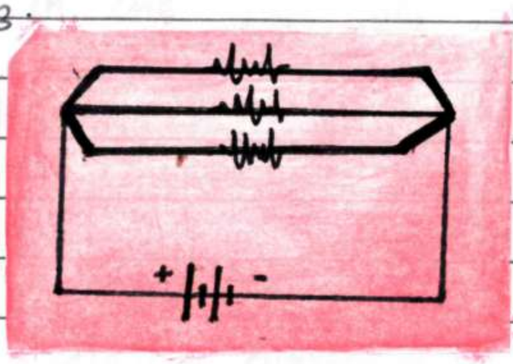
$$\cancel{I}(R) = \cancel{I}(R_1 + R_2 + R_3)$$

$$R = R_1 + R_2 + R_3$$

⑦ ∴ we conclude that equivalent resistance of a series connection is equal to sum of all resistors.

Parallel

The figure shows 3 resistors connected in parallel. If current across R_1 is I_1, R_2 is I_2 and R_3 is I_3.



Let total current across the circuit be I
The total current in combination of resistors in parallel connection is equal to sum of currents in seperate branch of resistors.

$$I = I_1 + I_2 + I_3 \quad \text{—— (1)}$$

Applying Ohm's law to the whole circuit,

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

Applying Ohm's law to 3 resistors seperately,

$$I_1 = \frac{V}{R_1} \quad \text{—— (2)}$$

$$I_2 = \frac{V}{R_2} \quad \text{—— (3)}$$

$$I_3 = \frac{V}{R_3} \quad \text{—— (4)}$$

Substituting (2), (3), (4) in (1)

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

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

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

∴ We can conclude that the reciprocal of equivalent resistance in parallel circuit is equal to sum of reciprocal of individual resistors

Heating Effects

- In purely resistive (Nichrome wire) circuits, the source of energy continuously gets dissipated entirely in the form of heat.

- Source of electrical energy Cell / Battery

↓

Chemical reactions in them = P.D

↓

flow of current

⇓

energy + HEAT

↓

↑ Temperature of appliances

- electrical energy ⟶ heat energy

Joules Law of Heating

The heat produced in wire is directly propotional to,

square of current for given R = $H \propto I^2$

resistance of a given current = $H \propto R$

time for which i flows through R = $H \propto T$

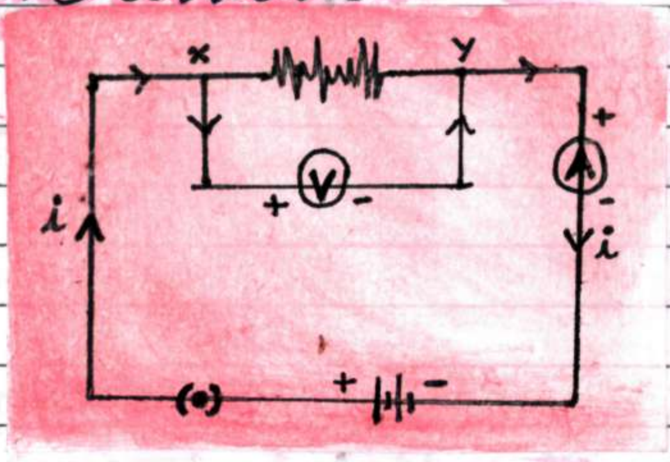
$$H = I^2RT$$

$$H = \frac{V^2}{R}T$$

$$H = VQ$$

$$H = VIT$$

Derivation



① If a current I flows through a resistor of resistance R and t be the time taken for Charge Q to flow through it,

② Then the work done to move the charge Q through the potential difference V is,

$W = QV$ ——— ①

③ From definition of Current we know that,

$I = Q/t$ (or) $Q = I \times t$ ——— ②

④ From Ohm's Law we know that,

$V = IR$ ——— ③

⑤ Substituting ② and ③ in ①

$W = [I \times R] \times [t \times I] = I^2 \times R \times T$

$W = I^2 R t$

⑥ Assuming that work energy is converted into heat energy.

⑦ ∴ The heat produced is given by

$W = H = I^2 R T$ ——— Ohm's Law

$W = H = V^2 T / R$ ——— Ohm's Law

$W = H = V I T$ ——— Electric current

$W = H = VQ$ ——— electric potential

APPLICATION:

Electric Bulb

O_2 Ar Tungsten

- the bulb's filament = Tungsten [3380°C] ← MP
- most power consumed - dissipated = ΔHEAT
  some ⟶ light ∵ ↑ρ & ↑M.P.
- Filament
  - thermally isolated [insulated]
  - filled with chemically inactive Oxygen & Argon to prolong life of filament

Electric Fuse

Lead, Tin PROCELAIN

- safety device in household circuits
  ↓
  STOPS unduly ↑ i
- connected in Series with main supply
- alloy of LEAD & TIN - encased PROCELAIN cartridge
- i flowing - circuit > Safe limit
  ⇓
  fuse temp ↑ ∴ wire melts & breaks circuit
- Protects other circuit element from hazards of ↑i

Power :

Amount of electric energy consumed in a circuit per unit time.

▶ DERIVATION :

W is the amount of energy consumed in a circuit in t seconds, then the electric power is given by,

$$P = \frac{W}{t} = \frac{\text{energy consumed}}{\text{time taken}}$$

But, W = electrical energy = $Vq = VIt$

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

$$P = VI$$

According to Ohm's law,

$V = IR$ (or) $I = \frac{V}{R}$

$P = [IR] \times I$ (or) $P = \frac{V}{R} \times \cancel{R} \times \frac{V}{\cancel{R}}$

$P = I^2R$

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

▶ SI Unit : W (Watt) = 1 volt × 1 ampere = VA

1 watt is when 1 ampere of current flows through a circuit having 1 volt potential difference

▶ $P = \frac{W}{T} = \frac{E}{T}$ $P = I^2R$ (heat/ohm) $P = \frac{V^2}{R}$ (ohm)

$P = VI$ $P = \frac{VQ}{T}$

kWh

Kilo watt hour
commersial unit of energy

DERIVATION

$$1\,kWhr = 1000\,Whr \quad (1\,hour)$$
$$= 1000\,W \times 3600\,s \leftarrow (60 \times 60)$$
$$= 3600000\,Ws$$
$$= 3600000\,\frac{J \times s}{s}$$
$$= 3600000\,J$$
$$= 3.6 \times 10^6\,J$$

$$\therefore 1\,kWh = 3.6 \times 10^6\,J$$

	W / Heat / Workdone	Power
①	I^2RT	I^2R
②	$\frac{V^2}{R}T$	$\frac{V^2}{R}$
③	VQ	$\frac{VQ}{T}$
④	VIT	VI
	$H = PT$	$P = \frac{E}{T} = \frac{W}{T} = \frac{H}{T}$