Theory class.

you can send msg to monitor

Chapter
19

Focus on concepts write later.

Current Electricity

Electric Current

$i = \frac{dQ}{dt}$

Formula $i_{av} = \frac{\Delta Q}{t}$

(1) The time rate of flow of charge through any cross-section is called current. $i = \lim_{\Delta t \to 0} \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$. If flow is uniform then $i = \frac{Q}{t}$. Current is a scalar quantity. It's S.I. unit is *ampere* (*A*) and C.G.S. unit is *emu* and is called *biot* (*Bi*), or *ab ampere*. 1*A* = (1/10) *Bi* (*ab amp*.)

(2) *Ampere* of current means the flow of 6.25 × 10^{18} *electrons/sec* through any cross-section of the conductor.

(3) The conventional direction of current is taken to be the direction of flow of positive charge, *i.e.* field and is opposite to the direction of flow of negative charge as shown below.

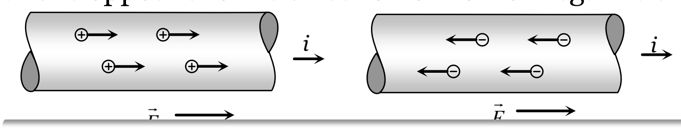


Fig. 19.1

when Q is given function of time

$i = \frac{dQ}{dt}$

(4) The net charge in a current carrying conductor is zero.

(5) For a given conductor current does not change with change in cross-sectional area. In the following figure $i_1 = i_2 = i_3$

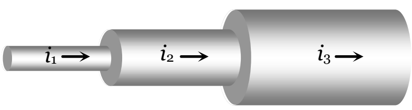
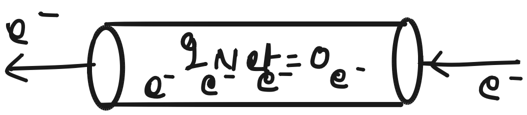


Fig. 19.2

when direct charge flow & time given

$i_{av} = \frac{\Delta Q}{t}$



(6) **Current due to translatory motion of charge :** If *n* particle each having a charge *q*, pass

$i = neAV_d$ ← drift velocity

Area of cross section of conductor

no. of Free electrons in unit volume of wire.

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

$i = neAV_d$

through a given area in time t then $i = \frac{nq}{t}$

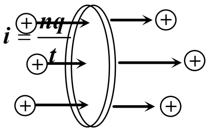
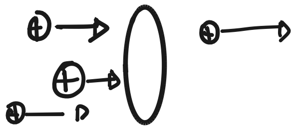


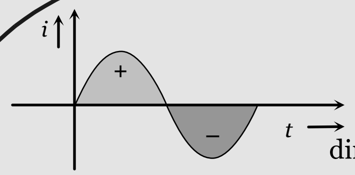
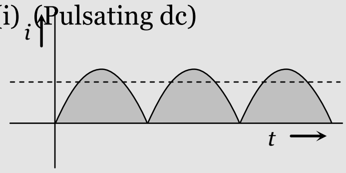
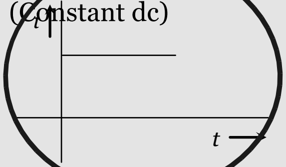
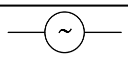
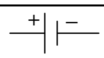
Fig. 19.3



If n particles each having a charge q pass per second per unit area, the current associated with cross-sectional area A is $i = nqA$

If there are n particle per unit volume each having a charge q and moving with velocity v, the current thorough, cross section A is $i = nqvA$

Table : 19.1 Types of current

Alternating current (ac)	Direct current (dc)
(i)  Magnitude and direction both varies with time ac → Rectifier → dc	(i) (Pulsating dc)  (Constant dc)  dc → Inverter → ac
(ii) Shows heating effect only	(ii) Shows heating effect, chemical effect and magnetic effect of current
(iii) It's symbol is 	(iii) It's symbol is 

(7) **Current due to rotatory motion of charge** : If a point charge q is moving in a circle of radius r with speed v (frequency ν, angular speed ω and time period T) then corresponding current $i = q\nu = \frac{q}{T} = \frac{qv}{2\pi r} = \frac{q\omega}{2\pi}$

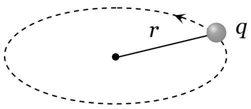
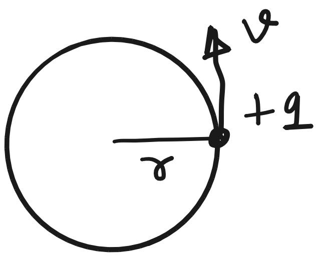


Fig. 19.4



$V = \frac{2\pi r}{T}$, $T = \frac{2\pi r}{v}$

$$i = \frac{q}{T} = \frac{q}{\frac{2\pi r}{v}} = \frac{qv}{2\pi r}$$

read.

(8) **Current carriers :** The charged particles whose flow in a definite direction constitutes the electric current are called current carriers. In different situation current carriers are different.

(i) Solids : In solid conductors like metals current carriers are free electrons.

(ii) Liquids : In liquids current carriers are positive and negative ions.

(iii) Gases : In gases current carriers are positive ions and free electrons.

(iv) Semi conductor : In semi conductors current carriers are holes and free electrons.

Current Density (J)

Current density at any point inside a conductor is defined as a vector having magnitude equal to current per unit area surrounding that point. Remember area is normal to the direction of charge flow (or current passes) through that point.

in general current density $\frac{i}{\text{Area}} = J$

(1) Current density at point P is given by $\vec{J} = \frac{di}{dA}\vec{n}$

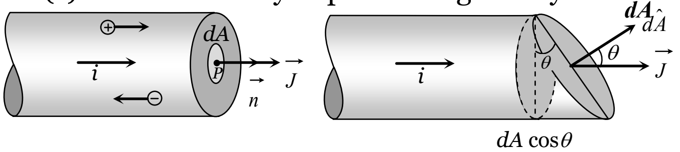
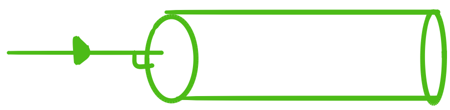


Fig. 19.5

Only when current is ⊥ to Area

(2) If the cross-sectional area is not normal to the current, but makes an angle θ with the direction of current then

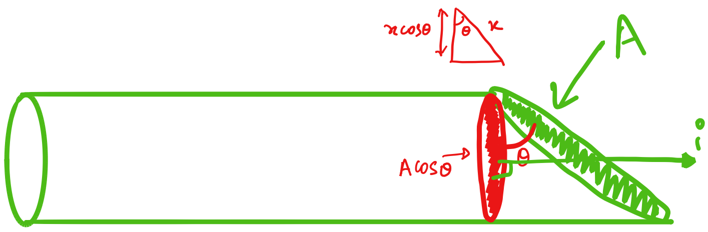


$$J = \frac{di}{dA\cos\theta} \Rightarrow di = JdA\cos\theta = \vec{J}.\vec{dA} \Rightarrow i = \int \vec{J}\cdot\vec{dA}$$

(3) If current density $\vec{J}$ is uniform for a normal cross-section $\vec{A}$ then $J = \frac{i}{A}$

(4) Current density $\vec{J}$ is a vector quantity. It's direction is same as that of $\vec{E}$. It's S.I. unit is *amp/m*² and dimension [$L^{-2}A$].

(5) In case of uniform flow of charge through a cross-section normal to it as $i = nqvA \Rightarrow J = \frac{i}{A} = nqv$.



$J = \frac{i}{A\cos\theta}$

$i = neAv_d$

$\boxed{J = neV_d}$ $J = \frac{i}{A} = neV_d$

(6) Current density relates with electric field as $\vec{J} = \sigma \vec{E} = \frac{\vec{E}}{\rho}$; where σ = conductivity and ρ = resistivity or specific resistance of substance.

$\boxed{\vec{J} = \frac{\vec{E}}{\rho}}$, $\boxed{\vec{J} = \sigma \vec{E}}$

Drift Velocity

Drift velocity is the average uniform velocity acquired by free electrons inside a metal by the application of an electric field which is responsible for current through it. Drift velocity is very small it is of the order of 10^{-4} m/s as compared to thermal speed $(\simeq 10^5\ m/s)$ of electrons at room temperature.

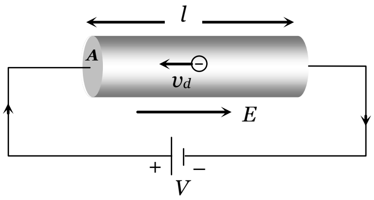


Fig. 19.6

drift velocity

If suppose for a conductor

n = Number of electron per unit volume of the conductor

A = Area of cross-section

V = potential difference across the conductor

E = electric field inside the conductor

$i = neAV_d$

$\frac{i}{A} = neV_d$

Suppose i is constant

i = current, J = current density, ρ = specific resistance, σ = conductivity $\left(\sigma = \frac{1}{\rho}\right)$ then current relates with drift velocity as $i = neAv_d$ we can also write

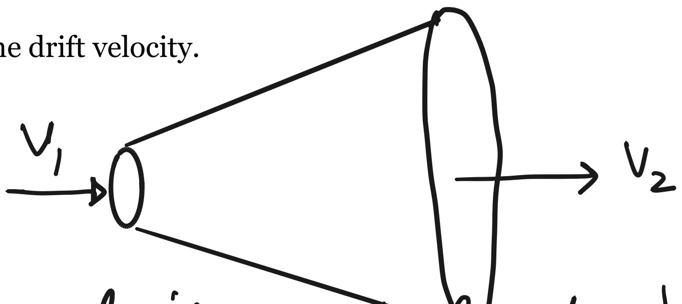
$$\boxed{v_d = \frac{i}{neA} = \frac{J}{ne} = \frac{\sigma E}{ne} = \frac{E}{\rho ne} = \frac{V}{\rho l n e}.}$$ NEET

$\uparrow V_d \propto \frac{1}{\text{Area} \downarrow}$

(1) The direction of drift velocity for electron in a metal is opposite to that of applied electric field (*i.e.* current density $\vec{J}$).

$v_d \propto E$ *i.e.*, greater the electric field, larger will be the drift velocity.

$V_1 > V_2$



if current is constant, $v_d \propto \frac{1}{\text{Area}}$.

(2) When a steady current flows through a conductor of non-uniform cross-section drift velocity varies inversely with area of cross-section $\left(v_d \propto \frac{1}{A}\right)$

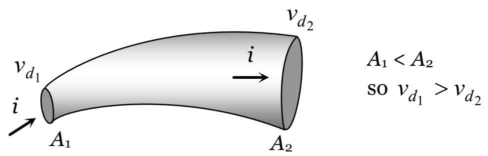


Fig. 19.7

(3) If diameter (d) of a conductor is doubled, then drift velocity of electrons inside it will not change.

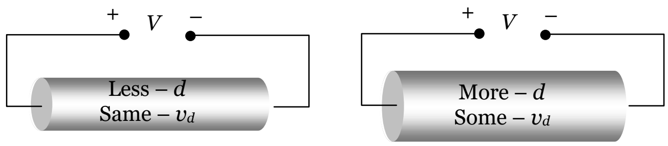


Fig. 19.8

(1) **Relaxation time (τ) :** The time interval between two successive collisions of electrons with the positive ions in the metallic lattice is defined as relaxation time $\tau = \frac{\text{mean free path}}{\text{r.m.s. velocity of electrons}} = \frac{\lambda}{v_{rms}}$. With rise in temperature v_{rms} increases consequently τ decreases.

(2) **Mobility :** Drift velocity per unit electric field is called mobility of electron *i.e.* $\mu = \frac{v_d}{E}$. It's unit is $\frac{m^2}{volt - \sec}$.

$\mu = \frac{V_d}{E}$ (direct Qustion)

Ohm's Law

If the physical conditions of the conductor (length, temperature, mechanical strain etc.) remains some, then the current flowing through the conductor is directly proportional to the potential difference across it's two ends *i.e.* $i \propto V \Rightarrow V = iR$ where R is a proportionality constant, known as electric resistance.

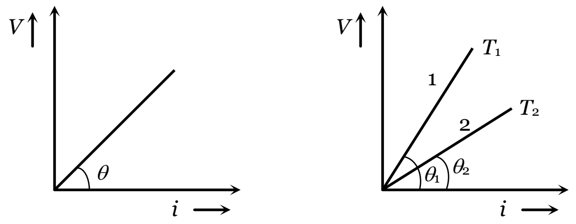
(1) Ohm's law is not a universal law, the substances, which obey ohm's law are known as ohmic substance.

$V = iR$ $V \leftarrow$ potential

$i \propto V$ where $R \leftarrow$ Resistance

$iR = V$

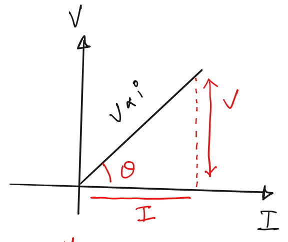
(2) Graph between V and i for a metallic conductor is a straight line as shown. At different temperatures V-i curves are different.



(A) Slope of the line $= \tan\theta = \frac{V}{i} = R$

(B) Here $\tan\theta_1 > \tan\theta_2$ So $R_1 > R_2$ i.e. $T_1 > T_2$

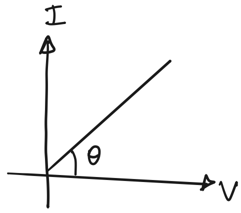
Fig. 19.9



$V = IR$

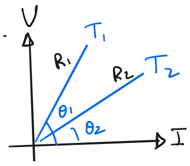
$R = \frac{V}{I}$

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



$R = \frac{1}{\tan\theta}$

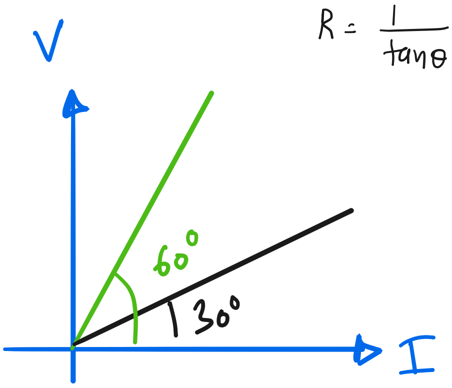
when we increase temp. of conductors their resistance increases.



$\tan\theta_1 > \tan\theta_2$

$R_1 > R_2$

$T_1 > T_2$



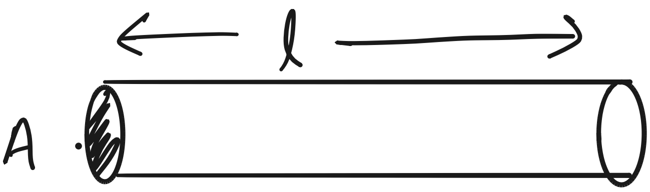
$$3 = \frac{\sqrt{3}}{1/\sqrt{3}} = \frac{R_1}{R_2} = \frac{\tan 60^\circ}{\tan 30^\circ} =$$

Resistance

(1) The property of substance by virtue of which it opposes the flow of current through it, is known as the resistance.

(2) **Formula of resistance :** For a conductor if l = length of a conductor A = Area of cross-section of conductor, n = No. of free electrons per unit volume in conductor, τ = relaxation time then resistance of conductor $R = \rho\frac{l}{A} = \frac{m}{ne^2\tau}\cdot\frac{l}{A}$; where ρ = resistivity of the material of conductor

(3) **Dependence of resistance :** Resistance of a conductor depends upon the following factors.



$R \propto l$

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

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

(i) Length of the conductor : Resistance of a conductor is directly proportional to it's length *i.e.* $\boldsymbol{R \propto l}$ and inversely proportional to it's area of cross-section *i.e.* $R \propto \frac{1}{A}$

temp.

(ii) Temperature : For a conductor

Resistance $\propto$ temperatur e .

$R = R_0(1 + \alpha t)$

Resistance at T °c

Resistance at 0°c

If R_0 = resistance of conductor at $0°C$

R_t = resistance of conductor at $t°C$

and α, β = temperature co-efficient of resistance

then $R_t = R_0(1 + \alpha t + \beta t^2)$ for $t > 300°C$ and

$\boldsymbol{R_t = R_0(1 + \alpha t)}$ for $t \leq 300°C$ or $\alpha = \frac{R_t - R_0}{R_0 \times t}$

Short cut (NEET)

$R_2 = R_1(1 + \alpha(T_2 - T_1))$

Approx Answer.

If R_1 and R_2 are the resistances at $t_1°C$ and $t_2°C$ respectively then $\frac{R_1}{R_2} = \frac{1 + \alpha t_1}{1 + \alpha t_2}$.

The value of α is different at different temperature. Temperature coefficient of resistance averaged over the temperature range $t_1°C$ to $t_2°C$ is given by $\alpha = \frac{R_2 - R_1}{R_1(t_2 - t_1)}$ which gives $R_2 = R_1[1 + \alpha(t_2 - t_1)]$. This formula gives an approximate value.

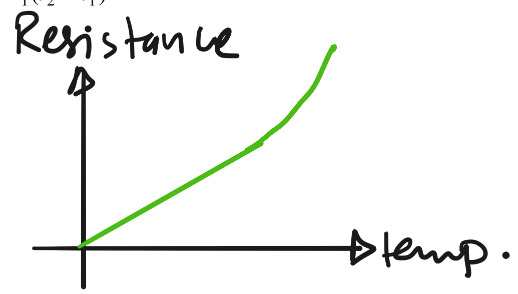


Table 19.2 : Variation of resistance of some electrical material with temperature

Material	Temp. coefficient of resistance (α)	Variation of resistance with temperature rise
Metals	Positive	Increases
Solid non-	Zero	Independent

metal		
Semi-conductor	Negative	Decreases
Electrolyte	Negative	Decreases
Ionised gases	Negative	Decreases
Alloys	Small positive value	Almost constant

Resistivity (ρ), Conductivity (σ) and Conductance (C)

(1) **Resistivity :** From $R=\rho\frac{l}{A}$; If l = 1*m*, A = 1 m^2 then $R=\rho$ *i.e.* resistivity is numerically equal to the resistance of a substance having unit area of cross-section and unit length.

(i) Unit and dimension : It's S.I. unit is *ohm* × *m* and dimension is $[ML^3T^{-3}A^{-2}]$

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

(ii) It's formula : $\rho=\frac{m}{ne^2\tau}$

$l = 1m$
$A = 1m^2$
$\boxed{R=\rho}$

(iii) Resistivity is the intrinsic property of the substance. It is independent of shape and size of the body (*i.e.* l and A).

$\underset{(\text{Maximum for fused quartz})}{\rho_{insulator}} > \rho_{alloy} > \rho_{semi\text{-}conductor} > \underset{(\text{Minimum for silver})}{\rho_{conductor}}$

unit of ρ is ohm x meter

(v) Resistivity depends on the temperature. For metals $\rho_t=\rho_0(1+\alpha\Delta t)$ *i.e.* resitivity increases with temperature.

(vi) Resistivity increases with impurity and mechanical stress.

(vii) Magnetic field increases the resistivity of all metals except iron, cobalt and nickel.

(viii) Resistivity of certain substances like selenium, cadmium, sulphides is inversely proportional to intensity of light falling upon them.

(2) **Conductivity :** Reciprocal of resistivity is called conductivity (σ) *i.e.* $\sigma=\frac{1}{\rho}$ with unit *mho/m* and dimensions $[M^{-1}L^{-3}T^3A^2]$.

conductivity = $\frac{1}{\text{resistivity}}$

(3) **Conductance :** Reciprocal of resistance is known as conductance. $C = \frac{1}{R}$ It's unit is $\frac{1}{\Omega}$ or Ω^{-1} or "Siemen".

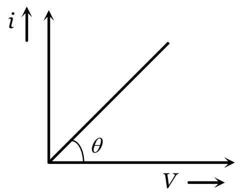


Fig. 19.11

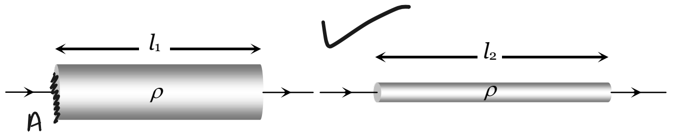
Stretching of Wire

special case when $R \propto \frac{l}{A}$ is not valid.

If a conducting wire stretches, it's length increases, area of cross-section decreases so resistance increases but volume remain constant.

Suppose for a conducting wire before stretching it's length = l_1, area of cross-section = A_1, radius = r_1, diameter = d_1, and resistance $R_1 = \rho \frac{l_1}{A_1}$

Before stretching After stretching



Volume remains constant *i.e.* $A_1 l_1 = A_2 l_2$

Fig. 19.12

$\uparrow R \propto \frac{1}{(\text{radius})^4} \downarrow$ or $\uparrow R \propto \frac{1}{(\text{Area})^2} \downarrow$

$R = \frac{\rho l}{A} \times \frac{l}{l} = \frac{\rho l^2}{\text{vol.}} =$

$R \propto l^2$, $\frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2$

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

$R = \frac{\rho\, \text{vol.}}{A^2}$

$\frac{R_1}{R_2} = \left(\frac{A_2}{A_1}\right)^2 = \left(\frac{\pi r_2^2}{\pi r_1^2}\right)^2 = \left(\frac{r_2}{r_1}\right)^4$

After stretching length = l_2, area of cross-section = A_2, radius = r_2, diameter = d_2 and resistance $= R_2 = \rho \frac{l_2}{A_2}$

Ratio of resistances before and after stretching $\boxed{\frac{R_1}{R_2} = \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \left(\frac{l_1}{l_2}\right)^2 = \left(\frac{A_2}{A_1}\right)^2 = \left(\frac{r_2}{r_1}\right)^4 = \left(\frac{d_2}{d_1}\right)^4}$

(1) If length is given then $R \propto l^2 \Rightarrow \frac{R_1}{R_2} = \left(\frac{l_1}{l_2}\right)^2$

(2) If radius is given then $R \propto \frac{1}{r^4} \Rightarrow \frac{R_1}{R_2} = \left(\frac{r_2}{r_1}\right)^4$

Grouping of Resistance

(1) **Series grouping**

(i) Same current flows through each resistance but potential difference distributes in the ratio of resistance *i.e.* $V \propto R$

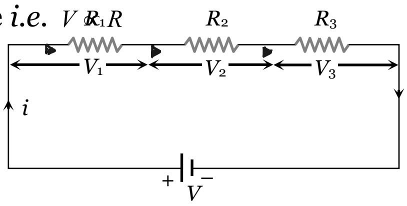


Fig. 19.15

In series combination current remains same.

KVL.

$$\boxed{R_{eq} = R_1 + R_2 + R_3}$$

$$V = V_1 + V_2 + V_3 \quad , \quad \boxed{V - V_1 - V_2 - V_3 = 0}$$

(ii) $R_{eq} = R_1 + R_2 + R_3$ equivalent resistance is greater than the maximum value of resistance in the combination.

(iii)If n identical resistance are connected in series $R_{eq} = nR$ and potential difference across each resistance $V' = \frac{V}{n}$

(2) **Parallel grouping**

(i) Same potential difference appeared across each resistance but current distributes in the reverse ratio of their resistance *i.e.* $i \propto \frac{1}{R}$

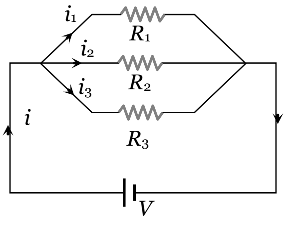


Fig. 19.16

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

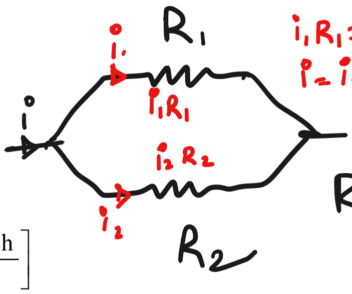
$$\frac{1}{R_{eq}} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$$

$$R_{eq} = R/2 \quad ,$$

(ii) Equivalent resistance is given by $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ or $R_{eq} = (R_1^{-1} + R_2^{-1} + R_3^{-1})^{-1}$ or $R_{eq} = \frac{R_1 R_2 R_3}{R_1 R_2 + R_2 R_3 + R_2 R_1}$

Equivalent resistance is smaller than the minimum value of resistance in the combination.

(iv) If two resistance in parallel $R_{eq} = \frac{R_1 R_2}{R_1 + R_2} = \frac{\text{Multiplication}}{\text{Addition}}$



$i_1 R_1 = i_2 R_2$ — A
$i = i_1 + i_2$ — B

$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

(v) Current through any resistance

$$i' = i \times \left[\frac{\text{Resistance of opposite branch}}{\text{Total resistance}}\right]$$

Where i' = required current (branch current),

In paralle potential remains same

i = main current

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

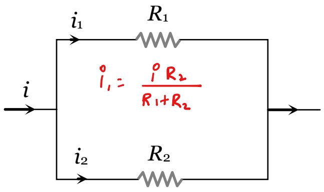


Fig. 19.17

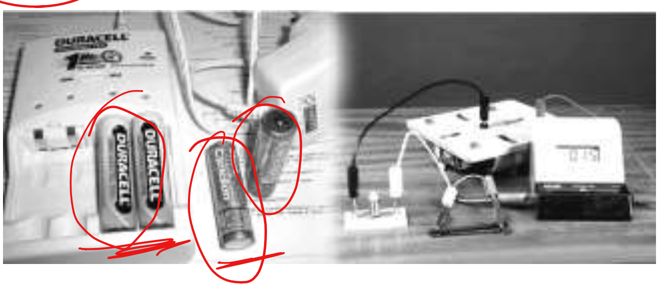
and $i_2 = i\left(\frac{R_1}{R_1 + R_2}\right)$

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

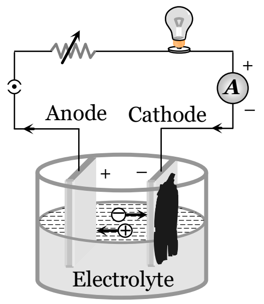
(vi) In n identical resistance are connected in parallel

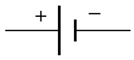
$R_{eq} = \frac{R}{n}$ and current through each resistance $i' = \frac{i}{n}$

Cell



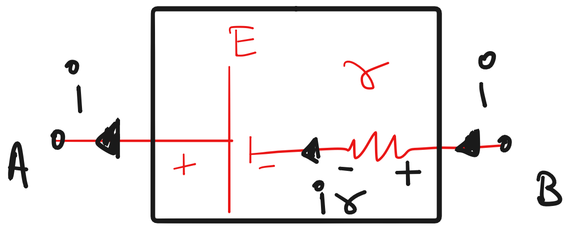
The device which converts chemical energy into electrical energy is known as electric cell. Cell is a source of constant emf but not constant current.





Symbol of cell

Fig. 19.18



$V_{AB} = E - ir$ ← internal resistance.

terminal potential of cell

(1) **Emf of cell (E)** : The potential difference across the terminals of a cell when it is not supplying any current is called it's emf.

(2) **Potential difference (V)** : The voltage across the terminals of a cell when it is supplying current to external resistance is called potential difference or terminal voltage. Potential difference is equal to the product of current and resistance of that given part *i.e.* $V = iR$.

(3) **Internal resistance (r)** : In case of a cell the opposition of electrolyte to the flow of current through it is called internal resistance of the cell. The internal resistance of a cell depends on the distance between electrodes ($r \propto d$), area of electrodes [$r \propto (1/A)$] and nature, concentration ($r \propto C$) and temperature of electrolyte [$r \propto (1/\text{temp.})$].

A cell is said to be ideal, if it has zero internal resistance.

Cell in Various Positions

(1) **Closed circuit :** Cell supplies a constant current in the circuit.

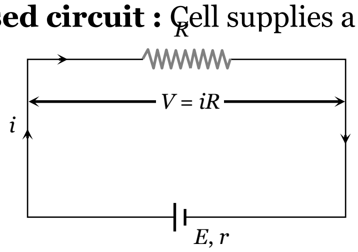
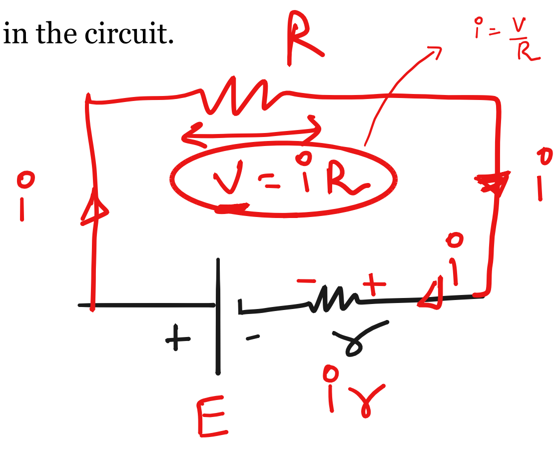


Fig. 19.19



$$i = \frac{E}{R + r}$$

$$E = iR + ir \quad , \quad E = V + ir$$

$\boxed{V = E - ir}$ terminal

$V = E - \frac{V}{R} r$

potential of cell.

(i) Current given by the cell $i = \frac{E}{R+r}$

(ii) Potential difference across the resistance $V = iR$

$\frac{V}{R} r = E - V$

(iii) Potential drop inside the cell = ir

(iv) Equation of cell $E = V + ir$ $(E > V)$

$r = \left(\frac{E}{V} - 1\right) R$

(v) Internal resistance of the cell $r = \left(\frac{E}{V} - 1\right) \cdot R$

$\boxed{r = R\left(\frac{E}{V} - 1\right)}$

(vi) Power dissipated in external resistance (load)

$$P = Vi = i^2 R = \frac{V^2}{R} = \left(\frac{E}{R+r}\right)^2 .R$$

Power delivered will be maximum when $R = r$ so $P_{max} = \frac{E^2}{4r}$.

This statement in generalised from is called "*maximum power transfer theorem*".

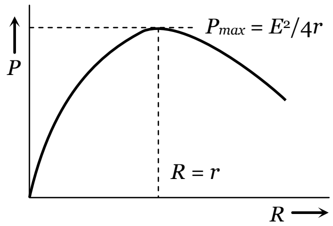
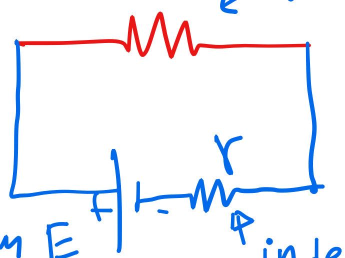


Fig. 19.20

$r = R$ then

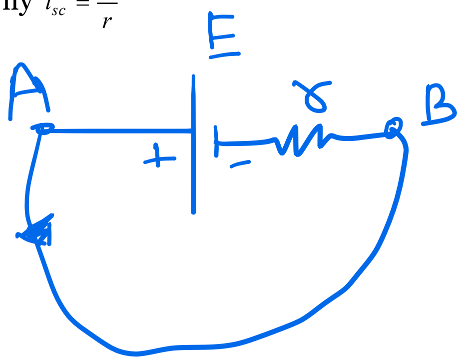
R ← device



only at R we get maximum power.

(vii) When the cell is being charged *i.e.* current is given to the cell then $E = V - ir$ and $E < V$.

(i) Maximum current (called short circuit current) flows momentarily $i_{sc} = \frac{E}{r}$



(ii) Potential difference $V = 0$

$i_{sc} = \frac{E}{r}$

$V_{AB} = 0$

Grouping of Cells

Group of cell is called a battery.

In series grouping of cell's their emf's are additive or subtractive while their internal resistances are always additive. If dissimilar plates of cells are connected together their emf's are added to each other while if their similar plates are connected together their emf's are subtractive.

$E_{eq} = E_1 + E_2$
$r_{eq} = r_1 + r_2$

$E_{eq} = E_1 - E_2$ $(E_1 > E_2)$
$r_{eq} = r_1 + r_2$

Fig. 19.23

(1) **Series grouping :** In series grouping anode of one cell is connected to cathode of other cell and so on. If n identical cells are connected in series

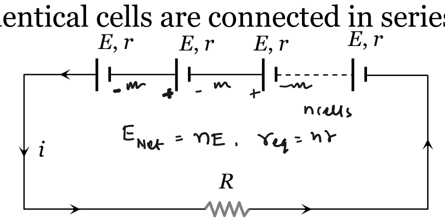
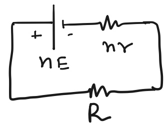


Fig. 19.24



$I = \frac{nE}{nr+R}$

V. IMP. Out of n cell if m cells connected wrongly then

$E_{eq} = nE - 2mE$

(2) **Parallel grouping :** In parallel grouping all anodes are connected at one point and all cathode are connected together at other point. If n identical cells are connected in parallel

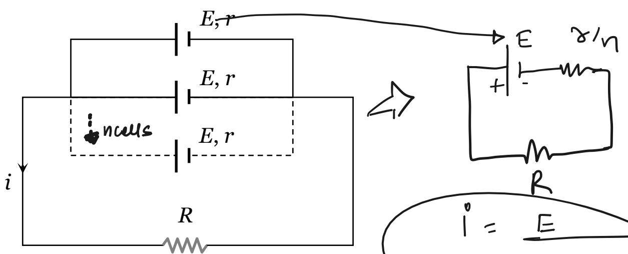
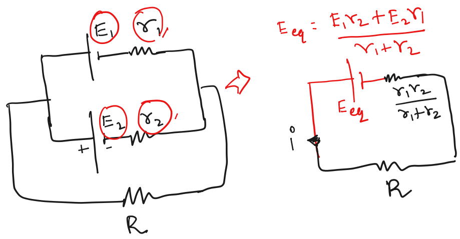
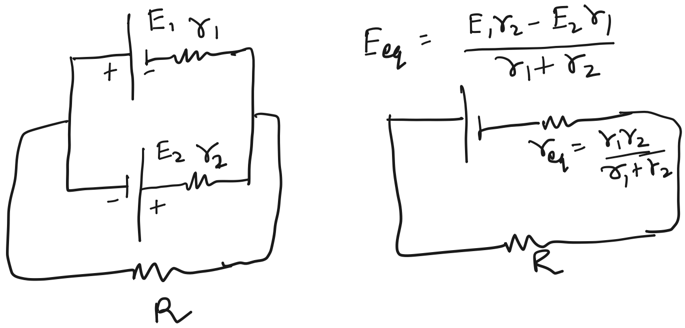


Fig. 19.25

$i = \frac{E}{R + r/n}$

most imp for IIT mains.





(3) **Mixed Grouping :** If n identical cell's are connected in a row and such m row's are connected in parallel as shown.

$\frac{1}{nr}+\frac{1}{nr}+\frac{1}{nr}+\cdots$ m times

$\frac{1}{r_{eq}}=\frac{m}{nr}$, $r_{eq}=\frac{nr}{m}$

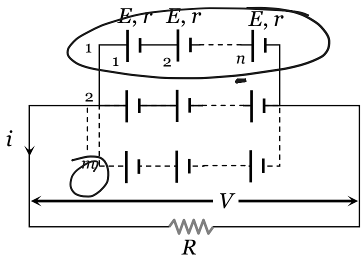
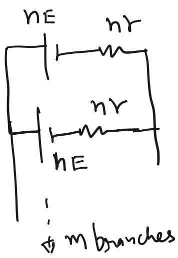
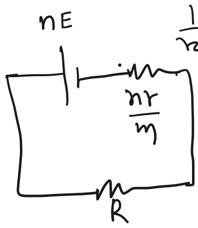


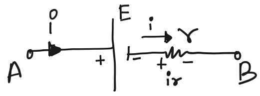
Fig. 19.26





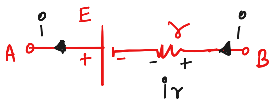
$$\boxed{i=\frac{nE}{R+\frac{nr}{m}}}$$

Charging of cell



$$\boxed{V_{AB}=E+ir}$$

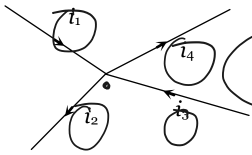
Dis changing of cell



$$\boxed{V_{AB}=E-ir}$$

Kirchoff's Laws

(1) **Kirchoff's first law :** This law is also known as junction rule or current law (*KCL*). According to it the algebraic sum of currents meeting at a junction is zero *i.e.* $\Sigma i = 0$.



$i_1+i_3=i_2+i_4$

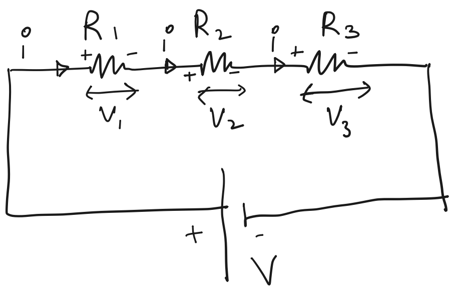
Fig. 19.27

In a circuit, at any junction the sum of the currents entering the junction must equal the sum of the currents leaving the junction. $i_1+i_3=i_2+i_4$

(ii) This law is simply a statement of "*conservation of charge*".

(2) **Kirchoff's second law :** This law is also known as loop rule or voltage law (KVL) and according to it "the algebraic sum of the changes in potential in complete traversal of a mesh (closed loop) is zero", *i.e.* $\Sigma V = 0$

(i) This law represents "*conservation of energy*".



$V-V_1-V_2-V_3=0$

(ii) If there are n meshes in a circuit, the number of independent equations in accordance with loop rule will be $(n-1)$.

(3) **Sign convention for the application of Kirchoff's law :** For the application of Kirchoff's laws following sign convention are to be considered

(i) The change in potential in traversing a resistance in the direction of current is $-iR$ while in the opposite direction $+iR$

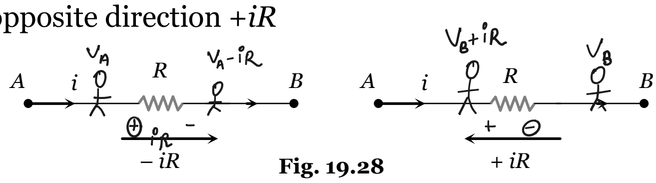


Fig. 19.28

(ii) The change in potential in traversing an emf source from negative to positive terminal is $+E$ while in the opposite direction $-E$ irrespective of the direction of current in the circuit.

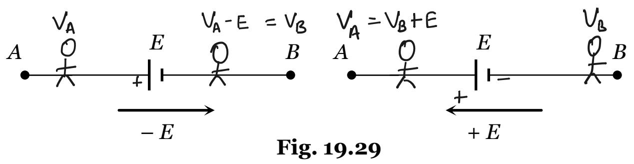
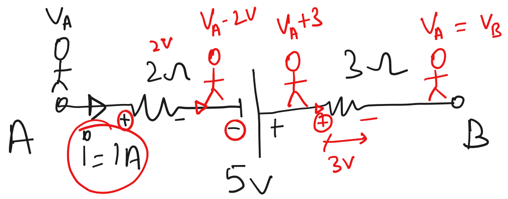
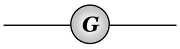


Fig. 19.29



Different Measuring Instruments

(1) **Galvanometer :** It is an instrument used to detect small current passing through it by showing deflection. Galvanometers are of different types *e.g.* moving coil galvanometer, moving magnet galvanometer, hot wire galvanometer. In dc circuit usually moving coil galvanometer are used.

(i) **It's symbol :** 

; where G is the total internal resistance of the galvanometer.

(ii) **Full scale deflection current :** The current required for full scale deflection in a galvanometer is called full scale deflection current and is represented by i_g.

(2) **Ammeter :** It is a device used to measure current and is always connected in series with the 'element' through which current is to be measured.

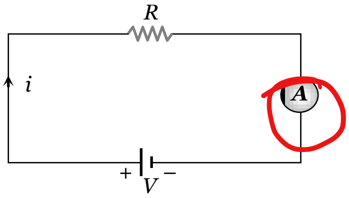
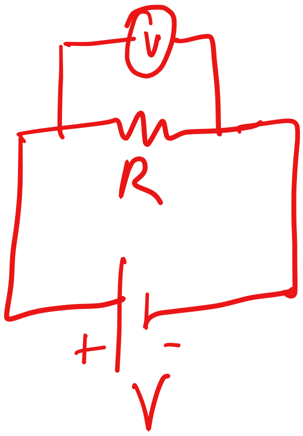


Fig. 19.32



(i) The reading of an ammeter is always lesser than actual current in the circuit.

(ii) Smaller the resistance of an ammeter more accurate will be its reading. An ammeter is said to be ideal if its resistance r is zero.

(iii) **Conversion of galvanometer into ammeter :** A galvanometer may be converted into an ammeter by connecting a low resistance (called shunt S) in parallel to the galvanometer G as shown in figure.

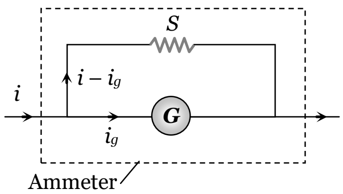
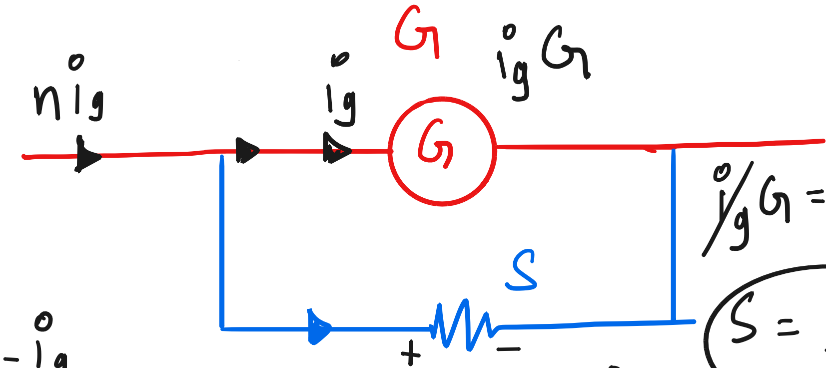


Fig. 19.33



$i_g G = S(n-1) i_g$

$S = \frac{G}{n-1}$

$i_g(n-1)$ $S(n-1) i_g$

(3) **Voltmeter :** It is a device used to measure potential difference and is always put in parallel with the 'circuit element' across which potential difference is to be measured.

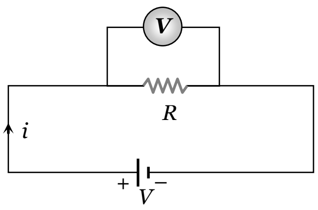


Fig. 19.34

(i) The reading of a voltmeter is always lesser than true value.

(ii) Greater the resistance of voltmeter, more accurate will be its reading. A voltmeter is said to be ideal if its resistance is infinite, *i.e.*, it draws no current from the circuit element for its operation.

(iii) **Conversion of galvanometer into voltmeter :** A galvanometer may be converted into a voltmeter by connecting a large resistance R in series with the galvanometer as shown in the figure.

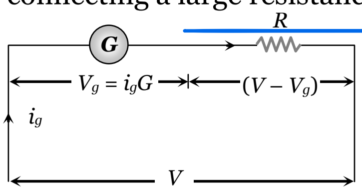
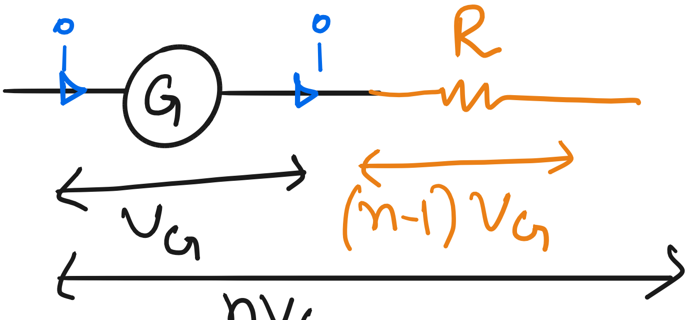


Fig. 19.35



(4) **Wheatstone bridge :** Wheatstone bridge is an arrangement of four resistance which can be used to measure one of them in terms of rest. Here arms AB and BC are called ratio arm and arms AC and BD are called conjugate arms

$$\frac{V_G}{G} = \frac{(n-1)V_G}{R}, \quad R = (n-1)G$$

$P/Q = R/S$ true.

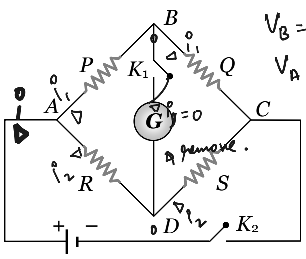


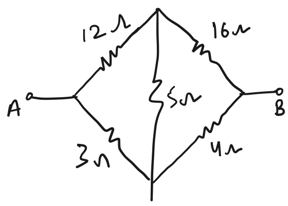
Fig. 19.36

$V_B = V_D$

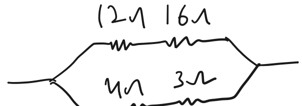
$V_A > V_B > V_C$

$$\boxed{\frac{P}{R} = \frac{Q}{S}}$$

at balanced condition.



$\frac{12}{3} = 4 \qquad \frac{16}{4} = 4$



$R_{eq.} = \frac{28 \times 7}{28+7}$

(5) **Meter bridge :** In case of meter bridge, the resistance wire *AC* is 100 *cm* long. Varying the position of tapping point *B*, bridge is balanced. If in balanced position of bridge $AB = l$, BC $(100 - l)$ so that $\frac{Q}{P} = \frac{(100-l)}{l}$. Also $\frac{P}{Q} = \frac{R}{S} \Rightarrow S = \frac{(100-l)}{l}R$

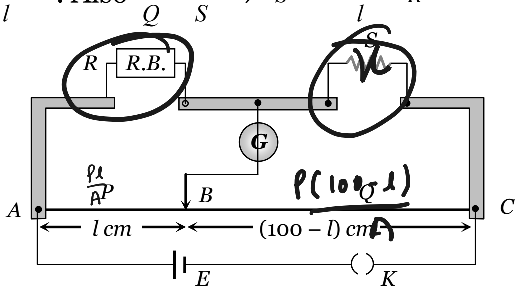
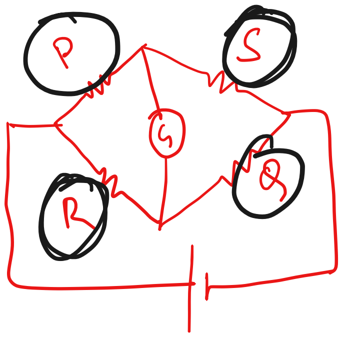


Fig. 19.37



$x = \frac{R.B.(100-l)}{l}$

$\frac{P}{R} = \frac{S}{Q}$

$\frac{R.B.}{\rho l / \cancel{A}} = \frac{x}{\cancel{\rho}(100-l) / \cancel{A}}$

Potentiometer

Potentiometer is a device mainly used to measure emf of a given cell and to compare emf's of cells. It is also used to measure internal resistance of a given cell.

(1) **Circuit diagram :** Potentiometer consists of a long resistive wire *AB* of length *L* (about 6*m* to 10 *m* long) made up of mangnine or constantan and a battery of known voltage *e* and internal resistance *r* called supplier battery or driver cell. Connection of these two forms primary circuit.

One terminal of another cell (whose emf *E* is to be measured) is connected at one end of the main circuit and the other terminal at any point on the resistive wire through a galvanometer *G*. This forms the secondary circuit. Other details are as follows

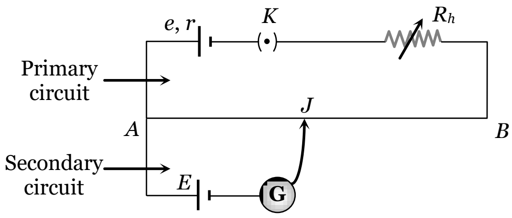


Fig. 19.38