CURRENT ELECTRICITY

- I = dq/dt

  I = Q/t = ne/t
- If a point charge q is moving in circle with constant speed and frequency f, then corresponding current. I = fq
- Current density $J = \frac{I}{a\cos\theta}$ here θ is angle between direction of current area vector of cross-section
- Resistance :

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

  ρ : resistivity of conductor

  l: length ; A : Area of cross section

  (i) Effect of stretching a wire on its resistance

  l_1 and l_2 be the initial and final lengths of the wire and r_1 and r_2 are the initial and final radius then

  $$\frac{R_1}{R_2} = \frac{l_1^2}{l_2^2} = \frac{r_2^2}{r_1^2}$$

  (ii) % change in resistance for % change in length

  $$\frac{dR}{R}\% = 2\frac{dl}{l}\times 100$$
- Conductance S = 1/R is called conductivity unit Ω^{-1} or seimen(s)

  Conductivity = 1/resistivity

  σ = 1/ρ

  Unit of conductivity = $\Omega^{-1}m^{-1}$

  Dimensional formula for conductivity $M^{-1}L^{-3}T^3A^2$
- Current $I = neAV_d$

  Here v_d is drift velocity.

CURRENT ELECTRICITY. THERMAL , CHEMICAL, MAGNETIC EFFECT OF CURRENT

- Resistivity ρ

$$\rho = \frac{m}{ne^2\tau}$$

m : mass of electron

n : number density of electron per unit m^3

τ : Relaxation time

e : charge of electrons

- Mobility:

$$\mu = \frac{v_d}{E}$$

- Temperature Dependence of Resistivity

$$\rho = \rho_0\left[1 + \alpha\left(\theta - \theta_0\right)\right]$$
$$R = R_0\left[1 + \alpha\left(\theta - \theta_0\right)\right]$$

ρ: resistivity at temperature θ

ρ_o : resistivity at reference temperature θ_o

R : resistance at temperature θ

R_o: resistance at reference temperature θ_o

α : temperature coefficient

- If R_1 is resistance at temperature t_1 and R_2 is resistance at temperature t_2 then

$$\frac{R_1}{R_2} = \frac{1 + \alpha t_1}{1 + \alpha t_2}$$

temperature coefficient α is

$$\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1}$$

- Terminal voltage

When discharging V = E - Ir

When battery is charging V = E + Ir

When battery is charging, charging voltage is V and R is resistance to control current, r is internal resistance of battery, then

energy $VIt = EIt + I^2Rt + I^2rt$

Charging current I

$$I = \frac{V - \varepsilon}{r + R}$$

- Connections of Resistors:

  Series connection

  $R = R_1 + R_2 + R_3 + ...$

  Parallel connection

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

  Kirchoff's Rules:

  First rule: `` The algebraic sum of all the electric currents meeting at the junction is zero.'' $\sum I = 0$

  Second Rule: `` For any closed loop the algebraic sum of the products of resistance and the respective currents flowing through them is equal to the algebraic sum of the emfs applied along the loop.'' $\sum IR = \sum \varepsilon$

  Sign convention: If direction of path and direction of current is same then IR is negative else it is positive

  While going through the path if negative terminal of battery appears first take ε as positive else negative

- Connection of two Cells:

  two cells of emfs ε_1 and ε_2 having internal resistance $r_1$and r_2 respectively. current flowing through external resistance R is I (i) Series Connection Current I is

  $$I = \frac{\varepsilon_1 + \varepsilon_2}{R + (r_1 + r_2)}$$

  Equivalent emf $\varepsilon = \varepsilon_1 + \varepsilon_2$

Equivalent internal resistance r = $r_1 + r_2$

(ii)Parallel Connection

$$I = \frac{\varepsilon_{eq}}{R + r_{eq}}$$

equivalent emf

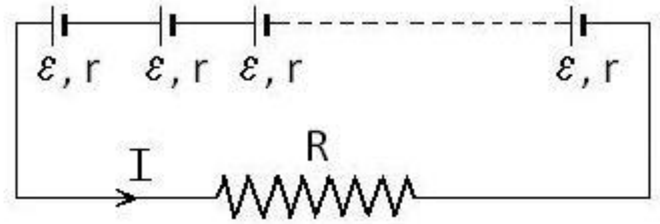
$$\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$$

Equivalent internal resistance

$$r = \frac{r_1 r_2}{r_1 + r_2}$$

- grouping of n cells having same emf ε and internal resistance r

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



(i) Equivalent emf of the combination $\varepsilon_{eq} = n\varepsilon$

(ii) Equivalent internal resistance r_{eq} = nr

(iii) Current from each cell and resistance R :

$$I = \frac{n\varepsilon}{R + nr}$$

(iv) Potential difference across external resistance V = IR

(v) Potential difference across each cell v' = V/n

(vi) Power dissipated in the external circuit

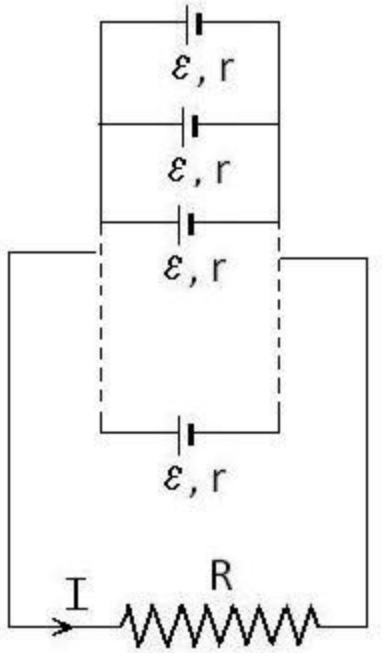
$$\left(\frac{n\varepsilon}{R + nr}\right)^2 R$$

(vii) Condition for maximum power R = nr

$$P_{max} = n\left(\frac{\varepsilon^2}{4r}\right)$$

(viii) This type of combination is used when nr << R.

(B) Parallel grouping: In parallel grouping all anodes are connected at one point and all cathodes are connected together at other point. of n identical cells are connected in parallel.



(i) Equivalent emf of the combination $\varepsilon_{eq} = \varepsilon$

(ii) Equivalent internal resistance $r_{eq} = r/n$

(iii) Current from each cell and resistance R :

$$I = \frac{\varepsilon}{R + \frac{r}{n}}$$

(iv) Potential difference across external resistance V= potential across each cell = IR

(v) Current through each cell I' = I/n

(vi) Power dissipated in the external circuit

$$P = \left(\frac{\varepsilon}{R + \frac{r}{n}}\right)^2 R$$

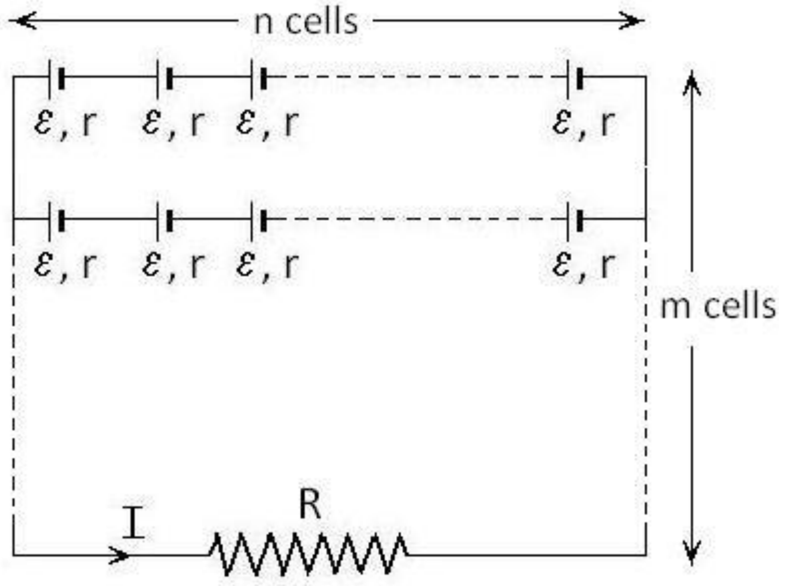
(vii) Condition for maximum power R = r/n

$$P_{max} = n\left(\frac{\varepsilon^2}{4r}\right)$$

(viii) general equation

$$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \ldots + \frac{\varepsilon_n}{r_n}$$

(C) Mixed Grouping: If n identical cells are connected in a row and such m rows are connected in parallel as shown, then



(i) Equivalent emf of the combination $\varepsilon_{eq} = n\varepsilon$

(ii) Equivalent internal resistance $r_{eq} = nr/m$

(iii) Current through resistance R :

$$I = \frac{mn\varepsilon}{mR + nr}$$

(iv) Potential difference across external resistance V = IR

(v) Potential difference across each cell v' = V/n

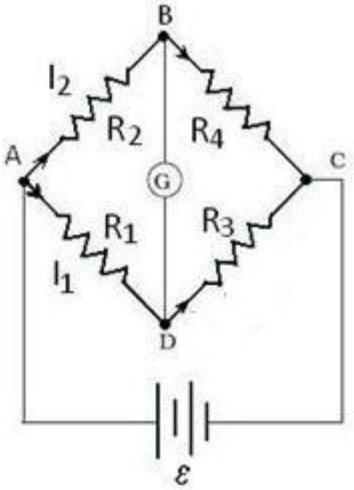
(vi) Current through each cell I' = I/n

(vii) Condition for maximum power R = nr /m

$$P_{max} = mn\left(\frac{\varepsilon^2}{4r}\right)$$

(viii) number of cell in circuit = mn

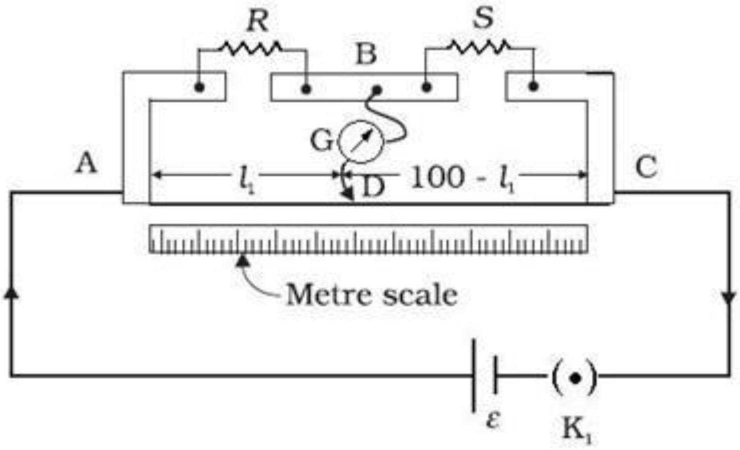
- Whetstone Bridge: For a balanced whetstone



For a balanced whetstone

$$\frac{R_2}{R_1} = \frac{R_4}{R_3}$$

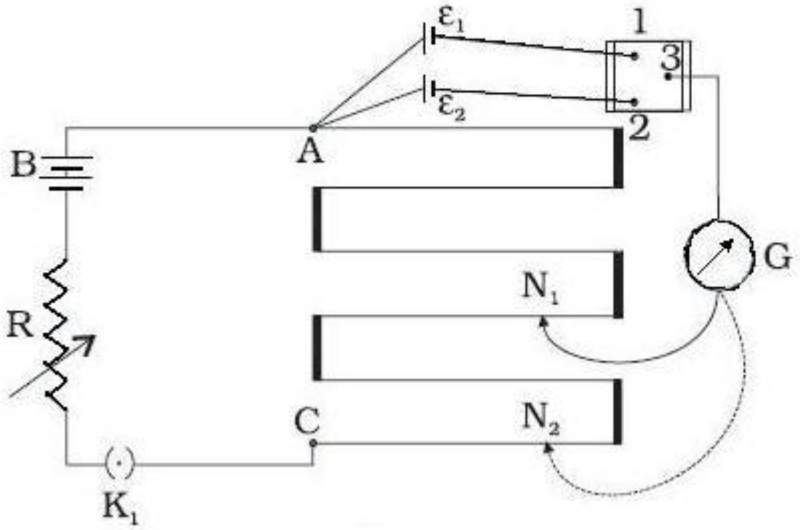
For practical circuit



$$\frac{R}{S} = \frac{\rho l_1}{\rho(100 - l_1)} = \frac{l_1}{100 - l_1}$$

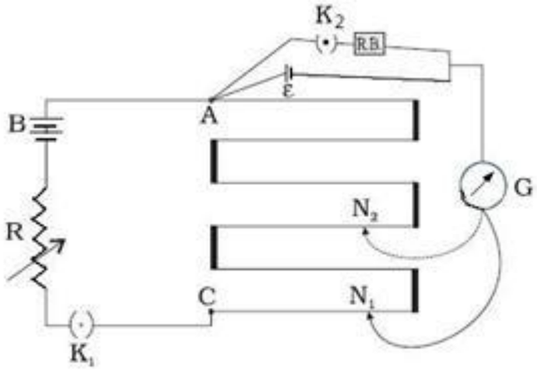
- Potentiometer:

  For comparing emf



$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

For finding internal resistance of cell 'r'



$AN_1 = l_1$ and $AN_2 = l_2$

$$r = R\left(\frac{l_1}{l_2} - 1\right)$$

THERMAL AND CHEMICAL EFFECTS OF CURRENT

- The work done in taking q coulomb of charge from one end of the wire to the other at a potential difference of V volt will be V×q joule. Thus work done by the battery or energy dissipated in the wire in t sec.

  $W = Vq = VIt$ joule

  If resistance of wire is R, the V = IR

  $\therefore W = I^2Rt$ joule

  or $W = V^2t/R$
- Electric power $p = W/t$

  $P = I^2R$

  $P = V^2/R$
- When total current is divided in two parts among two resistance R_1 and R_2

  Current through R_1 is

  $$I_2 = \frac{IR_2}{R_1 + R_2}$$

  Current through R_2 is

  $$I_1 = \frac{IR_1}{R_1 + R_2}$$
- When resistance of power P_1, P_2 .... P_n when voltage is V are connected in series with voltage V then Power obtained

  $$\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \ldots + \frac{1}{P_n}$$
- When resistance of power P_1, P_2 .... P_n when voltage is V are connected in parallel with voltage V then Power obtained

  $P = P_1 + P_2 + \ldots + P_n$
- Faraday's laws of electrolysis

  (a) First law : it states that the amount of substance deposited or liberated in electrolysis is directly proportional to the charge flowing through the electrolyte

If m is the amount of substance liberated, when charge q passes through the electrolyte then

$m = Zq$, here Z is called electrochemical equivalent of the substance

Or $m = ZIt$ (as q =It)

unit of Z is kg/coul.

Dimensional formula is [$M A^{-1} T^{-1}$]

(b) Second Law: If same amount of electricity is passed through different electrolytes for same time then the ratio of masses of the substance liberated at the respective electrodes is equal to the ratio of their chemical equivalents.

if e_1 and e_2 are chemical equivalents and there electrochemical equivalent is Z_1 and Z_2 respectively then

$$\frac{Z_1}{Z_2} = \frac{e_1}{e_2}$$

If M is molecular weight of substance deposited and p is valence then e = M/p

- Faraday Constant : Charge on one mole of electron is called faraday constant its value is 96500C/mol.

$F = e/Z$

MAGNETIC EFFECTS OF CURRENT

- Biot-Savart law

$$\overrightarrow{dB} = \frac{\mu_0}{4\pi}\frac{I\overrightarrow{dl}\times\vec{r}}{r^2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{idl\sin\theta}{r^2}$$

Here θ is the angle between direction of current and vector joining the point and current element,

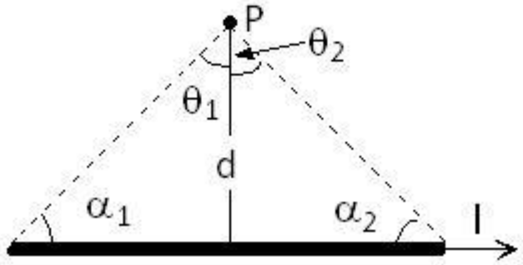
- $\mu_o = 4\pi\times10^{-7}$ wb amp^{-1} metre^{-1}

or $\mu_o = 4\pi\times10^{-7}$ T m A^{-1}

If θ = 0 or π dB = 0., thus for all the point along the length of the element , the magnetic field is zero

(ii) If θ = 90°, dB is maximum . thus field is maximum for all points lying in a plane through the element and perpendicular to its length

- Magnetic field due to



(A) Finite length of a wire

i is the current through conductor d is a perpendicular distance

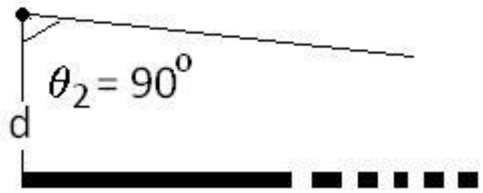
$$B = \frac{\mu_0}{4\pi}\frac{I}{d}(\sin\theta_1 + \sin\theta_2)$$

$$B = \frac{\mu_0}{4\pi}\frac{I}{d}(\cos\alpha_1 + \cos\alpha_2)$$

(B) Infinite length of a wire

put $\theta_1 = \theta_2 = 90°$ in first equation of (A)

(C) Semi - infinite length of a wire



take $\theta_1 = 0$ and $\theta_2 = 90°$ in first equation of (A)

$$B = \frac{\mu_0}{4\pi}\frac{I}{d}\left(\sin 0 + \sin 90\right)$$

$$B = \frac{\mu_0}{4\pi}\frac{I}{d}$$

(D) Magnetic field at the centre of current carrying coil

$$B = \frac{\mu_0 nI}{2r}$$

n is number of turns

(E) Magnetic field on the axis of the current carrying circular coil of n turns, of radius R

$$B = \frac{\mu_0 nIR^2}{2\left(R^2 + x^2\right)^{3/2}}$$

(i) At centre x = 0

$$B = \frac{\mu_0 nI}{2R}$$

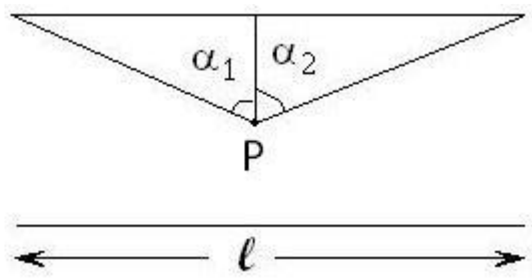
(ii) At a point at very large distance from the coil

For such point $x_2 >> R_2$

$$B = \frac{\mu_0 nIR^2}{2x^3}$$

(F) For Solenoid

(i) Finite length solenoid



Angle α_1 and α_2 are the angle subtended by two ends of the solenoid with normal drawn from point p

$$B = \frac{\mu_0 NI}{2l}\left[\sin\alpha + \sin\beta\right]$$

(ii) Infinite length solenoid

$\alpha_1 = \alpha_2 = 90°$

if n is the number of turns per unit length

$$B = \mu_0 nI$$

(iii) Mag. field at either end

$\alpha_1 = 0$ $\alpha_2 = 90$

$$B = \frac{\mu_0 nI}{2}$$

(G) Toroid:

$$B = \frac{\mu_0 NI}{2\pi r}$$

N is total number of turns, and r is the radius of toroid

(H) Magnetic field inside Lethe conductor

Let "a" be the radius of cylindrical conductor and "r" be the perpendicular distance from axis of cylinder. r > a, then

$$B = \left(\frac{\mu_0 I}{2\pi a^2}\right) r$$

Force on a charged particle in magnetic field.

(A) $\vec{F} = q(\vec{v} \times \vec{B})$

$F = qvB \sin\theta$

θ is the angle between direction of velocity $\vec{v}$ and direction of magnetic field $\vec{B}$

(i) Magnetic force is zero if v = 0 or charge is stationary, or θ = 0

(ii) Magnetic force is maximum when θ = 0

(iii) Direction of force can be determine by using Fleming's Left and rule

(iv) charged particle moves on straight line if θ =0

(V) If θ = 90 then charged particle moves on circular path of radius r

$$r = \frac{mv}{qB} = \frac{p}{qB}$$

$$r = \sqrt{\frac{2mK}{qB}} = \frac{1}{B}\sqrt{\frac{2mv}{q}}$$

(B) Fleming's Left and rule

First finger indicates ⇒ direction of magnetic field.

Middle finger indicates ⇒ direction of motion of POSITIVE charge particle

Thumb indicates ⇒ direction of force

(C) If θ is neither zero nor perpendicular it performs Helical path.

(i) radius of helical path r

$$r = \frac{mv\sin\theta}{qB}$$

(ii) periodic time

$$T = \frac{2\pi m}{qB}$$

(iii) pitch of the helix = Tv cosθ , here v is velocity

$$pitch = \frac{2\pi mv\cos\theta}{qB}$$

$$pitch = \frac{2\pi r}{\tan\theta}$$

(iv) number of pith = length(l) /Pitch distance

- Lorentz's force

  $$\vec{F} = q\left[\vec{E} + \left(\vec{v} \times \vec{B}\right)\right]$$

- Cyclotron frequency

  $$f = \frac{2\pi m}{qB}$$

  Maximum energy of positive ions

  $$E = \frac{B^2 q^2 R^2}{2m}$$

  Limitation of cyclotron

  As the charged particle is accelerated, its velocity increases and thence the masses, according to formula

  $$m = \frac{m_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

  Since t ∝ m, charge particles takes more time in Dees. Since the electric field charges after fix interval, the charge particle lags behind the field, finally it becomes impossible to accelerate the charged particle as it becomes completely out of step of the applied A.C.

- Force between two parallel current carrying wires.

  $$F = \frac{\mu_0}{4\pi} \frac{I_1 I_2}{d} l$$

  d is perpendicular distance between wires

  Case (i) If I_1 and I_2 are flowing in same direction Attraction.

  Case (ii) If I_1 and I_2 are flowing in opposite direction Repulsion.

- Torque acting on a rectangle frame carrying current i , in uniform magnetic field B

  τ= BINA sin θ (i) If frame is parallel to the field θ = 0, τ = 0

  (ii) If frame is perpendicular to the field θ = 90, τ = BINA

- Moving coil Galvanic meter.

  (i) τ= BINA

  restoring force = Kϕ

  Where ϕ = deflection in galvanometer

  BINA = Kϕ

  $$I = \left(\frac{k}{BNA}\right)\phi$$

  (ii) Current sensitivity (Si) : The deflection produced in the Galvanometer per unit current flowing through it.

  $$S_i = \frac{BNA}{k}$$

  (iii) Voltage sensitivity (S_v) :

  The deflection produced in the Galvanometer per unit voltage applied to it.

  $$S_V = \frac{\phi}{V} = \frac{BNA}{kR}$$

- Ammeter:

  Formula for shunt

  $$S = \frac{GI_g}{I - I_g}$$

  here I : is maximum current , I_g is current through galvanometer for full scale deflection

  G is resistance of galvanometer

  S is resistance connected in parallel to galvanometer

- Voltmeter

  Series Resistance

  $$R_S = \frac{V}{I_g} - G$$

  R_s is resistance connected in series with Galvanometer, I_g is current through galvanometer for full scale deflection

G is resistance of galvanometer, V is the potential difference to be measured