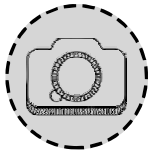
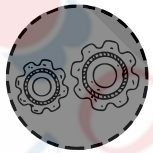
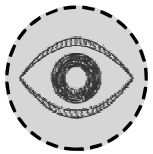
MIND MAPS
Learning Made Simple





anytime, as frequency as you like till it becomes a habit!



When?

What?

Presenting words and concepts as pictures!!

MIND MAP
AN INTERACTIVE MAGICAL TOOL

Why?

- To Unlock the imagination and come up with ideas
- To Remember facts and figures easily
- To Make clearer and better notes
- To Concentrate and save time
- To Plan with ease and ace exams

Result

Learning made simple
'a winning combination'

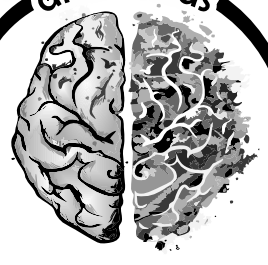
How?

With a blank sheet of paper coloured pens and your creative imagination!

What are Associations?

It's a technique connecting the core concept at the Centre to related concepts or ideas. Associations spreading out straight from the core concept are the First Level of Association. Then we have a Second Level of Association emitting from the first level and the chronology continues. The thickest line is the First Level of Association and the lines keep getting thinner as we move to the subsequent levels of association. This is exactly how the brain functions, therefore these Mind Maps. Associations are one powerful memory aid connecting seemingly unrelated concepts, hence strengthening memory.

Electric Charges and Fields



Electric charges

- Always normal to conducting surface
- Lines originating from +ve charge
- Terminating at –ve charge
- Never intersect each other
- Do not form closed loop
- Are imaginary lines.

Electric field lines

Quantization of charge

All charges must be a multiple of charge (e)
$Q = ne$
Where n is an integer

- Two kinds of charges + ve and – ve
- S.I unit is coulomb (C)
  1 C = charge flowing through a wire in 1 sec if current in it is 1A
  $1e = 1.602 \times 10^{-19}$C

Conservation of charge

It is not possible to create or destroy net charge of an isolated system.

Electric Field

$\vec{E} = \frac{\vec{F}}{q} = k\ \frac{Q}{r^2}$ (N/C)

$\because$ unit = N/C

- Due to discrete distribution of charges
  $\vec{E} = \sum_{i}^{n} \vec{E}_i$
- Due to continuous distribution of charge
  $\vec{E} = k \int \frac{dQ}{r^3}\vec{r}$
  $|\vec{E}| = k \int \frac{dQ}{r^2}$

Electric field due to point charge

Coulomb's Law

- Force between two charged particles
  $\vec{F} = \frac{k\, q_1\, q_2\, \vec{r}}{r^3} = \frac{kq_1\, q_2\, \hat{r}}{r^2}$, force is attractive when q_1 and q_2 are of opposite sign, otherwise repulsive
  $|\vec{F}| = \frac{k\, q_1\, q_2}{r^2}$
  $k = \frac{1}{4\pi\varepsilon_0} \approx 9 \times 10^9 \text{Nm}^2\text{C}^{-2}$
- Force between multiple charges
  $\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \vec{F}_{15} + \ldots\ldots = \frac{q_1}{4\pi\varepsilon_0} \sum_{i=2}^{n} \frac{q_i}{r_{1i}^2}\, \hat{r}_{1i}$

where is the unit vector along charge particle under consideration
$\hat{r}_{li}$ = distance between Ist and i^{th} particle

"The electric force with which two charges attract or repel one another are not affected by the presence of other charges''. It is known as Superposition Principle.

Applications of Gauss's Law

- Electric Field due to linear charge distribution
  $E = \lambda/2\pi\,\varepsilon_0 r$,
  λ = linear charge density
- ElectricField due to a plane sheet of charge
  $E = \sigma/2\varepsilon_0$,
  σ = charge per unit area
- Electric Field due to a charged conducting plate
  $E = \sigma/\varepsilon_0$,
  σ = charge per unit area
- Electric Field inside a conductor = 0

Electric field due to uniformly charged spherical shell at :

- Outside point,
  $E = Q/4\pi\varepsilon_0 r^2$
- Internal point,
  E = 0
- The surface,
  $E = Q/4\pi\varepsilon_0 R^2$

Electric Dipole moment, $\vec{p} = q\vec{d}$

- Electric field due to dipole at axial position,
  $\vec{E} = \frac{1}{4\pi\,\varepsilon_0}\left(\frac{2p}{r^3}\right)\hat{r}$
- Electric field due to dipole at an equatorial position,
  $|E| = \frac{1}{4\pi\,\varepsilon_0}\left(\frac{P}{r^3}\right)$
- Torque on an electric dipole placed in an electric field $(\vec{E})$
  $\vec{\tau} = \vec{p} \times \vec{E} = p\,E\sin\theta$

Gauss's Theorem

$\oint \vec{E}.\vec{ds} = q_{in}/\varepsilon_0 = \phi$

where, q_{in} = net charge enclosed
ϕ = flux through a closed surface

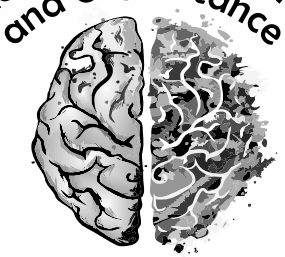
Electric flux

$\Delta\phi = \vec{E}.\Delta\vec{S}$, $\Delta\vec{S}$ = area vector
$\vec{E}$ = electric field
$\phi = \int \vec{E}.\vec{ds}$

In 1985, Charles Augustin de Coulomb gave Coulomb's law

Trace the Mind Map
First Level · Second Level · Third Level

Electrostatic Potential and Capacitance



- Work done per unit test charge by an external agent in moving the test charge from reference point to the desired point. Its SI unit is J/C
  $V_0 = W/q_0$.

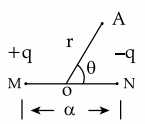
Electric potential

- $V_P = Q/4\pi\varepsilon_0 r$ — Electric potential due to a point charge
- $V = \frac{1}{4\pi\varepsilon_0}\sum\frac{Q_i}{r_i}$ — Potential due to a system of charges
- Potential due to a dipole:

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

Where, $p = qd$

$\theta = \angle AON$



At $\theta = 0°$, $V = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^2}$ [axial position]

At $\theta = 90°$, $V = 0$ [equitorial position]

In 1774, Alessandro Volta wrote treatise"on the forces of attraction of electric fire".

Equipotential surface

- Potential is same at all the points of the surface.
- Component of electric field parallel to an equipotential surface is zero.

Electric potential energy

- It is negative count of work done by the electric force as the configuration of the system changes.
- $Ur_2 - Ur_1 = -W = \frac{q_1 \cdot q_2}{4\pi\varepsilon_0}\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$
- If the separation between charges is 'r', then $U_{(r)} = \frac{q_1 \cdot q_2}{4\pi\varepsilon_0 r}$
- Potential Difference,

  $V_B - V_A = \frac{U_B - U_A}{q}$

  $U_B - U_A$ = Change in Potential energy

  q = Test charge

Capacitance, $C = \frac{Q}{V}$

Capacitance of a parallel plate capacitor,
$C = K\varepsilon_0 A/d$, K = dielectric constant

Parallel grouping of capacitors,
$C = C_1 + C_2 + C_3 + ---- + C_n$
for two capacitors, $C = C_1 + C_2$

Series grouping of capacitors,
$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ---- + \frac{1}{C_n}$
For two, $C = \frac{C_1 C_2}{C_1 + C_2}$

Capacitance when material slab is inserted between the plates
$C = K\varepsilon_0 A/[Kd - x(K-1)]$
where, x = thickness of the slab inserted

Energy stored in a capacitor,
$U = \frac{1}{2}CV^2 = \frac{Q^2}{2C} = 1/2\,QV$

Capacitance of a spherical capacitor,
$C = 4\pi\varepsilon_0/\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
For isolated sphere,
$C = 4\pi\varepsilon_0 R$

Dielectric

- Force $F = \frac{q_1\, q_2}{4\pi K\varepsilon_0 r^2}$, K = dielectric constant of medium
- A dielectric is an electrical insulator that can be polarized by "application of" electric field.

Conductors & Insulators

Conductors	Insulators
A material which when placed in an electric field, the free electrons move in a direction opposite to the field.	material in which electrons are tightly bound, and when exposed in an electric field, electrons do not move *i.e.* having no free electrons.

- Electric field inside a conductor is always zero.
- Electric field is always perpendicular to the charged surface.
- In static state, there will be no additional charge in a conductor.

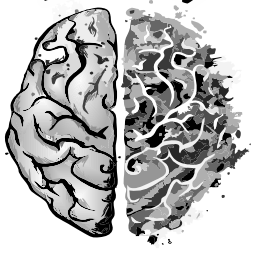
Potential energy of a dipole

$dU = pE\sin\theta d\theta$
If we choose P.E. of dipole to be zero when $\theta = 90°$, then
$U_\theta - U_{90°} = \int_{90°}^{\theta} pE\sin\theta\, d\theta$
If it is rotated through angle θ against the torque,
$U_\theta = -pE\cos\theta = -\vec{p}\cdot\vec{E}$

Trace the Mind Map

First Level · Second Level · Third Level

Current Electricity



Trace the Mind Map

First Level · Second Level · Third Level

Electric Current

- $\vec{J} = \frac{\Delta i}{\Delta s \cos\theta} = \sigma E$
  - Δs = Area of cross-section
  - θ = Angle between Area vector and current flow
  - σ = Conductivity
- Rate of flow of charge through an area, $i = \frac{Q}{t}$, $i = \int \vec{J}.\vec{ds}$

Current density

$V_d = \frac{i}{neA} = \frac{J}{ne}$

Drift velocity

$\mu = \frac{V_d}{E} = \frac{e\tau}{m}$

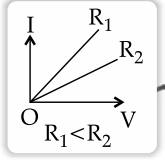
τ = Average collision time

Mobility

$J = \sigma E$ or $V = IR$

Ohm's Law

Characteristics



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

Resistance

Resistivity

$\rho = \frac{1}{\sigma} \Omega$ m

Conductivity

$\sigma = J/E$

Grouping of Resistors

$R = R_1 + R_2 + R_3 + - - - + R_n$

For two resistors, $R = R_1 + R_2$

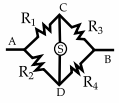
$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + - - + \frac{1}{R_n}$

For two resistors $R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$

Wheatstone Bridge

- Condition for balanced wheatstone bridge

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



- $V_c = V_D$

  No current through G

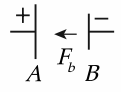
Electric cell

It is a device which maintains a potential difference between its two terminals.

EMF

emf = $E = \frac{W}{q} = \frac{F_b}{d}$

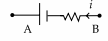
It is equal to the potential difference between the terminals when the they are not connected externally.



Internal Resistance

$V_A - V_B = E - ir$

r = Internal resistance of the cell



Grouping of Cell

Parallel grouping

$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$, $i = \frac{E_{eq}}{R + \frac{r_1 r_2}{r_1 + r_2}}$

Series grouping

$i = \frac{E_1 + E_2}{R_1 + (r_1 + r_2)} = \frac{E_0}{R_1 + R_2}$

$E_0 = E_1 + E_2$, $R_2 = r_1 + r_2$

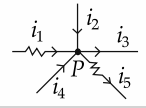
Kirchhoff's Law

Junction Law

$i_1 + i_2 + i_4 = i_3 + i_5$

The algebraic sum of all currents directed towards a point (junction) is zero.

$\Sigma I_p = 0$



Loop Law

The algebraic sum of all the potential difference along a closed loop is zero.

$\Sigma E = 0$

Potentiometer

$P = \frac{V_A - V_B}{l} = \frac{\text{Potential difference}}{\text{Length of wire}}$

Comparison of emf, $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

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

l_1 and l_2 are lengths of null point

Meter Bridge

Unknown resistance $S = \frac{R(100 - l)}{l}$

l = Balancing length

R = Known resistance

Temperature Dependence of Resistance

$R = R_0 [1 + \alpha (T - T_0)]$

$\rho = \rho_0 \quad [1 + \alpha (T - T_0)]$

R = Resistance at temperature T

R_0 = Resistance at temperature T_0

α = Coefficient of resistivity

Moving Charges and Magnetism

- It is a region around a magnet or current carrying conductor or a moving charge in which its magnetic effect can be felt
- SI unit is Tesla(T) = weber/m^2
- 1 Gauss = 10^{-4} Tesla where gauss is the CGS unit

Magnetic Field $(\vec{B})$

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

$= qvB \sin\theta$

- For $\theta = 0, \vec{F} = 0$ along the magnetic field
- For $\theta = 90°$, *i.e.* if charge's velocity is perpendicular to field direction, force is perpendicular to both field and velocity

$F = qvB = \frac{mv^2}{r}$

$r = \frac{mv}{qB}$ = Radius of the circle in which charge rotates

Time period $(T) = \frac{2\pi m}{qB}$

ν(frequency) $= \frac{1}{T} = \frac{qB}{2\pi m}$

If $\theta \neq 0, 180°, 90°$

Then, $F = qvB \sin\theta$

And the charge particle will follow helical path whose

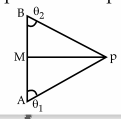
$r = \frac{mv_\perp}{qB}$ and pitch $= V_\parallel \times T = V_\parallel \times \frac{2\pi m}{qB}$

Magnetic Force on a moving charge

Magnetic field due to straight current carrying wire

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

where θ_1 and θ_2 are the angles corresponding to the lower and upper ends respectively



i.e $\theta_1 = 0$

$\theta_2 = \pi$

$B = \frac{\mu_0 i}{2\pi d}$

Oersted's Law

In April 1820, Hans Christian Oersted discovered that flow of current in a wire can deflect a nearby magnetic compass needle.

Solenoid

- Magnetic field at a point inside due to a long solenoid, $B = \mu_0 ni$
- At a point on one end $B = \frac{\mu_0 ni}{2}$

where n = number of turns per unit length along the length of solenoid.

Magnetic field due to Toroid

$B = \frac{\mu_0 Ni}{2\pi r}$, N = Total Number of turns

i = Current in toroid

Force between parallel current carrying wires

$F = \frac{\mu_0 i_1 i_2}{2\pi d}$

Torque experienced by a loop in uniform magnetic field

$\vec{\tau} = \vec{M} \times \vec{B}$

$\tau = NBiA$

Definition of Ampere

If two parallel wire kept 1 m apart, if and $F = 2 \times 10^{-7}$ N, then current = 1A in each wire.

Sensitivity

Voltage sensitivity = NBA/CG current sensitivity = NBA/C

Galvanometer

Ammeter

$S = \frac{Ig}{I - Ig} G$

Voltmeter

$R = \frac{V}{Ig} - G$

Field due to a current carrying circular ring

Field at a point far away from the centre

i.e. for $d >> a$

$B = \frac{\mu_0 i a^2}{2d^3}$

Field at an axial point

$B = \frac{\mu_0 i a^2}{2(a^2 + d^2)^{3/2}}$

Field at the centre

$B = \frac{\mu_0 i}{2a}$

Force on a current carrying conductor

$d\vec{F} = i(d\vec{l} \times \vec{B}) F = ilB$

biot-Savart Law

$d\vec{B} = \frac{\mu_0}{4\pi} \frac{id\vec{l} \times \vec{r}}{r^3}$ [θ = angle between $d\vec{l}$ and $\vec{r}$]

$dB = \frac{\mu_0}{4\pi} \frac{idl \sin\theta}{r^2}$ [Direction of field will be perpendicular to the plane containing current element and the point of observation]

where $\mu_0 = \frac{1}{\varepsilon_0 c^2}$

Ampere's Law

$\oint \vec{B}.\vec{dl} = \mu_0 i$

where i = Total current crossing the area bounded by closed curve.

Trace the Mind Map

First Level · Second Level · Third Level

Magnetism and Matter

Dipole moment

Current loop of area A = πr^2 carrying current i may be replaced by a magnetic dipole of dipole moment, $\mu = md = iA$

Circular Loop

$|\vec{\mu}| = iA = \frac{ev}{2\pi r} \times \pi r^2$

$= evr/2$

Revolving electron

$\vec{\mu} = \frac{-e}{2m_e}\vec{L}$

$\mu = md$

m = Magnetic charge or pole strength

d = Separation between poles

r = Radius of circular orbit

e = Charge on electron

v = Speed of electron;

L = Angular momentum

m_e = Mass of electron

Solenoid

$\mu = NIA$,

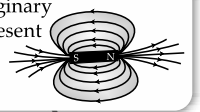
N = Number of turns

I = Current

A = Area

Magnetic field lines

Continuous imaginary lines which represent the direction of magnetic field.



Earth's magnetic field

Earth is a natural source of magnetic field having geometric north and geometric south pole

- **Declination**: Angle between magnetic meridian and geographical meridian.
- **Inclination or dip (δ)**: Angle made by Earth's magnetic field with horizontal in the magnetic direction, $\delta_{equator} = 0$, $\delta_{pole} = 90°$
- **Horizontal component**: $B_H = B\cos\theta$; B_H (at pole) = 0; B_H (at equator) is maximum

Magnetic terms

- Time period oscillating bar magnet: $T = 2\pi\sqrt{\frac{I}{MB}}$
- Intensity of magnetization: $I = \frac{M}{V}$
- Magnetic Susceptibility: $\chi = \frac{I}{H}$
- Magnetic permeability: $\mu = \mu_0(1+c_m)$
- Magnetic intensity: $H = \frac{B_0}{\mu}$

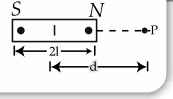
Magnetic substance

- **Para-magnetism**: Tendency to increase the magnetic field due to magnetization, *e.g. Al, Mn* ($c_m$low and –*ve*, $\mu_r > 1$)
- **Diamagnetism**: Tendency of strong magnetization in the direction of magnetic field. *e.g. Fe, Co, Ni,* ($\mu_r, \chi_m >> 1$)
- **Ferromagnetism**: Tendency to magnetise in a direction opposite to direction of magnetic field *e.g. Bi, Cu, Hg, Ni.* ($\mu_r, \chi_m < 1$)

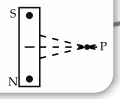
Bar magnet

Magnetic field intensity

- End–on–position $= \frac{\mu_0}{4\pi}\frac{2M}{d^3}$, $M = 2ml$, $d >>> l$



- Broadside Position, $B = \frac{\mu_0}{4\pi}\frac{M}{(d^2+l^2)^{3/2}}$, For $d >>> l$, $B = \mu_0 M/4\pi d^3$



Potential energy of a Field-Magnet System

$U_0 = U_0 - U_{90°} = -MB\cos\theta = -\vec{M}.\vec{B}$

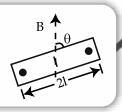
we take P.E. at $\theta = 90°$ to be zero

Torque

$\vec{\tau} = \vec{M} \times \vec{B} = MB\sin\theta$

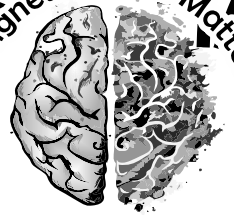
$M = 2ml$

B = Magnetic field



Electromagnets

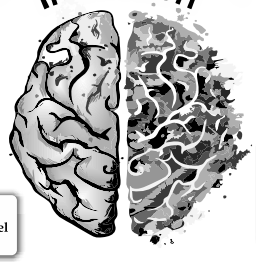
Magnet in which the magnetic field is produced by an electric current. Magnetic field disappears when current is turned off.



Trace the Mind Map

First Level · Second Level · Third Level

Electromagnetic Induction



Trace the Mind Map
First Level · Second Level · Third Level

Faraday's law of electromagnetic induction

1. Whenever magnetic flux through an area bounded by a closed conducting loop changes, an emf is produced in the loop.
2. The emf is given by $E = -d\phi/dt$ where $\phi = \int \vec{B}.\vec{ds}$ is the magnetic flux through the area.

Lenz's law

The direction of the induced current is such that it opposes the change that has induced it.

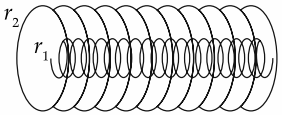
Mutual induction

$\phi = Mi$

$\frac{d\phi}{dt} = -M\frac{di}{dt}$

$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l$

$M_{21} = \mu_0 n_1 n_2 \pi r_2^2 l$



Emf induced in an AC generator, $E = NBA\omega \sin \omega t$

Induced EMF

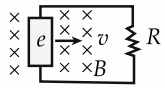
$E = -\frac{d\phi}{dt}$

Motional EMF

$E = \left|\frac{d\phi}{dt}\right| = \left|Bl\frac{dx}{dt}\right|$

$= Blv$

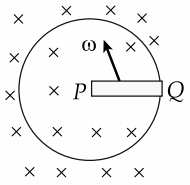
$i = Blv/(R+r)$



r = Resistance of rod moving with velocity v in uniform magnetic field $\vec{B}$

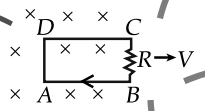
EMF induced in a rotating conductor

$E = \frac{1}{2}B\omega l^2$



Where l = Length of rod

Rectangular loop



Thermal power developed in the loop is

$P = \frac{v^2B^2l^2}{R}$

EMF induced

$E = vBl$

$i = \frac{vBl}{R}$

Magnetic force on the loop

$F = B^2l^2v/R$

= Force required to move the loop with constant velocity (v)

In 1831, Michael Faraday discovered electromagnetic induction and James Clerk Maxwell mathematically described it.

Self inductance of long solenoid

$L = \mu_0 n^2 \pi r^2 l$

n = Number of turns per unit length

ϕ = Flux = $(\mu_0 ni)\,\pi r^2$

r = Radius of each loop of solenoid

- **Growth of current in LR Circuit**

  $i = \frac{E}{R}(1 - e^{tR/L}) = i_0(1 - e^{-t/r})$

- **Decay of current**

  $i = i_0 e^{-t/r}$

- **Energy stored in an Inductor**

  $U = \frac{1}{2}Li^2$

Self induction

If we consider a solenoid of N turns, the flux through each turn, $\phi = \int \vec{B}.\vec{ds}$.

EMF induced between the ends of coil, $E = -N\frac{d}{dt}\int \vec{B}.\vec{ds}$

Induced current

$I = \frac{E}{R} = -\frac{1}{R}\frac{d\phi}{dt}$

Eddy current

It is induced when magnetic flux linked with the conductor changes.

Alternating Current

A C Circuits

R–C circuit

$i = i_0 \sin(\omega t + \phi)$

$Z = \sqrt{R^2 + X_c^2}$

$X_c = 1/\omega C$

$\tan\phi = 1/\omega CR$

$i_0 = E_0/Z$

- Power factor $\cos\phi = \dfrac{R^2}{\sqrt{R^2 + X_c^2}}$
- current leading.

L–C–R circuit

$i = i_0 \sin(\omega t \pm \phi)$

$Z = \sqrt{R^2 + (X_c - X_L)^2}$

$X = X_c - X_L$

$= \left(\dfrac{1}{\omega c} - \omega L\right)$

$\tan\phi = \left(\dfrac{1}{\omega c} - \omega L\right)/R$, $i_0 = \dfrac{E_0}{Z}$

L–R circuit

$i = i_0 \sin(\omega t + \phi)$

$Z = \sqrt{R^2 + X_L^2}$

$X_L = \omega L$

$\tan\phi = \omega L/R$

$i_0 = E_0/Z$

- power factor = R/Z
- voltage is leading

Inductive (L) circuit

$i = i_0 \sin\left(\omega t - \dfrac{\pi}{2}\right)$

Phase difference b/w $V\&I$, $\phi = \pi/2$

Power factor $\cos(\phi) = 0$

Voltage leads current by $\pi/2$

$P = 0$

L–C circuit

$i = i_0 \sin\left(\omega t \pm \dfrac{\pi}{2}\right)$

$X = X_L - X_C$

$\phi = \pi/2$

- Power factor = 0, Either voltage or current leading

Capacitive (C) circuit

$i = i_0 \sin\left(\omega t + \dfrac{\pi}{2}\right)$

$\phi = \pi/2$ or $-\pi/2$

Power factor $\cos\phi = 0$

Power $(P) = 0$

Current leads the voltage by $\pi/2$

Resistive (R) circuit

$i = i_0 \sin(\omega t)$

$\phi = 0°$

$\cos\phi = 1$

$P = V_0 I_0/2$

Current & voltage both are in same phase

Contribution

In 1883, Nikola Tesla inverted AC motor, AC generator and AC transmission technology.

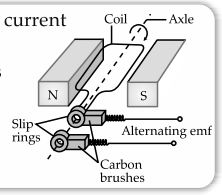
A C Generator

A device generating alternating current having elements magnet, Armature and graphite Brushes

emf induced through coil

$E = NBA\,\omega \sin\omega t$

$i = E/R = NBA\,\omega \sin\omega t/R$



Impedance

The ratio of emf applied and the current produced in an AC circuit $Z = E_0/i_0$ Ohm

Reactance

The hindrance offered by inductor or capacitor or both to the flow of AC (X_L or X_C)

AC Current

RMS value or root mean square value

$i_{rms} = i_0/\sqrt{2}$

$v_{rms} = v_0/\sqrt{2}$

Mean value or Average value

$i_{mean} = 2i_0/\pi$

$v_{rms} = 2v_0/\pi$

Peak value or Maxm value

$i_0 = \sqrt{2}\, i_{rms}$

$v_0 = \sqrt{2}\, v_{rms}$

Direction of current changes alternatively

$i = i_0 \sin\omega t$

$v = v_0 \sin\omega t$

Transformer

It is used to obtain a high AC voltage from a Low–voltage AC source or vice–versa

Efficiency of a transformer

η = output power/Input power

99% efficiency can easily achieved

Turns ratio

$\dfrac{E_s}{E_p} = \dfrac{I_p}{I_s} = \dfrac{N_s}{N_p} = K$

Power in AC Circuit

$P = E_{rms} i_{rms} \cos\phi = \dfrac{E_0}{\sqrt{2}} \times \dfrac{i_0}{\sqrt{2}} \cos\phi = \dfrac{1}{2} E_0 i_0 \cos\phi$

Trace the Mind Map

First Level · Second Level · Third Level

Electromagnetic Waves

Energy density

- Total energy per unit volume

$$U = \frac{1}{2}\varepsilon_0 E^2 + \frac{1}{2}\frac{B^2}{\mu_0}$$

- U_{av} over a long time

$$= \frac{1}{4}\varepsilon_0 E_0^2 + \frac{1}{4}\frac{B_0}{\mu_0}$$

$$= \frac{1}{2}\varepsilon_0 E_0^2 \quad [\text{as } c = \frac{E_0}{B_0} \text{ and } \mu_0\varepsilon_0 = \frac{1}{c^2}]$$

$$= \frac{1}{2}\frac{B_0^2}{\mu_0}$$

Electromagnetic spectrum

- Radio waves : $\lambda > 10^8$ nm
  Application : radio, TV signal
- Micro waves : $10^8 > \lambda > 10^5$ nm
  Application : micro wave oven, radar
- Infrared : $10^5 > \lambda > 700$ nm
  Application : night vision
- Visible light : $700 > \lambda > 400$ nm
  Application : to observe world
- UV rays : $400 > \lambda > 10$ nm
  Application : destroying bacteria
- X-rays : $10 > \lambda > 0.01$ nm
  Application : detect bone break
- γ rays : $0.01\text{nm} > \lambda$
  Application : to treat cancer

Characteristics of Electromagnetic waves

- Do not need any material medium for propagation
- Travel with speed of light $(c) = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$
- Produced by accelerated charged particles
- Transverse in nature
- Oscillating electric & magnetic fields are in phase and their ratio is constant $(c) = E_0/B_0$

History

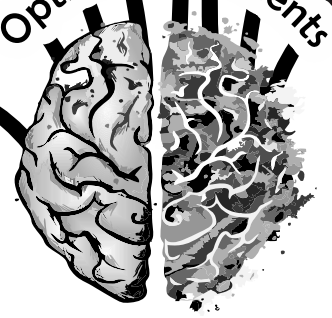
In 1886 Heinrich Hertz became the first person to transmit and receive controlled radio waves.

Definition

Combination of mutually perpendicular electric and magnetic fields is referred to as an electromagnetic wave

Trace the Mind Map
First Level · Second Level · Third Level

Ray Optics & Optical Instruments

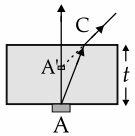


Refraction of light

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$$

$$\mu = \frac{\text{real depth}}{\text{apparent depth}}$$

$$\Delta t = \left(1 - \frac{1}{\mu}\right) t = \text{image shift}$$

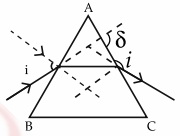


Prism

Angle of deviation $\delta = i + i' - A$

$\delta_{minimum} = 2i - A \quad [i = i']$

$\delta_{minimum} = (\mu - 1)A$, if A is small



Splitting of polychromatic light into constituent colours.

Optical Instruments

Microscope

$M = 1 + \frac{D}{f}$ [image at near point]

$M = D / f$ [image at infinity]

Compound Microscope

$M = \frac{v}{u}\left[\frac{D}{f_e}\right]$ [normal adjustment]

$M = \frac{v}{u}\left(1 + \frac{D}{f_e}\right) = -\frac{1}{f_o}\left(1 + \frac{D}{f_e}\right)$

For final image at least distance

Telescope

$M = \frac{f_o}{f_e}\left(1 + \frac{f_e}{D}\right)$ [image at near point]

$M = -\frac{fo}{fe}$ [image at infinity]

Total Internal Reflection

When ray passes from optically denser to rarer medium, if incident angle (i) greater than critical angle, entire light is then reflected back to the denser medium again, this process is called T.I.R. It is used in optical fibre.

Lens Marker's Formula

$$\frac{1}{v} - \frac{1}{u} = \frac{\mu_2 - \mu_1}{\mu_1}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \quad [If\ \mu_2 = \mu, \mu_1 = 1\ (air)]$$

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ (lens formula)

Lateral Magnification $= \frac{h_2}{h_1} = \frac{v}{u}$

Critical Angle

- Incident angle (θ_c) for which angle of refraction is 90°

i.e. $\sin\theta_c = 1/\mu$

$\theta_c = \sin^{-1}\left(\frac{1}{\mu}\right)$

When ray passes from optically denser to rarer medium.

Power of a lens

$P = \frac{1}{f}\ (m),\ P = \frac{100}{f}\ (cm)$

[For combination of lens when they are in contact]

$P = \frac{1}{f_1} + \frac{1}{f_2}$

[For combination of lens when they are separated]

$P = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

Refraction on Spherical surface

$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$

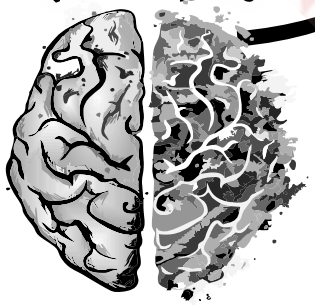
Lateral Magnification

$m = \frac{h_2}{h_1} = \frac{\mu_1 v}{\mu_2 u}$

Trace the Mind Map

First Level · Second Level · Third Level

Wave Optics



Huygens' Principle

Each point on the primary wavefront is the source of a secondary wavelets

Wave front

- Locus of all particles vibrating in some phase

For spherical wavefront

$I \propto \frac{1}{r^2}$

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

Diffraction of light by single slit

$a \sin\theta = \eta\lambda$ (dark fringe)

Linear width of central maxima

Width of central maxima $= \frac{2\lambda}{d}$

Angular width $= \frac{2D\lambda}{d}$

$d \sin\theta = (2n+1)\frac{\lambda}{2}$

(for maxima bright fringe)

Coherent source

Two sources of light are said to be coherent if the initial phase difference between the waves emitted by the sources remains constant in time, otherwise they are called incoherent source of light.

Interference of Light

Two waves superimpose to form a resultant wave of greater or lower or same amplitude.

$I = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = \beta\left(A_1 + A_2\right)^2$

- For constructive Interference, $A = A_1 + A_2$
- For destructive interference, $A = \left(A_1 \sim A_2\right)$

Young's Double Slit Experiment

Path difference

- For bright fringe $\Delta\phi = n\lambda$
- For dark fringe $\Delta\phi = \left(n - \frac{1}{2}\right)\lambda$

Fringe-width

$\beta = \frac{D}{d}\lambda$

It is the distance between two consecutive, bright or dark fringes.

Based on interference of light

Distance between n^{th} dark fringe and central fringe

$x_n = \frac{(2n-1)\lambda D}{2d}$

d = distance between slits

Distance between n^{th} bright fringe and central fringe

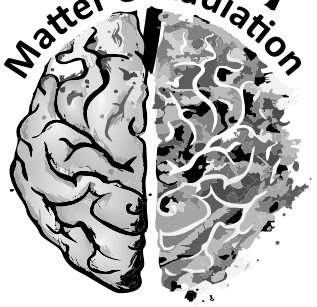
$x_n = \frac{n\lambda D}{d}$

D = distance between source and screen

Trace the Mind Map

First Level · Second Level · Third Level

Dual Nature of Matter & Radiation



Dual Nature of Radiation

- Light has both wave character as well as particle nature
- When light is of sufficiently small wavelength, it behaves as particle
- Light particles having definite energy and definite linear momentum are called "photons"
  Energy of each photon $= h\nu = hc/\lambda$
  Momentum of each photon $= h/\lambda = E/c$

Contribution

Einstein, after an average academic career put forward quantum theory of light in 1905 while working as a grade III technical officer in a patent office.

de-Broglie relation

All matter can exhibit wave–like behaviour *e.g.*, beam of electrons can be diffracted like a water wave

Matter waves

$\lambda = h/p$

λ = wavelength associated with particle or de-Broglie wavelength

p = momentum

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2\,m\;K_{max}}}$$

Photoelectric Effect

- When light of sufficient small wavelength is incident on metal surface, electrons are ejected from the metal, the phenomenon is called photoelectric effect.
- Ejected electrons are called photoelectrons
- Minimum energy equal to work function (ϕ) must be given to an electron so as to bring it out of the metal

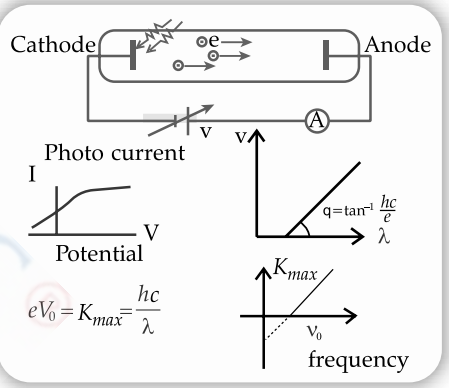
Einstein's Photoelectric equation

- If $\lambda = \lambda_0 = hc/\phi$
  $K_{max} = 0$, *i.e.*
  Electron may just come out onto the surface
- If $\lambda > \lambda_0$
  i.e. $E < \phi$
  no electron will come out
- If $\lambda \le \lambda_0$.
  Photoelectric effect takes place
- λ_0 = depends on metal used

- $K_{max} = E - \phi = eV_0$
  $= \frac{hc}{\lambda} - \phi$, V_0 = stopping potential
  K_{max} = maximum kinetic energy of ejected electrons

Here, $\lambda_0 = hc/\phi$
λ_0 = Threshold Wavelength
$\lambda_0 = c/\nu_0 = \phi/h$
ν_0 = Threshold frequency
$K_{max} = \lambda(\nu - \nu_0)$

Hertz and Lenard's Observation



Trace the Mind Map

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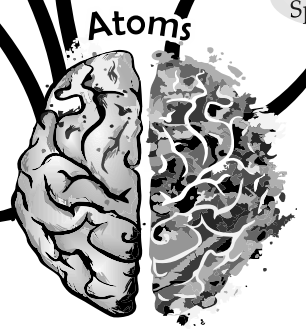
Atoms



Bohr Model

- Electron revolves around the nucleus in stationary orbits.
- Angular momentum of electron
  $mvr_n = n \times \frac{h}{2\pi}$ where n is an integer
  It is also known as principle Quantum Number.
- It explains spectrums of hydrogen or hydrogen like [He^+, Li^{++}] atoms.

Postulates

- Fails to explain spectrum of complex atoms/ions of multi electron system.
- Doesn't explain Zeeman's and Stark's effect.

Limitations

Bohr's orbit

$$r_n = \frac{\varepsilon_0 h^2}{\pi m e^2}\left(\frac{n^2}{Z}\right) = 0.53\ \frac{n^2}{Z}\text{ Å}$$

Radius of nth

Velocity of electron in n^{th} Bohr's orbit

$$v_n = \frac{e^2}{2\varepsilon_0 h}\left(\frac{Z}{n}\right) = 2.2 \times 10^6\ \frac{Z}{n}\text{ m/s}$$

Potential Energy

$$U_n = -\frac{kZe^2}{r_n} = \frac{-me^4}{4\varepsilon_0^2 h^2}\left(\frac{Z^2}{n^2}\right) = \frac{-27.2\,Z^2}{n^2}\,eV$$

Kinetic Energy

$$E_k = \frac{kZe^2}{2r_n} = \frac{me^4}{8\varepsilon_0^2 h^2}\frac{Z^2}{n^2} = \frac{13.6^2}{n^2}Z^2\,eV$$

Total Energy

$$E = U_n + E_k = -\frac{KZe^2}{2r_n} = \frac{-13.6Z^2}{n^2}\text{ eV} = \frac{U_n}{2} = -E_K$$

α – particle scattering experiment

- α- particle bombarded on thin gold foil
- Most of α– particles passed undeviated or with a small angle
- 1 out of 8000 α– particles were deflected by scattering angle

Impact parameter

$$b = \frac{Ze^2 \cot\theta/2}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)}$$

Rutherford's Model

Drawbacks

- Doesn't explain the stability of atom
- Doesn't explain the atomic spectra

Postulates

- Atoms have a central, massive, positively charged core called nucleus around which electrons revolve.
- Size of nucleus ≈ 1 fermi = 10^{-15}m

Contribution

In 1898, J.J Thomson proposed the first model of atom known as plum-pudding model.
In 1911, Rutherford prepared planeting model of atom.
In 1913, Niels Bohr prepared a model of Hydrogen atom based on quantum theory.

Hydrogen Spectrum

- Hydrogen gas heated in a sealed tube emits radiation when paused through prism components of different wavelength appear.
- Wavelength in each series given by
  $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]\ n_f > n_i$
- Lyman series [U.V. region]
  $n_i = 1,\ n_f = 2,3,4\ldots.$
  $\lambda_{min} = 912$ Å , $\lambda_{max} = 1216$ Å
- Balmer series [visible region]
  $n_i = 2$ $n_f = 3, 4, 5\ldots..$
  $\lambda_{min} = 3648$ Å , $\lambda_{max} = 6563$ Å
- Paschan series [IR region]
  $n_i = 3$ $n_f = 4, 5, 6\ldots..$
  $\lambda_{min} = 8208$ Å , $\lambda_{max} = 18761$ Å
- Brackett series [IR region]
  $n_i = 4$ $n_f = 5, 6, 7\ldots$
  $\lambda_{min} = 14592$ Å $\lambda_{max} = 40533$ Å
- Pfund [IR region]
  $n_i = 5$ $n_f = 6, 7, 8\ldots\ldots$
  $\lambda_{min} = 23850$ Å $\lambda_{max} = 74618$ Å

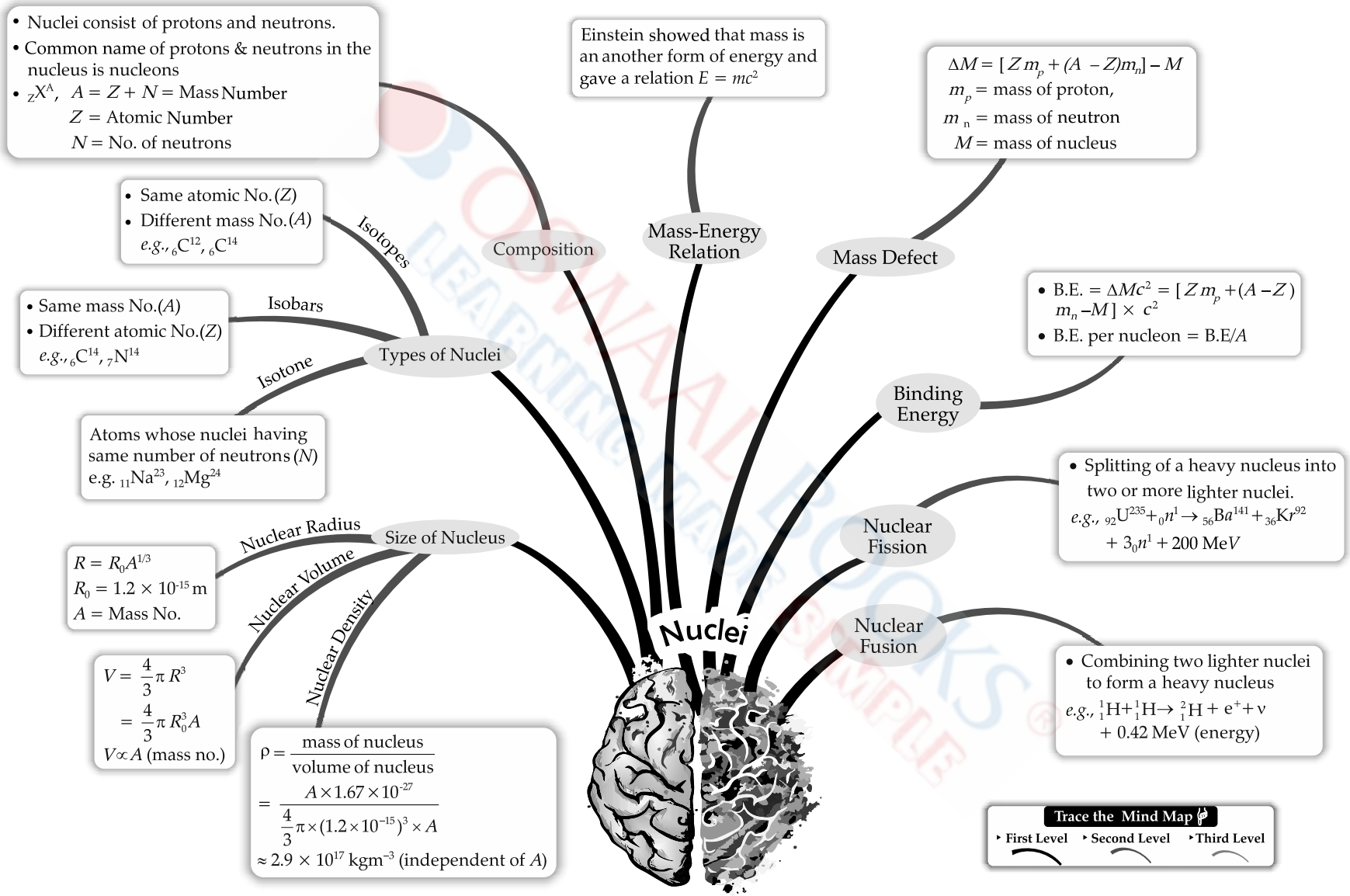
Energy Level

Energy of electron in each stationary orbits is
Given by $E_n = -13.6\frac{Z^2}{n^2}$ eV
Where $n = 1,2,3\ldots.$
Z = atomic number of atom

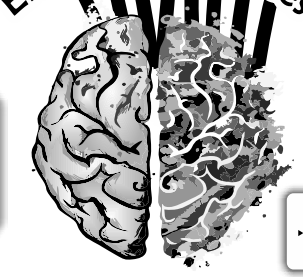
- These stationary energy orbits are also called energy levels.
- When electron jumps from higher energy level to lower energy level, it releases energy.

$$\Delta E = E_f - E_i = 13.6\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]Z^2\text{eV}$$

Trace the Mind Map
First Level · Second Level · Third Level


Nuclei
Composition
• Nuclei consist of protons and neutrons.
• Common name of protons & neutrons in the nucleus is nucleons
• $_ZX^A$, $A = Z + N$ = Mass Number
Z = Atomic Number
N = No. of neutrons
Isotopes
• Same atomic No. (Z)
• Different mass No. (A)
e.g., $_6C^{12}$, $_6C^{14}$
Isobars
• Same mass No. (A)
• Different atomic No. (Z)
e.g., $_6C^{14}$, $_7N^{14}$
Isotone
Atoms whose nuclei having same number of neutrons (N)
e.g. $_{11}Na^{23}$, $_{12}Mg^{24}$
Types of Nuclei
Mass-Energy Relation
Einstein showed that mass is an another form of energy and gave a relation $E = mc^2$
Mass Defect
$\Delta M = [Z m_p + (A - Z)m_n] - M$
m_p = mass of proton,
m_n = mass of neutron
M = mass of nucleus
Binding Energy
• B.E. = $\Delta Mc^2 = [Z m_p + (A - Z) m_n - M] \times c^2$
• B.E. per nucleon = B.E/A
Nuclear Fission
• Splitting of a heavy nucleus into two or more lighter nuclei.
e.g., $_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + 200$ MeV
Nuclear Fusion
• Combining two lighter nuclei to form a heavy nucleus
e.g., $_1^1H + {}_1^1H \rightarrow {}_1^2H + e^+ + \nu + 0.42$ MeV (energy)
Size of Nucleus
Nuclear Radius
$R = R_0A^{1/3}$
$R_0 = 1.2 \times 10^{-15}$ m
A = Mass No.
Nuclear Volume
$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$
$V \propto A$ (mass no.)
Nuclear Density
$\rho = \frac{\text{mass of nucleus}}{\text{volume of nucleus}} = \frac{A \times 1.67 \times 10^{-27}}{\frac{4}{3}\pi \times (1.2 \times 10^{-15})^3 \times A}$
$\approx 2.9 \times 10^{17}$ kgm^{-3} (independent of A)
Trace the Mind Map
First Level
Second Level
Third Level

Electronic Devices



Trace the Mind Map

First Level · Second Level · Third Level

A range of energies associated with the quantum states of electrons in a crystalline solid

- **Valance Band**: The energy band which are completely filled with electron at OK.
- **Conduction Band**: The bands with higher energy above the valence band
  

- **Band gap or forbidden gap**: The difference between the highest energy in a valence band and lowest energy in the next higher band.

Contribution

In 1927, Walter Heitler and Fritz London discovered bands

Classification of metals, Semiconductor & Insulator on the basis of bond theory

- **Conductor**
  - → Eg = 0 or least
  - → Density of charge carriers is very high
  - (For electrons e) = 9×10^{23} m^{-3} for
  - For Hole (h) = 0 m^{-3} (in case of copper)
  - $\frac{|C.B.|}{|V.B.|} E_g = 0$
- **Semiconductor**
  - → Eg = 0.72 eV for Ge
  - ≈ 1.1ev for Si
  - $0 < E_g <$ Insulator
  - → very low (e)
    - For– n–type $= 7 \times 10^{15} m^{-3}$ for *Si* doped with P
      

    - For– p–type $= 1 \times 10^{9} m^{-3}$ for Si doped with Al
- **Insulators**
  - → Eg = very high ≈ 7eV for diamond
  - → negligible ≈ 0
    

Intrinsic Semiconductor

- Pure semiconductor
- Charge carrier concentration $n_i = n_e = n_h$
- $I = n_e + n_h$
- e.g., Si (Silicon)

Extrinsic Semiconductor

Impure or doped semiconductor

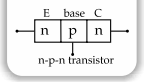
- **p–type Semiconductor**
  - Si or Ge doped with pentavalent (P,As, Sb) element
  - Electrons are majority carriers
  - Holes are minority carriers
- **n–type Semiconductor**
  - Si or Ge doped with trivalent (B, Al) element
  - Electrons are minority carriers
  - Holes are majority carriers

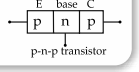
Semiconductor Diode

- **p–n junction Diode**: Device made by a close contact of n– type and p–type semiconductors
  - **Forward Biased**
    - +ve terminal to P-side
    - –ve to N–side
    - diffusion current increases
    - depletion layer reduced
  - **Reverse Biased**
    - –ve terminal to P– side
    - +ve terminal to N–Side
    - diffusion current decreases
    - depletion layer increases
- **Light emitting Diode / LED**: used in T.V. or electronic gadgets.
- **Photo Diode**: is a (p–n) junction whose function is controlled by the light allowed to fall on it.
- **Zener Diode**: used as a voltage regulator

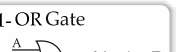
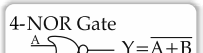
Transistor

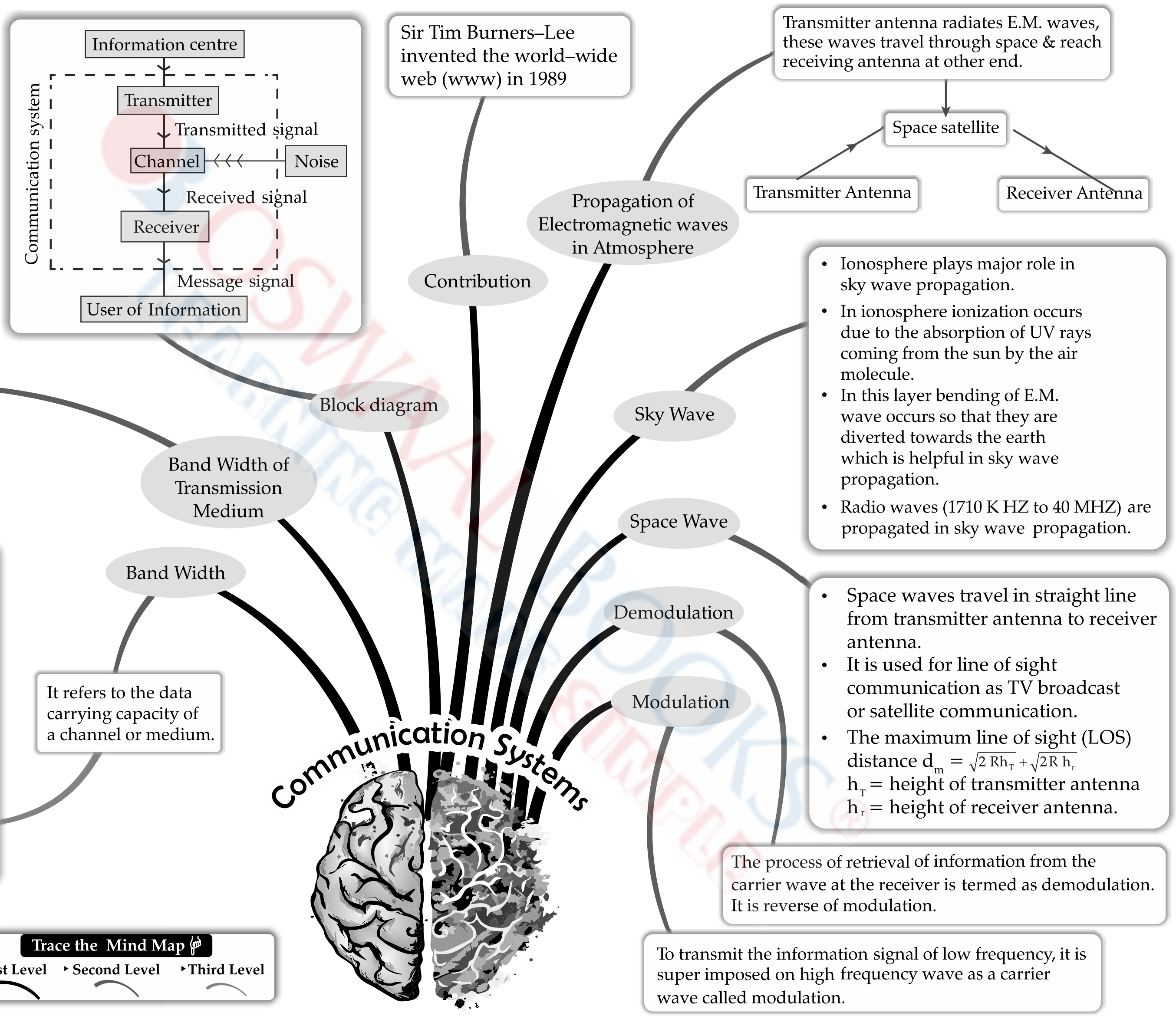
is a three terminal device

- **n-p-n transistor**
  $I_E = I_B + I_c$
  $\alpha = I_c / I_E$
  $\beta = I_c / I_B$
  $\beta = \frac{\alpha}{1-\alpha}$
  

- **p-n-p transistor**
  - In normal operation emitter, base junction is always forward biased
    

Logic Gates

- 1- OR Gate 
- 2-AND Gate 
- 3- NOT Gate 
- 4-NOR Gate 
- 5-NAND Gate 



Signal	Band width
speech/voice	300 Hz – 3100 Hz
Music signals	20 Hz – 20 kHz
Video signal	4.2 MHz
TV signals (both voice & video)	6 MHz

Signal	Band width
Mobile phone	896 – 901 M Hz 840 – 935 M Hz
Satellite	5.9 – 6.4 G Hz
Communication	3.7 – 4.2 G Hz
AM	540 – 1600 kHz
FM	88 – 108 M Hz
TV (V HF)	54 – 72 M Hz
(V HF)	76 – 216 M Hz 420 – 890 M Hz