# केंद्रीय विद्यालय संगठन
# KENDRIYA VIDYALAYA SANGATHAN
## मुंबई संभाग    MUMBAI REGION

G20
भारत 2023 INDIA

तत् त्वं पूषन् अपावृणु
केन्द्रीय विद्यालय संगठन

आज़ादी का
अमृत महोत्सव

सत्र / SESSION-
2023-2024

## कक्षा - बारहवीं
## CLASS -XII

OBJECTIVE

## मास्टर कार्ड
## MASTER CARD
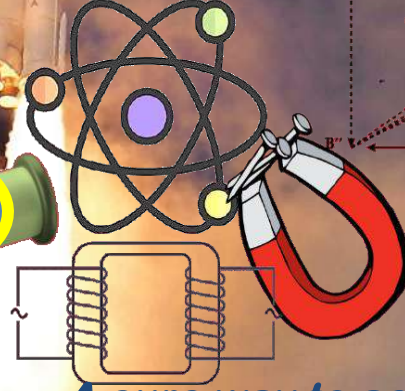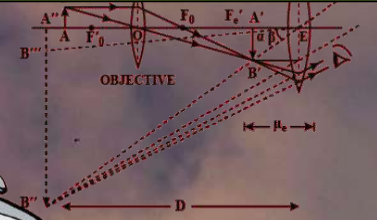
*A sure way to achieve the Goal*

## भौतिक विज्ञान
## PHYSICS

**केंद्रीय विद्यालय संगठन, मुंबई संभाग**
**Kendriya Vidyalaya Sangathan, Regional Office, Mumbai**
**आई आई टी   कैंपस , पवई , मुंबई    IIT Campus, Powai, Mumbai-400076**
**दूरभाष Tel:-(022) 2572 8060 , 2572 2328,2572 1614**
**वेबसाइट Website- https://romumbai.kvs.gov.in**

# हमारे संरक्षक
# OUR PATRONS

श्रीमती निधि पांडे, आईआईएस     Mrs. NIDHI PANDEY, IIS
आयुक्त     COMMISSIONER
केंद्रीय विद्यालय संगठन     KENDRIYA VIDYALAYA SANGATHAN

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पाठ्यक्रम निदेशक     COURSE DIRECTOR
प्राचार्य के वि ओझर     PRINCIPAL KV OJHAR

श्री एम. गोपाला रेड्डी     Mr. M.GOPALA REDDY
संसाधक     RESOURCE PERSON
स्नात्तकोत्तर शिक्षक भौतिक विज्ञान     PGT PHYSICS
के वि आर एच ई पुणे     KV RHE PUNE

## समीक्षा, संपादन एवं संकलन
## REVIEW, EDITING & COMPILATION

| समग्र समीक्षक का नाम<br>NAME OF OVERALL REVIEWER | पद<br>DESIGNATION | केंद्रीय विद्यालय का नाम<br>NAME OF KV |
|---|---|---|
| Mr. M.GOPALA REDDY | PGT PHYSICS | KV RHE PUNE |

| सामग्री<br>CONTENT | संपादक/ संकलक का नाम एवं पद<br>NAME AND DESIGNATION OF EDITOR/ COMPILER | केंद्रीय विद्यालय का नाम<br>NAME OF KV |
|---|---|---|
| STUDY MATERIAL<br>& MASTER CARD<br>COVER PAGE DESIGN | Mr. PREM PRAKASH SINGH<br>PGT PHYSICS | KVIIT POWAI, MUMBAI |

## संकुल वॉर अध्ययन सामग्री निर्माता टीम
## CLUSTER WISE TEAM OF PREPARERES

| पाठ<br>Ch.<br>No. | पाठ का नाम<br>NAME OF CHAPTER | कोर सदस्य का नाम<br>NAME OF CORE MEMBER | संकुल का नाम<br>NAME OF CLUSTER |
|---|---|---|---|
| 1.<br>2. | ELECTRIC CHARGES AND FIELDS<br>ELECTRIC POTENTIAL AND CAPACITANCE | Mr. VILAS PAWAR<br>PGT PHYSICS<br>K. V. No. 2, AFS Pune | PUNE-2 |

| क्र. सं<br>S. No. | सदस्य का नाम<br>NAME OF MEMBERS | पद<br>DESIGNATION | केंद्रीय विद्यालय का नाम<br>NAME OF KV |
|---|---|---|---|
| 1. | Mr. R. N. TIWARI | PGT PHYSICS | K.V. No. 1, AFS Lohegaon,Pune |
| 2. | Mrs. RICHA SHUKLA | PGT PHYSICS | K.V. 9 BRD, PUNE |
| 3. | Mrs. SEEMA BUDHIRAJA | PGT PHYSICS | K.V. 9 BRD, PUNE |
| 4. | Mr. PRAMOD KUMAR | PGT PHYSICS | K.V. BSF, Chakur |
| 5. | Mr. ASHOK KUMAR GUPTA | PGT PHYSICS | K.V. Ganeshkhind, Pune |
| 6. | Dr. SANDIP KAMAT | PGT PHYSICS | K.V. DIAT, Girinagar PUNE |
| 7. | Mr. PRASHANT C. KULKARNI | PGT PHYSICS | K.V. Solapur |
| 8. | Mr. RAJESH KUMAR | PGT PHYSICS | K.V. BEG Pune |
| 9. | Ms. VAISHALI JAISWAL | PGT PHYSICS | K.V. No. 2 AFS Pune |

## संकुल वॉर अध्ययन सामग्री निर्माता टीम
## CLUSTER WISE TEAM OF PREPARERES

| पाठ Ch. No. | पाठ का नाम NAME OF CHAPTER | कोर सदस्य का नाम NAME OF CORE MEMBER | संकुल का नाम NAME OF CLUSTER |
|---|---|---|---|
| 3. | CURRENT ELECTRICITY | Mr. M.GOPALA REDDY PGT PHYSICS KV RHE PUNE | PUNE-1 |

| क्र. सं S. No. | सदस्य का नाम NAME OF MEMBERS | पद DESIGNATION | केंद्रीय विद्यालय का नाम NAME OF KV |
|---|---|---|---|
| 1. | Ms. MINTA MEHRA | PGT PHYSICS | KV LONAVALA |
| 2. | Mr. SONAWANE SACHIN | PGT PHYSICS | KV ARMY AREA PUNE |
| 3. | Mr. SHASHIKANT | PGT PHYSICS | KV ARMY AREA PUNE |
| 4. | Mrs. K. SHANTHI | PGT PHYSICS | KV CME Pune |
| 5. | Ms. NEELAM | PGT PHYSICS | KV SC , Pune |
| 6. | Mrs PARVATHA VARTHINI GIRI | PGT PHYSICS | KV SC , Pune |

| पाठ Ch. No. | पाठ का नाम NAME OF CHAPTER | कोर सदस्य का नाम NAME OF CORE MEMBER | संकुल का नाम NAME OF CLUSTER |
|---|---|---|---|
| 4. 5. | MOVING CHARGES AND MAGNETISM MAGNETISM AND MATTER | Dr. RAVINDRA KAMBALE PGT PHYSICS K. V. KOLIWADA | MUMBAI -1 |

| क्र. सं S. No. | सदस्य का नाम NAME OF MEMBERS | पद DESIGNATION | केंद्रीय विद्यालय का नाम NAME OF KV |
|---|---|---|---|
| 1. | Mrs. C. MANJULA | PGT PHYSICS | KV IIT POWAI |
| 2. | Mrs. SAROJANI KUMARI | PGT PHYSICS | KV INS HAMLA MUMBAI |
| 3. | Mrs. MANJU RANI RAWAT | PGT PHYSICS | KV NO 2 COLABA |
| 4. | Mr. AKANSHA KHARADIYA | PGT PHYSICS | KV NO 2 COLABA |
| 5. | Mr. M K SINGH | PGT PHYSICS | KV NO 1 COLABA |
| 6. | Mr. S B AGARWAL | PGT PHYSICS | KV BHANDUP |
| 7. | Mrs. USHA SANKARASUBRAMANIAN | PGT PHYSICS | KV BHANDUP |
| 8. | Mr. PREM PRAKASH SINGH | PGT PHYSICS | KV IIT POWAI |
| 9. | Mrs. VINEETA SMRITI | PGT PHYSICS | KV KOLIWADA |

# संकुल वॉर अध्ययन सामग्री निर्माता टीम
# CLUSTER WISE TEAM OF PREPARERES

| पाठ Ch. No. | पाठ का नाम NAME OF CHAPTER | कोर सदस्य का नाम NAME OF CORE MEMBER | संकुल का नाम NAME OF CLUSTER |
|---|---|---|---|
| 6. 7. | ELECTROMAGNETIC INDUCTION ALTENATING CURRENT | Mr. SANTOSH V. SONTAKKE PGT PHYSICS KV AJNI NAGPUR | NAGPUR |

| क्र. सं S. No. | सदस्य का नाम NAME OF MEMBERS | पद DESIGNATION | केंद्रीय विद्यालय का नाम NAME OF KV |
|---|---|---|---|
| 1. | Mr. RAHUL SHIRBHATE | PGT PHYSICS | KV VSN NAGPUR |
| 2. | Ms. VIDYA ARORA | PGT PHYSICS | KV VSN NAGPUR |
| 3. | Mr. C.R. RAMTEKE | PGT PHYSICS | KV VSN NAGPUR |
| 4. | Mr. KAMLESH DHARNE | PGT PHYSICS | KV KAMPTEE |
| 5. | Mr. SANJAY CHANDAN | PGT PHYSICS | KV KAMPTEE |
| 6. | Mr. PANKAJ DESHMUKH | PGT PHYSICS | KV WCL NEW MAJRI |
| 7. | Mr. G.G. BHAGAT | PGT PHYSICS | KV YAVATMAL |
| 8. | Mr. B R JAGTAP | PGT PHYSICS | KV OF CHANDA |
| 9. | Mr. KAILASH SHINGADE | PGT PHYSICS | KV OF AMBAJHARI |

| पाठ Ch. No. | पाठ का नाम NAME OF CHAPTER | कोर सदस्य का नाम NAME OF CORE MEMBER | संकुल का नाम NAME OF CLUSTER |
|---|---|---|---|
| 8. 11. | ELECTROMAGNETIC WAVES DUAL NATURE OF RADIATION AND MATTER | Ms. NEHA SHARMA PGT PHYSICS KV INS MANDOVI ,GOA | GOA |

| क्र. सं S. No. | सदस्य का नाम NAME OF MEMBERS | पद DESIGNATION | केंद्रीय विद्यालय का नाम NAME OF KV |
|---|---|---|---|
| 1. | Mr. SHASHI PAUL | PGT PHYSICS | KV PONDA,GOA |

## संकुल वॉर अध्ययन सामग्री निर्माता टीम
## CLUSTER WISE TEAM OF PREPARERES

| पाठ Ch. No. | पाठ का नाम NAME OF CHAPTER | कोर सदस्य का नाम NAME OF CORE MEMBER | संकुल का नाम NAME OF CLUSTER |
|---|---|---|---|
| 9. 10. | RAY OPTICS AND OPTICAL INSTRUMENTS WAVE OPTICS | Mr. GANESH AHIRRAO PGT PHYSICS KV ONGC PANVEL | MUMBAI -2 |

| क्र. सं S. No. | सदस्य का नाम NAME OF MEMBERS | पद DESIGNATION | केंद्रीय विद्यालय का नाम NAME OF KV |
|---|---|---|---|
| 1. | Mrs. RAZIYA PARAKKAL | PGT PHYSICS | KV AFS THANE |
| 2. | Mrs. R. KARPAGAMBAL | PGT PHYSICS | KV ONGC PANVEL |
| 3. | Mrs. NEELOPHAR SHEIKH | PGT PHYSICS | KV AMBARNATH |
| 4. | Mr. MANDEEP | PGT PHYSICS | KV NAD KARANJA |
| 5. | Mrs. S. SUGANDI | PGT PHYSICS | KV MANKHURD |
| 6. | Mrs. SWATI CHHABRA | PGT PHYSICS | KV AFS THANE |
| 7. | Mrs. GIRIJA A. | PGT PHYSICS | KV AMBARNATH |
| 8. | Mrs. SAVITA RUHELA | PGT PHYSICS | KV ONGC PANVEL |

| पाठ Ch. No. | पाठ का नाम NAME OF CHAPTER | कोर सदस्य का नाम NAME OF CORE MEMBER | संकुल का नाम NAME OF CLUSTER |
|---|---|---|---|
| 12. 13. | ATOMS NUCLEI | Mr. SUNIL JADHAV PGT PHYSICS KV Cantt. Aurangabad | AHMEDNAGAR |

| क्र. सं S. No. | सदस्य का नाम NAME OF MEMBERS | पद DESIGNATION | केंद्रीय विद्यालय का नाम NAME OF KV |
|---|---|---|---|
| 1. | Mrs. Varsha Kadam | PGT PHYSICS | KV No1 Ahmednagar |
| 2. | Mr. Avinash Ingle | PGT PHYSICS | KV MIRC Ahmednagar |
| 3. | Mr. PULGAM RAMESH | PGT PHYSICS | KV SCR NANDED |

## संकुल वॉर अध्ययन सामग्री निर्माता टीम
## CLUSTER WISE TEAM OF PREPARERES

| पाठ<br>Ch.<br>No. | पाठ का नाम<br>NAME OF CHAPTER | कोर सदस्य का नाम<br>NAME OF CORE MEMBER | संकुल का नाम<br>NAME OF CLUSTER |
|---|---|---|---|
| 14. | SEMICONDUCTOR MATERIAL: ELECTRONIC DEVICES | Mr. ASHOK KUMAR<br>PGT PHYSICS<br>KV OF VARANGAON BHUSAWAL | NASHIK |

| क्र. सं<br>S. No. | सदस्य का नाम<br>NAME OF MEMBERS | पद<br>DESIGNATION | केंद्रीय विद्यालय का नाम<br>NAME OF KV |
|---|---|---|---|
| 1. | Mrs. UJJWALA CHANDURKAR | PGT PHYSICS | KV NRC NASHIK |
| 2. | Mrs. YOGITA VISHAL THAKUR | PGT PHYSICS | KV ISP NASHIK |
| 3. | Mr. M.B. MALI | PGT PHYSICS | KV AFS OJHAR NASHIK |
| 4. | Mrs. PRATIBHA S.B. | PGT PHYSICS | KV AFS OJHAR NASHIK |

इकाई वॉर अध्ययन सामग्री समीक्षकर्ता टीम
# UNIT WISE TEAM OF REVIEW TEAM

| इकाई सं. Unit No. | इकाई का नाम Name of the Unit | अध्ययन सामग्री निर्माता संकुल Name of the Cluster material prepared | अध्ययन सामग्री समिक्षकर्ता संकुल Name of the cluster reviewing the material | संकुल के प्रभारी का नाम Name of the core in charge |
|---|---|---|---|---|
| 1 | Electrostatics | Pune – 2 | Nashik Mr Ashok Kumar | Mr. Vilas Pawar (KV No.2 AFS) |
| 2 | Current Electricity | Pune – 1 | Goa Ms Neha Sharma | Mr. M G Reddy (KV RHE) |
| 3 | Magnetic Effects of Current and Magnetism | Mumbai - 1 | Pune – 2 Mr. Vilas Pawar | Mr. Ravindra Kamble (KVKoliwada) |
| 4 | Electromagnetic Induction and Alternating Currents | Nagpur | Mumbai –2 Mr. Ganesh Ahirrao | Mr. Santosh V Sontakke (KV Ajni Nagpur) |
| 5 | Electromagnetic waves | Goa | Ahmednagar Mr. Sunil Jadhav | Ms. Neha Sharma (KV INS Mandovi) |
| 6 | Optics | Mumbai - 2 | Nagpur Mr. Santosh V Sontakke | Mr. Ganesh Ahirrao (KV ONGC Panvel) |
| 7 | Dual Nature of Radiation and Matter | Goa | Ahmednagar Mr. Sunil Jadhav | Ms. Neha Sharma (KV INS Mandovi) |
| 8 | Atoms and Nuclei | Ahmednagar | Mumbai – 1 Mr. Ravindra Kamble | Mr. Sunil Jadhav (KV CANT Aurangabad) |
| 9 | Electronic Devices | Nashik | Pune – 1 M.G Reddy | Mr. Ashok Kumar (KV OF Varangaon) |

# विषय सूची
# INDEX

# CLASS XII (2023-24) PHYSICS (THEORY)

**Time: 3 hrs.**                                                              **Max Marks: 70**

| | | No. of Periods | Marks |
|---|---|---|---|
| **Unit–I** | **Electrostatics** | 26 | |
| | Chapter–1: Electric Charges and Fields | | |
| | Chapter–2: Electrostatic Potential and Capacitance | | 16 |
| **Unit-II** | **Current Electricity** | 16 | |
| | Chapter–3: Current Electricity | | |
| **Unit-III** | **Magnetic Effects of Current and Magnetism** | 25 | |
| | Chapter–4: Moving Charges and Magnetism | | |
| | Chapter–5: Magnetism and Matter | | 17 |
| **Unit-IV** | **Electromagnetic Induction and Alternating Currents** | | |
| | Chapter–6: Electromagnetic Induction | 24 | |
| | Chapter–7: Alternating Current | | |
| **Unit–V** | **Electromagnetic Waves** | 04 | |
| | Chapter–8: Electromagnetic Waves | | |
| **Unit–VI** | **Optics** | | 18 |
| | Chapter–9: Ray Optics and Optical Instruments | 30 | |
| | Chapter–10: Wave Optics | | |
| **Unit–VII** | **Dual Nature of Radiation and Matter** | 8 | |
| | Chapter–11: Dual Nature of Radiation and Matter | | |
| **Unit–VIII** | **Atoms and Nuclei** | 15 | 12 |
| | Chapter–12: Atoms | | |
| | Chapter–13: Nuclei | | |
| **Unit–IX** | **Electronic Devices** | | |
| | Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits | 10 | 7 |
| | **Total** | 160 | 70 |

## COURSE STRUCTURE    2023-2024

**Unit I: Electrostatics**                                                                          **26 Periods**
**Chapter–1: Electric Charges and Fields**
 Electric charges, Conservation of charge, Coulomb's law-force between two- point charges, forces between multiple charges; superposition principle and continuous charge distribution. Electric field, electric field due to a point charge, electric field lines, electric dipole, electric field due to a dipole, torque on a dipole in uniform electric field. Electric flux, statement of Gauss's theorem and its applications to find field due to infinitely long straight wire, uniformly charged infinite plane sheet and uniformly charged thin spherical shell (field inside and outside).

**Chapter–2: Electrostatic Potential and Capacitance**
Electric potential, potential difference, electric potential due to a point charge, a dipole and system of charges; equipotential surfaces, electrical potential energy of a system of two-point charges and of electric dipole in an electrostatic field. Conductors and insulators, free charges and bound charges inside a conductor. Dielectrics and electric polarization, capacitors and capacitance, combination of capacitors in series and in parallel, capacitance of a parallel plate capacitor with and without dielectric medium between the plates, energy stored in a capacitor (no derivation, formulae only).

 **Unit II: Current Electricity**                                                               **18 Periods**
**Chapter–3: Current Electricity**
Electric current, flow of electric charges in a metallic conductor, drift velocity, mobility and their relation with electric current; Ohm's law, V-I characteristics (linear and non-linear), electrical energy and power, electrical resistivity and conductivity, temperature dependence of resistance, Internal resistance of a cell, potential difference and emf of a cell, combination of cells in series and in parallel, Kirchhoff's rules, Wheatstone bridge.

**Unit III: Magnetic Effects of Current and Magnetism**                      **25 Periods**
**Chapter–4: Moving Charges and Magnetism**
 Concept of magnetic field, Oersted's experiment. Biot - Savart law and its application to current carrying circular loop. Ampere's law and its applications to infinitely long straight wire. Straight solenoid (only qualitative treatment), force on a moving charge in uniform magnetic and electric fields. Force on a current-carrying conductor in a uniform magnetic field, force between two parallel current-carrying conductors-definition of ampere, torque experienced by a current loop in uniform magnetic field; Current loop as a magnetic dipole and its magnetic dipole moment, moving coil galvanometer- its current sensitivity and conversion to ammeter and voltmeter.

**Chapter–5: Magnetism and Matter**
Bar magnet, bar magnet as an equivalent solenoid (qualitative treatment only), magnetic field intensity due to a magnetic dipole (bar magnet) along its axis and perpendicular to its axis (qualitative treatment only), torque on a magnetic dipole (bar magnet) in a uniform magnetic field (qualitative treatment only), magnetic field lines. Magnetic properties of materials- Para-, dia- and ferro - magnetic substances with examples, Magnetization of materials, effect of temperature on magnetic properties.
**Unit IV: Electromagnetic Induction and Alternating Currents**            **24 Periods**
**Chapter–6: Electromagnetic Induction**
 Electromagnetic induction; Faraday's laws, induced EMF and current; Lenz's Law, Self and mutual induction.

**Chapter–7: Alternating Current**
Alternating currents, peak and RMS value of alternating current/voltage; reactance and impedance; LCR series circuit (phasors only), resonance, power in AC circuits, power factor, wattless current. AC generator, Transformer.

**Unit V: Electromagnetic waves**                      **04 Periods**
**Chapter–8: Electromagnetic Waves**
Basic idea of displacement current, Electromagnetic waves, their characteristics, their transverse nature (qualitative idea only). Electromagnetic spectrum (radio waves, microwaves, infrared, visible, ultraviolet, X-rays, gamma rays) including elementary facts about their uses.

**Unit VI: Optics**                                  **30 Periods**
**Chapter–9: Ray Optics and Optical Instruments**
**R**ay Optics: Reflection of light, spherical mirrors, mirror formula, refraction of light, total internal reflection and optical fibers, refraction at spherical surfaces, lenses, thin lens formula, lens maker's formula, magnification, power of a lens, combination of thin lenses in contact, refraction of light through a prism. Optical instruments: Microscopes and astronomical telescopes (reflecting and refracting) and their magnifying powers.

**Chapter–10: Wave Optics**
Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width (No derivation final expression only), coherent sources and sustained interference of light, diffraction due to a single slit, width of central maxima (qualitative treatment only).

**Unit VII: Dual Nature of Radiation and Matter**           **08 Periods**
**Chapter–11: Dual Nature of Radiation and Matter**
 Dual nature of radiation, Photoelectric effect, Hertz and Lenard's observations; Einstein's photoelectric equation-particle nature of light. Experimental study of photoelectric effect Matter waves-wave nature of particles, de-Broglie relation.

**Unit VIII: Atoms and Nuclei**                     **15 Periods**
**Chapter–12: Atoms**
Alpha-particle scattering experiment; Rutherford's model of atom; Bohr model of hydrogen atom, Expression for radius of nth possible orbit, velocity and energy of electron in nth orbit, hydrogen line spectra (qualitative treatment only).
**Chapter–13: Nuclei**
Composition and size of nucleus, nuclear force Mass-energy relation, mass defect; binding energy per nucleon and its variation with mass number; nuclear fission, nuclear fusion.

**Unit IX: Electronic Devices 10 Periods**
**Chapter–14: Semiconductor Electronics:**
Materials, Devices and Simple Circuits Energy bands in conductors, semiconductors and insulators (qualitative ideas only) Intrinsic and extrinsic semiconductors- p and n type, p-n junction Semiconductor diode - I-V characteristics in forward and reverse bias, application of junction diode -diode as a rectifier

# MIND MAP- Chapter -1 ELECTRIC CHARGES AND FIELDS

**Electric Field ($\overrightarrow{E}$)**

**Gauss Theorem of Electrostatics**

Force acting per unit charge

* Vector
* SI unit N/C or V/m

* $\vec{E} = \vec{F}/q$ , F= Force q=charge
* Field at distance r from q

$E = 1/4\pi\varepsilon_0 \ q/r^2$

* Field due to system of charge

$\vec{E} = E_1 + E_2 + \dots E_n \ = \sum_{i=0}^{n}(q_i/r_i^2)\hat{r_i}$

**ELECTRIC DIPOLE:**

**Two equal and opposite charges separated by small distance.**

Electric Field Intensity (Axial point):

$E_{Axial} = \frac{1}{4\pi\varepsilon_0}\left[\frac{2p}{r^3}\right]$

Electric Field Intensity (equatorial line):

$E_{equat} = -\frac{1}{4\pi\varepsilon_0}\left[\frac{p}{r^3}\right]$

Field lines

Another way to represent electric field

Lines originates from +ve charge & terminate at −ve charge

* Are imaginary lines
* Do not form close loop
* Always normal to the equipotential surface
* Never intersect

# Chapter -1 ELECTRIC CHARGES AND FIELDS

## MasterCard

### ELECTRIC CHARGES AND FIELDS

**Basic properties of charges**

**Coulomb's Law :**

$$F = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1 q_2}{r^2}\right)$$

$$\vec{F} = \frac{1}{4\pi\varepsilon}\left(\frac{q_1 q_2}{r^2}\right)\hat{r}$$

**Electric field due to point charge**

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\left(\frac{Q}{r^2}\right)\hat{r}$$

**ELECTRIC DIPOLE** Two equal and opposite charges separated by small distance
**Dipole Moment:**
$$|\vec{p}| = (q \times 2a)$$

**Electric Flux:** -The total number of electric field lines crossing the area.

**Additivity of charges :** Total charge is the algebraic sum of individual charges.

**Conservation of charges** : The total charge of an isolated system is always conserved.

Closer field lines indicate the stronger region and rarer field lines shows weaker region

**Electric field lines**

**Electric Flux: -**
$$\Phi_{E\ Total} = \oint_s \vec{E}.\overrightarrow{dS}$$
$$\Phi_{E\ Total} = \oint_s E\ dS\ cos\theta$$

**Gauss Theorem** The total electric flux over closed surfaces enclosing volume V in vacuum is $1/\epsilon_0$ times the total charge enclosed inside closed surface S.

$$\Phi_{E\ Total} = \frac{q_{enclosed}}{\epsilon_0}$$

They never interest each other.

**Quantisation of charges** : Charge of an object is always in the form of integral multiple of electronic charge and never its fraction.

They emerge from positive charge and terminate at negative charge.

**Electric field lines**

Electric field intensity at point 'P' outside shell distant r (r >R).

$\therefore$ E=q/4π $\epsilon_o$ r$^2$

Electric field at a point P on the surface of sphere r= R

E= σ / $\epsilon_o$

Electric field at a point P inside shell (r < R)=> E= 0

**Electric Field Intensity (equatorial line):**
$$E_{equat} = -\frac{1}{4\pi\varepsilon_0}\left[\frac{p}{r^3}\right]$$

**Electric Field Intensity (Axial point):**
$$E_{Axial} = \frac{1}{4\pi\varepsilon_0}\left[\frac{2p}{r^3}\right]$$

Electric field at a point due to uniformly charged spherical shell.

Electric field intensity due to uniformly charged thin infinite plane sheet.   E= σ/2$\epsilon_o$

Electric field due to infinitely long uniformly charged straight wire
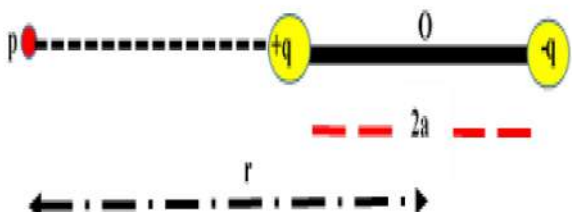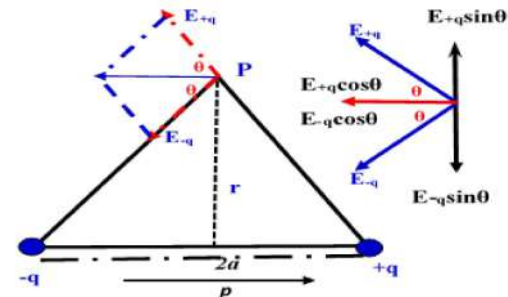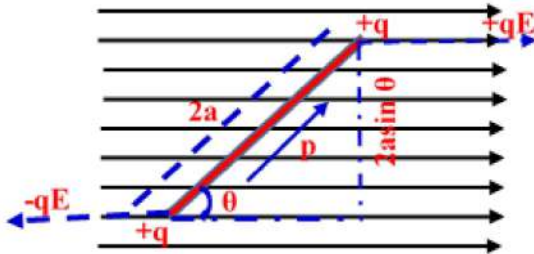E= λ/2π$\epsilon_o$r= 2λ/4π$\epsilon_o$r

# ELECTRIC DIPOLE

- *Electric dipole is a pair of equal and opposite charges separated by a very small distance.*
- **Electric dipole moment is a vector quantity used to measure the strength of an electric dipole. $\vec{p} = (q \times 2a)$**

## ELECTRIC FIELD INTENSITY DUE TO AN ELECTRIC DIPOLE

| Axial line | Equatorial line |
|---|---|
|  |  |
| $E_{Axial} = \dfrac{1}{4\pi\varepsilon_0}\left[\dfrac{2p}{r^3}\right]$ | $E_{equat} = -\dfrac{1}{4\pi\varepsilon_0}\left[\dfrac{p}{r^3}\right]$ |

## ELECTRIC DIPOLE IN A UNIFORM ELECTRIC FIELD
### TORQUE                                     POTENTIAL ENERGY



**If θ = 180°, then U = pE (Unstable Equilibrium**

$\tau = \vec{p} \times \vec{E}$
**Case i: If θ = 0°, then τ = 0.**
**Case ii: If θ = 90°, then τ = pE (maximum value).**
**Case iii: If θ = 180°, then τ = 0.**

*Potential Energy U = - p E cos θ*

If θ = 90°, then U = 0

**If θ = 0°, then U = - pE (Stable Equilibrium)**

3

# Electric Flux and Gauss Theorem

**Electric Flux**

**SI Unit:-** $Nm^2C^{-1}$ or V-m

**Dimensiona Formula** =$[M^1L^3T^{-3}A^{-1}]$.

Outward flux- $\Phi_E > 0$
Inward flux- $\Phi_E < 0$
Outward flux=
Inward flux, $\Phi_E = 0$

**Formulae**
i) $d\Phi_E = \vec{E} . \vec{dS}$
ii) $\Phi_E = \oint_s \vec{E} . \vec{dS}$
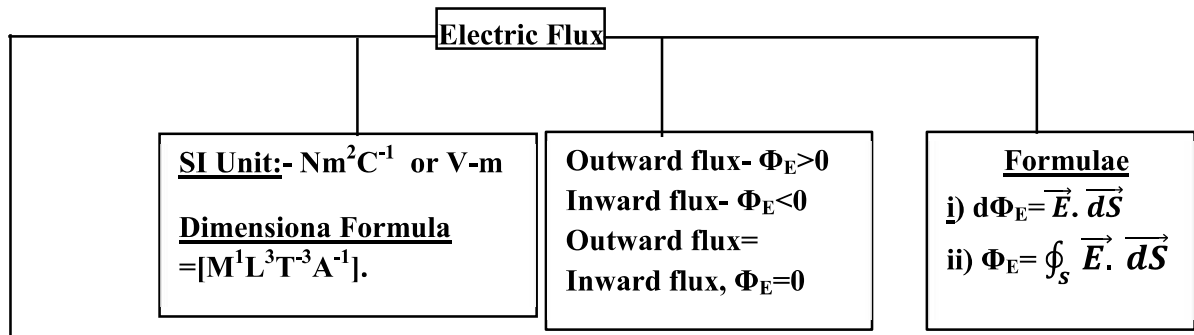
**Definition-**Electric flux over an area represents/measures total number of electric field lines crossing the area when it is held normal to the field direction.

**Gauss' Theorem**

**Statement-**It states that total electric flux over closed surfaces enclosing volume V in vacuum is $1/\epsilon_0$ times the total charge enclosed inside closed surface S.

$\oint_s \vec{E} . \vec{dS} = q_{Total} / \epsilon_0$

**Applications**

Electric field due to infinitely long uniformly charged straight wire $E = \lambda/2\pi\epsilon_0 r$



Electric field intensity due thin infinite plane sheet of charge $E = \sigma/2\epsilon_0$



Electric field intensity due to uniformly charged thin spherical shell



**Proof-**

Let +q – the point charg at O. Consider spherically symmetric Gaussian surface around it as shown. Elemental area = dS and $\vec{r}$ = the position vector.

Electric field $\vec{E}$ due to point charge +q at point P and $\vec{dS}$ are in the same direction as shown. Then the total electric flux through closed surface S is
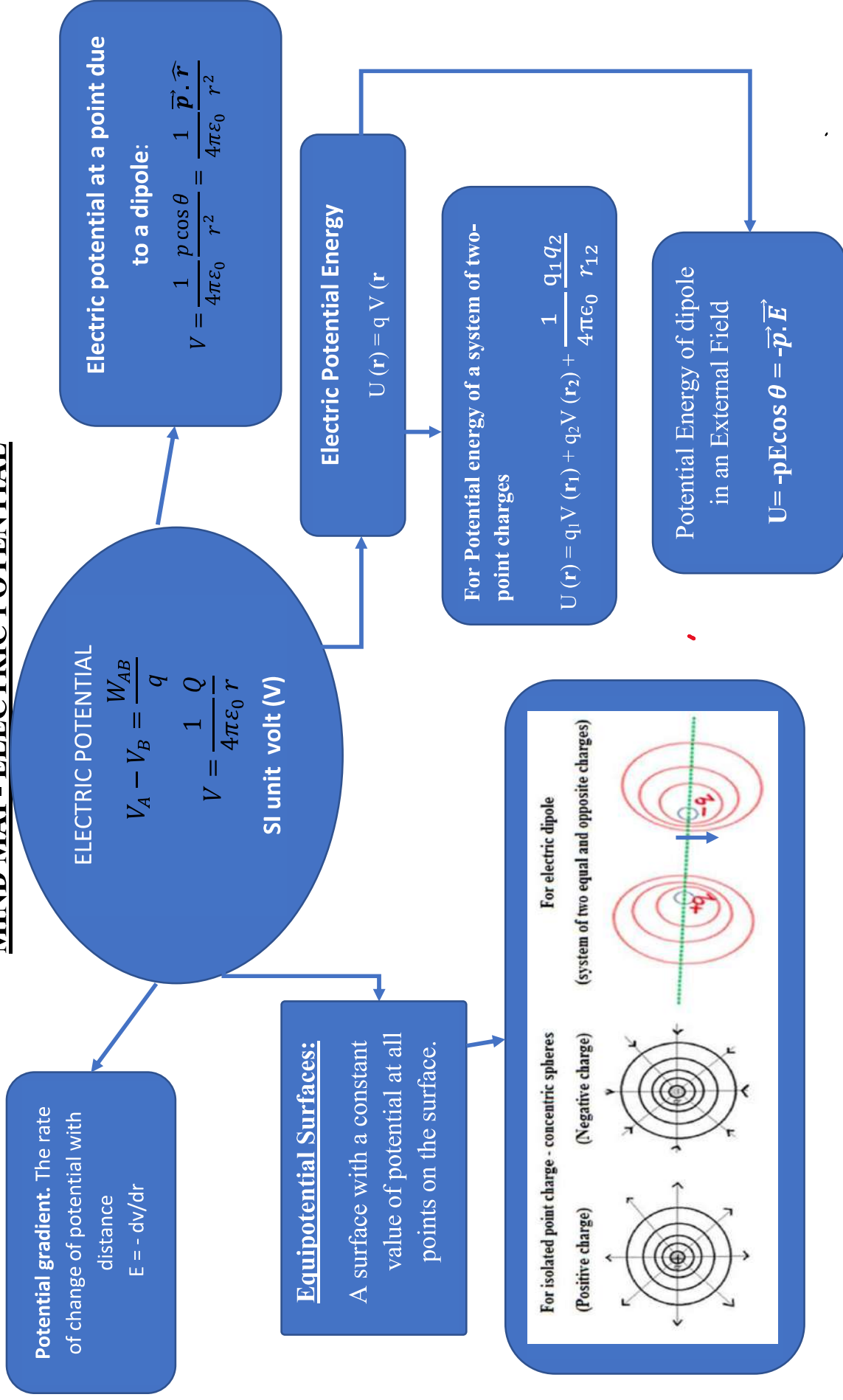
$\Phi_{E\ Total} = \oint_s \vec{E} . \vec{dS}$ = $\oint_s E\ dS \cos \theta$ = $\oint_s E\ dS \cos 0^o$

$\Phi_{E\ Total} = E \oint_s dS = q/4\pi\epsilon_0 r^2 \oint dS$ =$q/4\pi\epsilon_0 r^2$ x $(4\pi r^2)$

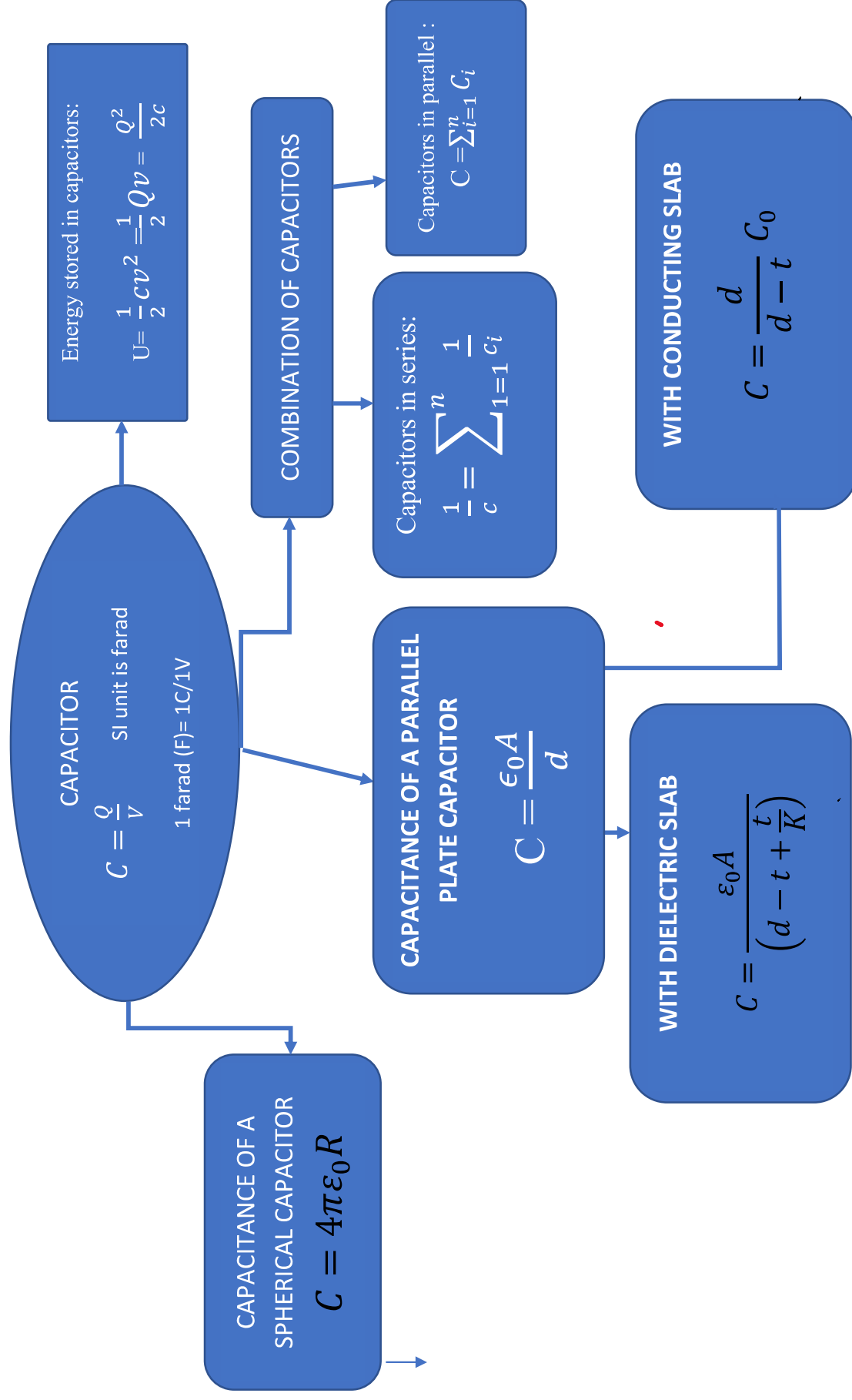$\Phi_{E\ Total} = q/\epsilon_0$

At point 'P' outside shell distant r (r >R)

$E = q/4\pi \epsilon_0 r^2$

At a point on the surface of sphere r=R

$E = \sigma/ \epsilon_0$

At point inside shell (r < R)

$E = 0$

# MIND MAP- ELECTRIC POTENTIAL

**ELECTRIC POTENTIAL**

$$V_A - V_B = \frac{W_{AB}}{q}$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

SI unit volt (V)

**Electric potential at a point due to a dipole:**

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

**Electric Potential Energy**

U (r) = q V (r

**For Potential energy of a system of two-point charges**

$$U(r) = q_1 V(r_1) + q_2 V(r_2) + \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}}$$

**Potential Energy of dipole in an External Field**

$$U = -pE\cos\theta = -\vec{p}.\vec{E}$$

**Potential gradient.** The rate of change of potential with distance

E = - dv/dr

**Equipotential Surfaces:**

A surface with a constant value of potential at all points on the surface.



For isolated point charge - concentric spheres

(Positive charge)        (Negative charge)

For electric dipole

(system of two equal and opposite charges)

# MIND MAP- CAPACITORS

**CAPACITOR**

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

SI unit is farad

1 farad (F)= 1C/1V

**Energy stored in capacitors:**

$$U = \frac{1}{2}cv^2 = \frac{1}{2}Qv = \frac{Q^2}{2c}$$

**COMBINATION OF CAPACITORS**

Capacitors in parallel :

$$C = \sum_{i=1}^{n} C_i$$

Capacitors in series:

$$\frac{1}{c} = \sum_{1=1}^{n} \frac{1}{c_i}$$

**CAPACITANCE OF A PARALLEL PLATE CAPACITOR**

$$C = \frac{\epsilon_0 A}{d}$$

**WITH CONDUCTING SLAB**

$$C = \frac{d}{d-t} C_0$$

**WITH DIELECTRIC SLAB**

$$C = \frac{\varepsilon_0 A}{\left(d - t + \frac{t}{K}\right)}$$

**CAPACITANCE OF A SPHERICAL CAPACITOR**

$$C = 4\pi\varepsilon_0 R$$

# CHAPTER-2 ELECTROSTATIC POTENTIAL AND CAPACITANCES

## MASTER CARD- ELECTROSTATIC POTENTIAL

**Electric potential**:- The amount of work done per unit positive test charge in moving the test charge from infinity to that point.

It is scalar quantity.

SI Unit :- volt (V)

**Electric potential difference**:- If W is work done in moving a small positive test charge q, from point A to B in the electrostatic field of charge Q, then potential difference between points B and A,

$$V_A - V_B = \frac{W_{AB}}{q} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$$

**Electric potential due to group of charges.**

$$V = \frac{1}{4\pi\varepsilon_0}\left(\frac{q_1}{r_1} + \frac{q_2}{r_2} + \frac{q_3}{r_3} + - - - - - - + \frac{q_n}{r_n}\right)$$

**Potential gradient**

$$E = \frac{-dV}{dr}$$

**Electric potential at a point due to a dipole**:

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

**Equipotential Surfaces:** A surface with a constant value of potential at all points on the surface.

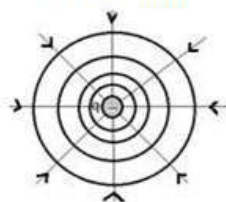Example: Surface of a charged conductor

## Equipotential Surfaces for various charge systems



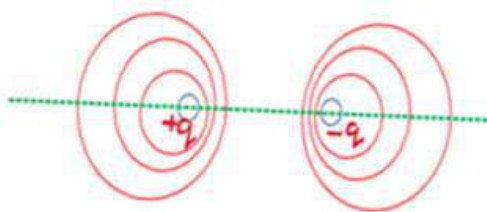For isolated point charge - concentric spheres
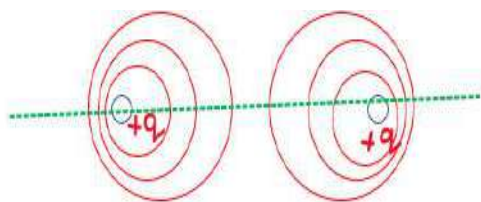(Positive charge)          (Negative charge)
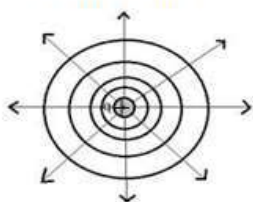
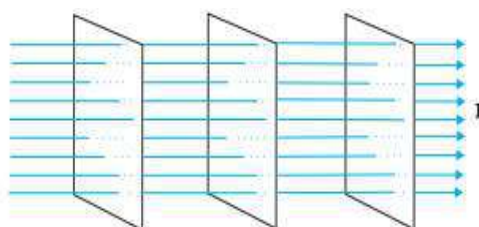For electric dipole
(system of two equal and opposite charges)

**For like charges:**
**Parallel planes perpendicular to the electric field**

**For uniform electric field:**

## Electric Potential Energy

The amount of work done in assembling the charges at their locations by bringing them in, from infinity.

Note that **U is +ve** for like charges and **-ve** for unlike charges.

**For Potential energy of a system of two-point charges:**

$$U\,(r) = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}}$$

**For Potential energy of a single point charge in external field:**

$U\,(r) = q\,V\,(r)$

**For Potential energy of a system of two-point charges in external field:**
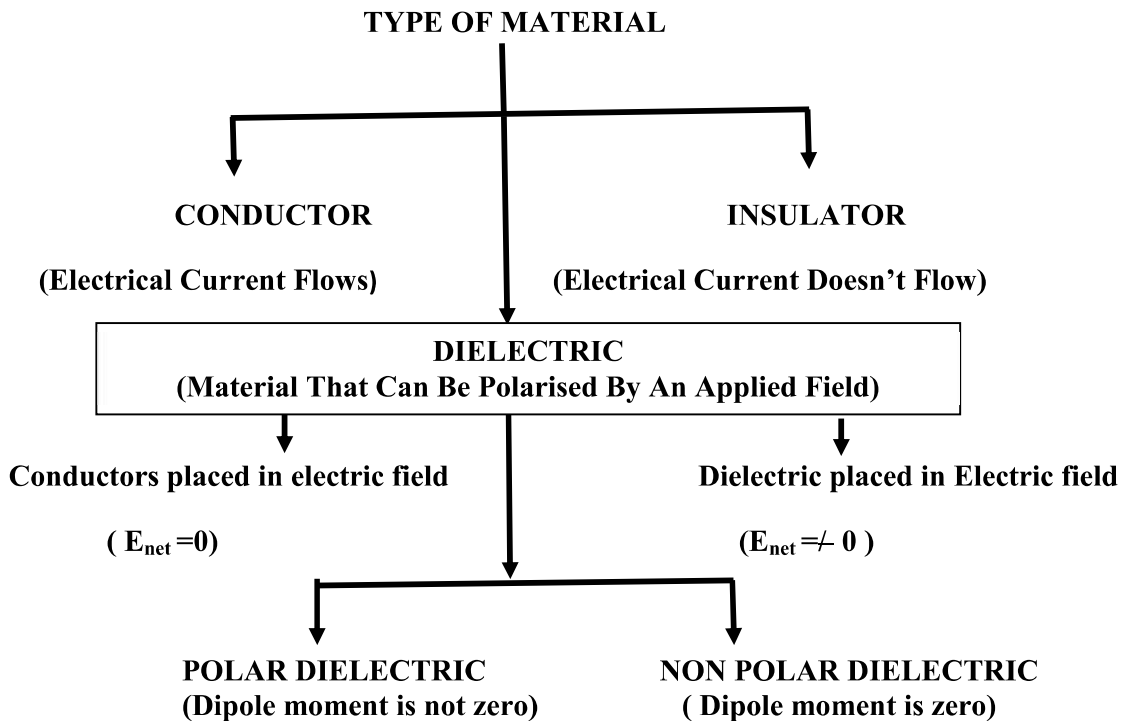
$$U\,(r) = q_1 V\,(r_1) + q_2 V\,(r_2) + \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}}$$

**For Potential energy of a system of three-point charges:**

$$U = \frac{1}{4\pi\epsilon_0}\left[\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right]$$

**Potential Energy of dipole in an External Field-**

$$U = -pE\cos\theta = -\vec{p}.\vec{E}$$

**TYPE OF MATERIAL**

**CONDUCTOR**

(Electrical Current Flows)

**INSULATOR**

(Electrical Current Doesn't Flow)

**DIELECTRIC**
(Material That Can Be Polarised By An Applied Field)

Conductors placed in electric field

( $E_{net}$ =0)

Dielectric placed in Electric field

($E_{net} =\neq 0$ )

**POLAR DIELECTRIC**
(Dipole moment is not zero)

**NON POLAR DIELECTRIC**
( Dipole moment is zero)

**DIELECTRIC CONSTANT**:( $K$ or $\varepsilon_r$ ).

$$K = \varepsilon_r = \frac{\varepsilon_0}{\varepsilon}$$

**POLARIZATION DENSITY**:.

$$P = \frac{Dipole\ moment\ of\ dielectric}{volume\ of\ dielcetric}$$

$$P = \frac{Qd}{Ad} = \frac{Q}{A} = \sigma_p$$

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**ELECTRIC SUSCEPTIBILITY:** The ratio of the polarization to $\varepsilon_0$ times the electric field is called the electric susceptibility of the dielectric.

The unit of electric susceptibility is $\mathbf{C^2/Nm^2}$

**DIELECTRIC STRENGTH:** The maximum electric field that can exist in a dielectric without causing the breakdown of its insulating property is called dielectric strength of the material.

The Unit of dielectric strength is $\mathbf{V/m}$.

**CAPACITOR:-**
A device to store charges & electrostatic potential energy.

**Capacitance:** $C = \dfrac{Q}{V}$

SI. unit : **farad (F)**

Capacitance of a parallel plate capacitor with no medium between plates :

$$C_0 = C = \frac{\epsilon_0 A}{d}$$

**Capacitance of a parallel plate capacitor with a dielectric medium** thickness t

$$C_m = \frac{\epsilon_0 A}{\left(d - t + \dfrac{t}{K}\right)}$$

**Capacitance of a parallel plate capacitor with a dielectric medium** thickness t

$$C_m = \frac{\epsilon_0 A}{\left(d - t + \dfrac{t}{K}\right)}$$

If t = d then $C_m = K\dfrac{\epsilon_0 A}{d}$

$\Rightarrow \quad C_m = KC_0$

**Combination of capacitors:**

(i) Capacitors in series: $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$

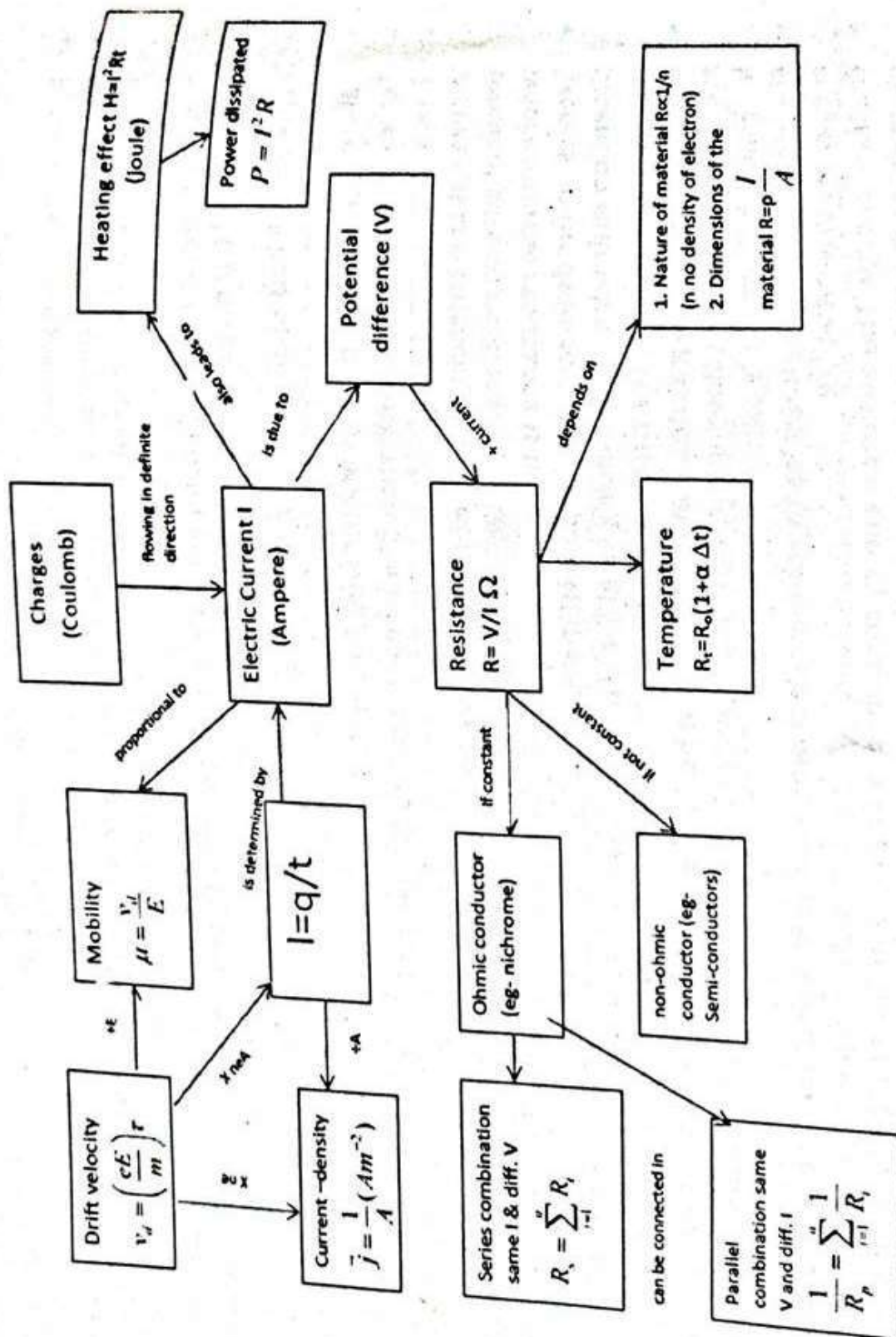(ii) Capacitors in parallel : $C = \sum_{i=1}^{n} C_i$

**Energy stored in capacitors:**

$U = \dfrac{1}{2}CV^2 = \dfrac{1}{2}QV = \dfrac{Q^2}{2C}$

**\*Introducing dielectric slab between the plates of the charged conductor with:**

| PROPERTY | BATTERY CONNECTED | BATTERY DISCONNECTED |
|---|---|---|
| Charge | $KQ_0$ | $Q_0$ |
| Potential difference | $V_0$ | $V_0/K$ |
| Electric Field | $E_0$ | $E_0/K$ |
| Capacitance | $KC_0$ | $KC_0$ |
| Energy | $K\dfrac{1}{2}\epsilon_0 E^2$ (Energy is supplied by battery) | $\dfrac{1}{K}\dfrac{1}{2}\epsilon_0 E^2$ (Energy used for polarization) |

# MIND MAP CHAPTER-3 – CURRENT ELECTRICITY

**Heating effect** $H = i^2 Rt$ (Joule)

**Power dissipated** $P = I^2 R$

**Charges (Coulomb)** — flowing in definite direction → **Electric Current I (Ampere)**

Electric Current I — is due to → **Potential difference (V)**

Potential difference (V) — ÷ current → **Resistance** $R = V/I$ $\Omega$

Resistance — depends on → 1. Nature of material $R \propto 1/n$ (n no density of electron) 2. Dimensions of the material $R = \rho \dfrac{l}{A}$

Resistance → **Temperature** $R_t = R_o (1 + \alpha \, \Delta t)$

Electric Current I — proportional to → **Mobility** $\mu = \dfrac{v_d}{E}$

Electric Current I — is determined by → $I = q/t$

**Drift velocity** $v_d = \left( \dfrac{eE}{m} \right) \tau$

Drift velocity — ÷ E → Mobility

Drift velocity — × neA → $I = q/t$

$I = q/t$ — ÷ A → **Current –density** $\bar{j} = \dfrac{I}{A} (Am^{-2})$

Drift velocity — ne × → Current –density

Resistance — if constant → **Ohmic conductor (eg- nichrome)**

Resistance — if not constant → **non-ohmic conductor (eg- Semi-conductors)**

Ohmic / non-ohmic — can be connected in →

**Series combination** same I & diff. V $R_s = \sum_{i=1}^{n} R_i$

**Parallel combination** same V and diff. I $\dfrac{1}{R_p} = \sum_{i=1}^{n} \dfrac{1}{R_i}$

# Master Card -UNIT-2 - CURRENT ELECTRICITY
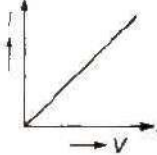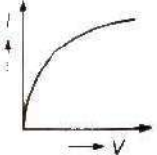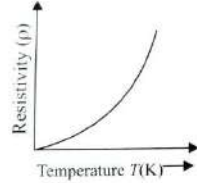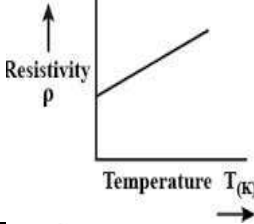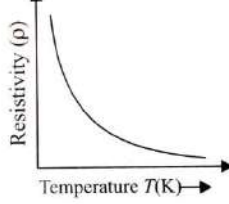
| Physical Quantity | FORMULA | MEANING | UNIT |
|---|---|---|---|
| Resistivity of metallic conductor | $\rho_T = \rho_0\left[1 + \alpha\left(T - T_0\right)\right]$ | $\rho_T$=Resistivity at T temperature<br>$\rho_0$= Resistivity at reference temperature<br>$\alpha$ = temperature co-efficient of resistivity | $\rho : \Omega$ m<br>$\alpha : {}^0C^{-1}$<br>$T : {}^0C$ |
| temperature co-efficient of resistivity | $\alpha = \dfrac{R_2 - R_1}{R_1(T_1 - T_2)}$ | $\alpha$ = temperature co-efficient of resistivity<br>$R_2$= Resistance at final temperature<br>$R_1$= Resistance at initial temperature<br>$T_1$ and $T_2$= Initial and final temperature | $\alpha : {}^0C^{-1}$<br>$R_1, R_2: \Omega$<br>$T_1, T_2 : {}^0C$ |
| Electrical Energy | $E = VIt = I^2Rt$ | E= Energy, V= Voltage, I= Current,<br>R= Resistance, t= Time | E: joule<br>V: volt<br>I: ampere |
| Power | $P = VI = I^2R = \dfrac{V^2}{R}$ | P= Power, V= Voltage, I= Current,<br>R= Resistance | P: watt |
| Combination of Resistors | 1] In Series:<br>$R_{eq} = R_1 + R_2 + ...... + R_n$<br>2] In Parallel:<br>$\dfrac{1}{R_{eq}} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + ....... + \dfrac{1}{R_n}$ | $R_{eq}$= Equivalent resistance | $R_{eq}: \Omega$ |
| EMF of Cell | $\varepsilon = \dfrac{W}{q}$ | $\varepsilon$= emf of cell<br>W= work done<br>q= charge | $\varepsilon$: volt<br>W: joule<br>q: coulomb |
| Potential Difference of Cell | $V = IR = \varepsilon - Ir$ | V= Potential difference, I= Current,<br>R= Resistance, $\varepsilon$= emf, r = Internal resistance | V: volt<br>$\varepsilon$: volt<br>r: $\Omega$ |
| Internal resistance of cell | $r = \dfrac{\varepsilon}{I} - R$ | r= Internal resistance, $\varepsilon$= emf, I= Current,<br>R= External resistance | r, R: $\Omega$ |
| | $I = \dfrac{\varepsilon}{R + r}$ | | I: ampere (A) |
| Combination of Cell | 1] In Series:<br>$\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$<br>$r_{eq} = r_1 + r_2$ | $\varepsilon_{eq}$= Equivalent emf<br>$r_{eq}$ = Equivalent resistance | $\varepsilon_{eq}$: volt<br>$r_{eq} = \Omega$ |
| | $I = \dfrac{nE}{(R + nr)}$ | I= Current, n= no. cells in series,<br>E= emf, R= external resistance, r= internal resistance | I: A<br>E: volt<br>R,r: $\Omega$ |
| | 2] In Parallel:<br>$V = \dfrac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2} - I\dfrac{r_1 r_2}{r_1 + r_2}$ | V= Potential Difference, I= Current,<br>$\varepsilon_1, \varepsilon_2$= emf's of cell 1 and 2<br>$r_1, r_2$= internal resistances of cell 1 and 2 | V: volt<br>$\varepsilon_1, \varepsilon_2$: volt<br>$r_1, r_2: \Omega$ |
| | $\varepsilon_{eq} = \dfrac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$ | $\varepsilon_{eq}$= equivalent emf,<br>$\varepsilon_1, \varepsilon_2$= emf's of cell 1 and 2<br>$r_1, r_2$= internal resistances of cell 1 and 2 | $\varepsilon_{eq}$ : volt<br>$\varepsilon_1, \varepsilon_2$: volt<br>$r_1, r_2: \Omega$ |
| | $r_{eq} = \dfrac{r_1 r_2}{r_1 + r_2}$ | $r_{eq}$= equivalent resistance<br>$r_1, r_2$= internal resistances of cell 1 and 2 | $r_{eq}: \Omega$<br>$r_1, r_2: \Omega$ |

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| | | | |
|---|---|---|---|
| | $$\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + \dots + \frac{\varepsilon_n}{r_n}$$ | | |
| | $$I = \frac{mE}{(mR + r)}$$ | I= Current, E= emf, R= external resistance, r= internal resistance, m= number of cells connected in parallel | I: ampere E: emf R. r: $\Omega$ |
| Kirchhoff's Rules: | 1] Junction Rule: $$\sum I = 0$$ 2] Loop Rule: $\sum V = 0$ OR $$\sum IR = 0$$ | | |
| Wheatstone Bridge: | $$\frac{R_1}{R_2} = \frac{R_3}{R_4}$$ | $R_1$, $R_2$, $R_3$, $R_4$= Resistances | |
| Meter Bridge: | $$\frac{R}{S} = \frac{l}{(100-l)}$$ OR $$R = S\frac{l}{(100-l)}$$ | R= unknown resistance S= known resistance $l$ = Balancing length | R, S: $\Omega$ $l$ : cm |

## Tips:

| | |
|---|---|
| 1] When components are connected in series, then current flowing through them is same. | 6] In numerical question diagrams are given, then see the direction of the cell placed in the circuit. |
| 2] When components are connected in parallel, then potential difference across them is same. | 7] Alloys have very high resistivity and low temperature coefficient of resistance. |
| 3] If the cells are connected facing each other, then effective emf will be the subtraction of both cells. | 8] While calculating total resistance use the internal resistance of cell also. |
| 4] If the storage battery is being charged, so it will not contribute in the total emf of the circuit. | 9] In Solving Kirchhoff's rules numerical, use appropriate sign conventions of current and emf of cell or voltage drop. |
| 5] Write the formulas clearly and correctly in numerical questions. | 10] In meter bridge numerical, first draw circuit diagram according to given conditions. |

## Graphs:

| | |
|---|---|
| Ohmic Conductors- slope of V-I graph gives Resistance |  |
| Non-Ohmic conductors   - V-I graph is not a straight line |  |
| Resistivity $\rho_T$ of copper as a function of temperature T. |  |
| Resistivity $\rho_T$ of nichrome as a function of temperature T. |  |
| Temperature dependence of resistivity for a typical semiconductor. |  |

$$\tau = \overrightarrow{m} X \overrightarrow{B}$$
$$max \ \tau = NIAB$$

If two parallel wire carrying same current are kept 1m apart , if experiences a force $F=2 \times 10^{-7}$ N then current is 1A in each wire

Voltage sensitivity$=\frac{NBA}{CR}$
current sensitivity$=\frac{NBA}{c}$

$$S = \frac{i_g}{i - i_g} G$$

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

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

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

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

$$\overrightarrow{F} = I(\overrightarrow{l} \times \overrightarrow{B})$$
$$F = BIl \ sin\theta$$

Ammeter

Voltmeter

Field at an axial point

Field at the centre

Torque experienced by loop in uniform magnetic field

Definition of ampere

Sensitivity

Galvanometer

Field due to current carrying circular ring

Force on a current carrying conductor
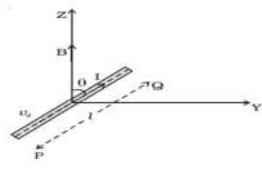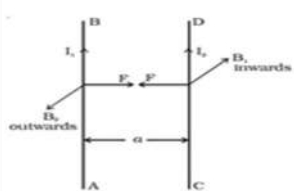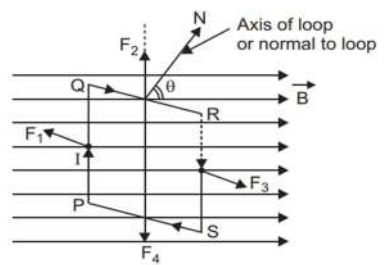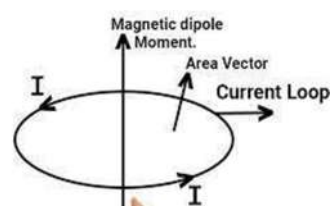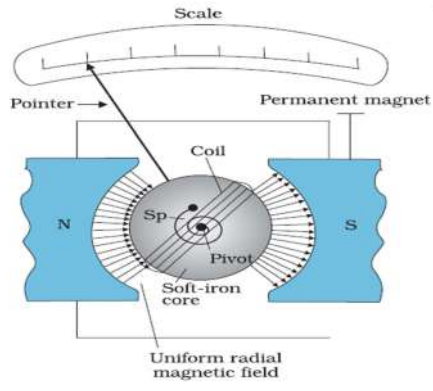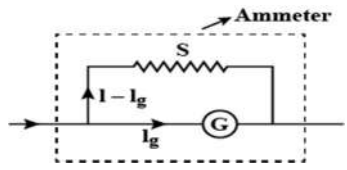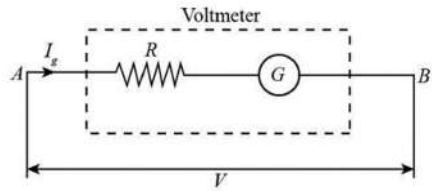
$$F = \frac{\mu_0 i_1 i_2}{2\pi d}$$

Force between parallel current carrying wires

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

Solenoid

In April 1820 Hans Christian oersted discovered that flow of current in a wire produces magnetic field

Oersted law

Magnetic field due to straight infinite current carrying wire

Magnetic field

Magnetic force on a moving charges

Biot savert law

MOVING CHARGES AND MAGNETISM

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

1) It is a region around a magnet or current carrying conductor or a moving charge in which its magnetic effect can be felt.
2) SI unit is Tesla(T)
3) 1 Gauss = $10^{-4}$ tesla

1) $\overrightarrow{F} = q\overrightarrow{v} X \overrightarrow{B} = qvB \ sin \ \theta$
2) For $\theta = 0$, F=0 along the magnetic field
3) For $\theta = 90^0$ , F=qvB i.e if charge velocity is perpendicular to field direction .

$$dB = \frac{\mu_0 \overrightarrow{idl} \ X \ \overrightarrow{r}}{4\pi r^3}$$
Direction of field will be perpendicular to the plane containing current element and the point of observation.

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# CHAPTER - 4 MOVING CHARGE AND MAGNETISM

| Sr. No. | Term | Formula | Diagram |
|---------|------|---------|---------|
| 1 | Biot Savart's Law | $$dB = \frac{\mu_0 I\, dl\, sin\theta}{4\pi r^2}$$ | |
| 2 | Magnetic field at a point on the axis of a current carrying circular coil | $$B = \frac{\mu_0 NIR^2}{2(R^2 + x^2)^{3/2}}$$ | |
| 3 | Magnetic field at a center of a current carrying circular coil | $$B = \frac{\mu_0 I}{2r}$$ | |
| 4 | Magnetic field due to a current in a straight conductor | $$B_0 = \frac{\mu_0}{4\pi}\frac{I}{r}(sin\phi_1 + sin\phi_2)$$ | |
| 5 | Ampere's circuital law | $$\oint \vec{B}.\vec{dl} = \mu_0 I$$ | |
| 6 | Magnetic field due to an infinitely long current carrying straight wire | $$B = \frac{\mu_0 I}{2\pi R}$$ | |
| 7 | Magnetic field due to straight solenoid | B = $\mu_0$ n I , where n = N/L  n = number of turns per unit length | |
| | | | |

| 8 | **Lorentz force** Force on a moving charge in uniform magnetic and electric fields | $\vec{F} = q(\vec{E} + \vec{V} \times \vec{B})$ | |
|---|---|---|---|
| 9 | Force on a current-carrying conductor in a uniform magnetic field | $\vec{F} = I(\vec{l} \times \vec{B})$ $F = BIl\ sin\theta$ |  |
| 10 | Force between two parallel current-carrying conductors | $F = \dfrac{\mu_0 I_1 I_2 l}{2\pi a}$ |  |
| 11 | Torque experienced by a current loop in uniform magnetic field | $\tau = NIBA\ sin\theta$ $\vec{\tau} = \vec{m} \times \vec{B}$ Where m = IA = magnetic moment |  |
| 12 | Current loop as a magnetic dipole and its magnetic dipole moment | $B = \dfrac{\mu_0}{4\pi}\dfrac{2m}{x^3}$ Where x is the distance along the axis from the center of the loop m = NIA = NI$\pi r^2$ |  |
| 13 | Moving coil galvanometer - | 1. $I = G\theta$ Where $G = \dfrac{k}{NAB} =$ galvanometer constant K = torsional N = number of turns A = area of coil B = magnetic field $\theta$ = deflection |  |

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| 14 | Moving coil galvanometer Current sensitivity | $I_s = \dfrac{\theta}{I} = \dfrac{NAB}{k}$ | |
|---|---|---|---|
| | Voltage sensitivity | $V_s = \dfrac{\theta}{IR} = \dfrac{NAB}{kR}$ | |
| 15 | Conversion of galvanometer to ammeter | $S = \dfrac{I_g}{I - I_g} G$  G = galvanometer resistance |  |
| 16 | Conversion of galvanometer to voltmeter | $R = \dfrac{V}{I_g} - G$  G = galvanometer resistance  R = high resistance in series |  |

## GRAPHS :-

### 1. Field pattern for force between two parallel current carrying conductors -



Same direction          Opposite direction

### 2. Magnetic field in the region r < a and r > a, for a long straight wire of a circular cross-section



(NCERT image)

A long straight wire of a circular cross-section

# MAGNETISM AND MATTER

## MAGNETIC TERMS

**Intensity of magnetization**
$$I = \frac{M}{V}$$

**Magnetic susceptibility**
$$\chi = \frac{1}{H}$$

**Magnetic permeability**
$$\mu = \mu_0(1+\chi_m)$$

**Magnetic intensity**
$$H = \frac{B_0}{\mu}$$

## MAGNETIC SUBSTANCES

**Para-magnetism**
Tendency to increase the magnetic field due to magnetization.
e.g. Al,Mn ($\chi_m$ low and –ve, $\mu_r$ >1)

**Diamagnetism**
Tendency to magnetise in a direction opposite to direction of magnetic field.
e.g. Bi,Cu,Hg,Ni ($\mu_r$, $\chi_m$ < 1)

**Ferromagnetism**
Tendency to display strong magnetism in the direction of magnetic field.
e.g. Fe,Co,Ni ($\mu_r$, $\chi_m$ >> 1)

## MAGNETIC FIELD LINES

Continuous imaginary lines which represent the direction of magnetic field.



## Solenoid

$\mu$ = NIA
N = Number of turns
I = Current
A =Area

## MAGNETIC FIELD INTENSITY

End-on-position
$$B = \frac{\mu_0}{4\pi} \frac{2M}{d^2}$$
d >>> l

Broad-side position,
$$B = \frac{\mu_0}{4\pi} \frac{M}{(d^2 + l^2)^{3/2}}$$
d >>> l
$B = \mu_0\, M/\, 4\pi\, d^3$

## BAR MAGNETIC

**Potential energy of a Field-Magnet System**
$U_\theta = U_\theta - U_{90°} = -MB\cos\theta = -\vec{M}.\vec{B}$
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



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# MIND MAP - ELECTRO MAGNETIC INDUCTION

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

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

$\phi = Mi$

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

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

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

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

*Faraday's Law of Electromagnetic Induction*

*Contribution*

*Mutual Inductance*

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

*Lenz's Law*

## Electromagnetic Induction

*Induced current*

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

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

$= Blv$

$i = vbl/(R+r)$

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

*Motional EMF*

*Self Induction*

If a solenoid of N turns, the flux through each each turn $= \phi = \int \vec{B}.\vec{ds}$
emf induced between the ends
of coil $= E = -N\dfrac{d}{dt}\int \vec{B}.\vec{ds}$

*Self Inductance of long Solenoid*

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

n = no. of turns per unit length

$\phi = $ flux $= (\mu_0 ni) \pi r^2$

r = radius of each loop of solenoid

- **Growth of current in LR Circuit**

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

- **Decay of current**

  $i = i_0 e^{-t/\tau}$

- **Energy stored in an Inductor**

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

*Induced EMF*

$E = \dfrac{d\phi}{dt}$

*Rectangular loop*

*Eddy Current*

It is induced when magnetic flux linked with the conductor changes

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

emf induced

$E = vBl$

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

Magnetic force on the loop

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

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

Thermal power developed in the loop is

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

# MASTER CARD : CHAPTER 6 ELECTROMAGNETIC INDUCTION

## ELECTROMAGNETIC INDUCTION

### Faraday's law of EMI

1st Law - Reason of induced emf or current is change in magnetic flux.

2nd law - $E = -N \dfrac{d\emptyset}{dt}$

$I = -\dfrac{N}{R}\dfrac{d\emptyset}{dt}$

### Lenz's law

Direction of induced emf or current is such that it always opposes the change in magnetic flux which produces it.

\# Lenz's law is based on law of conservation of energy.

### Motional EMF due to

**Translatory motion**

$E = Blv\sin\theta$

**Rotational motion**

$E = \dfrac{1}{2}BR^2\omega$

### Eddy current

Eddy current – It is induced current set up inside metal body due to change in magnetic flux.

Uses - To produce heat in induction furnace, Electromagnetic damping

Disadvantages - Heat up metallic core, Damage insulation of coil due to heat, Always oppose motion.

Minimization of eddy current – Using laminating iron core, Using slotted iron blocks.

### Mutual induction

$\emptyset = M I_p$

$E = M\dfrac{dI_p}{dt}$

Mutual inductance between two long solenoids of same length( M ) $= \mu_0 \, n_1 \, n_2 A l$

Factor on which mutual inductance depends

- Number of turns
- Common cross sectional area
- Relative separation
- Relative orientation of two coil
- Permeability of core material

### Magnetic flux

$\emptyset = AB\cos\theta$

Flux $= BA\cos\theta$

### Fleming Right Hand

Motion

Field

Current

### Self-induction

$\emptyset = LI$

$E = -L\dfrac{dI}{dt}$

Self-inductance of a long solenoid (L) = $\mu_0 n^2 lA$

where n - no of turns per unit length

Factors on which self-inductance depends

- Number of turns.
- Area of cross section.
- Permeability of core material.

# MIND MAP - ALTERNATING CURRENT

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

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

RMS value or root mean square value

In 1883 Nikola Tesla constructed the first induction motor at the age of 27 years only.

A device generating alternating current having elements magnet, Armature and graphite Brushes emf induced through coil

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

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

$E_2 = -N_2 E_1/N_1$

$i_2 = -N_1 E_1/N_2$

If $N_2 > N_1$ it is called step-up

If $N_1 > N_2$, it is called step-down

$i_{mean} = 2i_s/$

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

Mean value or Average value

Direction of current changes alternatively

$i = i_0 \sin \omega t$

$v = v_0 \sin \omega t$

AC Current

Contribution

A C Generator

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

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

Peak value or Max$^{m}$ value

$\cdot \eta$ = output power/Input power

$\cdot$ 99% efficiency can easily achieved

The ratio of emf applied and the current produced in an AC circuit

$Z = E_0/i_0$ Ohm

Impedance

Transformer

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

Efficiency of a transformer

The hindrance offered by inductance or capacitance or both to the flow of AC in AC denoted by (X) Ohm

Reactance

**Alternating Current**

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

Power in AC Circuit

A C Circuits

L-C-R circuit

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

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

$X = X_c - X_L$

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

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

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

Phase difference b/w

V & I, $\phi = \pi/2$

Power factor

$\cos(\phi) = 0$

Voltage leads current by $\pi/2$

$P = 0$

Inductive (L) circuit

Capacitive (C) circuit

Resistive (R) circuit

R-C circuit

L-C circuit

L-R circuit

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

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

$\cos\phi = 0$

Power(P) = 0

Current leads the voltage by $\pi/2$

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

$\phi = 0°$

$\cos\phi = 1$

$P = V_0 \, _0/2$

Current & voltage both are in same phase

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

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

$X_c = 1/\omega C$

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

$i_0 = E_0/Z$

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

current leading.

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

$X = X_L - X_C$

$\phi = \pi/2$

Power factor = 0, Either voltage or current leading

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

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

$X_L = \omega L$

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

$i_0 = E_0/Z$

power factor = R/Z

voltage is leading

# MASTER CARD: CHAPTER 7  ALTERNATING CURRENT

1. **AC VOLTAGE AND AC CURRENT**: -The voltage and current whose magnitude changes continuously and direction reverses periodically is called alternating voltage and alternating current.

| ALTERNATING  CURRENT | ALTERNATING VOLTAGE |
|---|---|
| $I = I_m \sin(\omega t + \phi)$ | $V = V_m \sin \omega t$ |
| I→instantanious value of current<br>$I_m$ →Peak value of current<br>ω→ angular freq. rad/s<br>$\phi$→ phase angle, it gives information about the variation of alternating current with respect to the alternating voltage. | $V$ →instantanious value of voltage<br>$V_m$ →Peak value of voltage<br>ω →  angular freq. rad/s |

2. **Average or mean value of AC over a cycle**: -
   Average Alternating current or voltage is zero over a complete cycle.

   Hence, Average value is measured over half of a cycle is $\boldsymbol{I_{av}} = \dfrac{\boldsymbol{2I_0}}{\boldsymbol{\pi}} = \boldsymbol{0.636 I_0}$.

   **Relation between R.M.S. value and peak value is**

   $$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 I_m \quad and \; V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707 \; V_m$$

3. Phase Difference between Voltage and Current
   If  $V = V_m \sin \omega t$  is  AC  voltage  is  connected  to  a  circuit  having  reactive components like **RLC** in series, then the current is $I = I_m \sin(\omega t + \varphi)$ where $\varphi$ is the phase difference between the voltage across the source and the current in the circuit.

| AC SOURCE CONNECTED WITH | PHASE $\varphi$ | Phase relation with AC source voltage | IMPEDENCE Z | PHASOR DIAGRAM |
|---|---|---|---|---|
| A pure RESISTOR | 0 | **voltage and current are in phase** | Z=R | $\overrightarrow{V_R}$ $\vec{\imath}$ |
| A pure INDUCTOR | $\dfrac{\pi}{2}$ | **voltage leads current by $90^o$** | $Z = X_L = \omega L$ | $\overrightarrow{V_L}$ $\vec{\imath}$ |
| A pure CAPACITOR | $\dfrac{\pi}{2}$ | **Voltage lags current by $90^o$** | $Z = X_C = \dfrac{1}{\omega C}$ | $\overrightarrow{V_C}$ $\vec{\imath}$ |
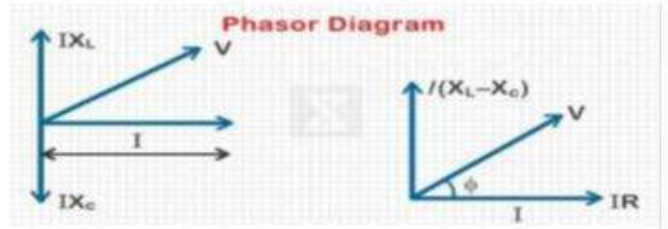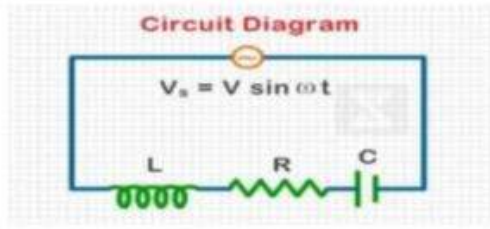
$$V_m = \sqrt{(I_m R)^2 + (I_m X_C - I_m X_L)^2} \qquad\qquad Z = \frac{V_m}{I_m} = \sqrt{(R)^2 + (X_C - X_L)^2}$$

The effective resistance in series RLC circuit is called the **Impedance Z.**

$$Phase\ difference\ between\ i\ and\ V\ , \qquad \tan\varphi = \frac{X_L - X_C}{R}$$

4. **Impedance and Reactance Impedance:**
   The effective resistance to alternating current in series RLC circuit is called the **Impedance Z.**

   $$Z = \frac{V_m}{I_m} = \sqrt{(R)^2 + (X_C - X_L)^2}$$

   **Reactance:** The opposition offered by inductance and capacitance or both in ac circuit is called reactance.
   It is denoted by $X_C$ or $X_L$.

   The opposition due to inductor alone is called the inductive reactance while that due to capacitance alone is called the capacitive reactance.

   Inductive reactance, $X_L = \omega L$

   Capacitive reactance $X_C = \dfrac{1}{\omega C}$

   If capacitor is charged initially and ac source is removed, then electrostatic energy of

   capacitor ( $\dfrac{q^2}{2C}$ ) isconverted into magnetic energy of inductor ( $\dfrac{1}{2} Li^2$ ) and vice

   versa periodically; such oscillations of energy are called LC oscillations. The frequency

   is given by $\omega = \dfrac{1}{\sqrt{LC}}$

5. **AC Generator:-** It is a device used to convert mechanical energy into electrical energy and is based on the phenomenon of electromagnetic induction. If a coil of N turns, area A is rotated at frequency $v$ in uniform magnetic field then motional induced EMF in coil (if initially it is perpendicular to field) is $E = E_o \sin\omega t$ with angular frequency $\omega = 2\pi f$ and Peak EMF $E_o = NBA\omega$.

# ELECTROMAGNETIC WAVES
## Master card

(i)  (i) $\oint \boldsymbol{E}.\boldsymbol{dS} = q/\epsilon_o$ (Gauss's law in electrostatics)

(ii) $\oint \boldsymbol{B}.\boldsymbol{dS} = 0$ (Gauss's law in magnetism

(iii $\oint \boldsymbol{E}.\boldsymbol{dl} = -d\emptyset_B/dt$ (Faraday's law of induction)

The current due to flow of charge is often called conduction current,
$$I_c = dq/dt$$

The current which arises due to time rate of change of electric flux ($\phi_E$) in some part of the electric circuit.
$$I_d = \epsilon_0 \, d\phi_E/dt$$

**Conduction Current**

**Maxwell's Equations**

**Displacement current**

Electromagnetic Waves

**Characterstics of EM waves**

**Electromagnetic Spectrum**

*Combination of mutually perpendicular Electric
 and magnetic fields is referred as an EM wave.
*Do not need any material for propagation.
*Travel with speed of light (c)= $1/\sqrt{\mu_o \epsilon_o} = 3 \times 10^8$ m/s
*Produced by accelerated charged particle
*Transverse in nature
*Oscillation Electric and magnetic field are in phase and ratio is equal to constant.
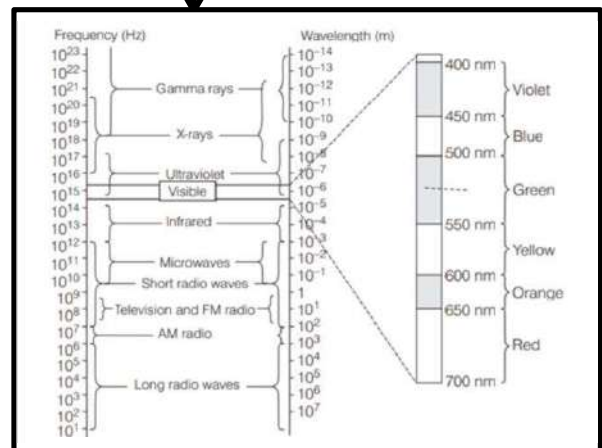


Energy Density

U,(Total energy per unit volume) = Electrostatic energy density ($\epsilon_o E^2/2$) +Magnetostatic energy density($B^2/2\,\mu_o$).
(Electrostatic and magnetic Energy is equally distributed )

# CONCEPT MAP

**Ray Optics**

- **Reflection**
  - Spherical mirror
    - Mirror equation and magnification
- **Refraction**
  - Refractive index – Real depth and apparent depth
    - Lens maker's formula
    - Spherical refracting surface
    - Total internal reflections and its applications
- **Optical instruments**
  - Microscope
    - Simple microscope
    - Compound microscope
  - Telescope
    - Astronomical telescope
    - Terrestrial telescope
    - Reflecting telescope
  - Dispersion and prism formula
  - Power of lens and its combination
  - Lens equation and magnification

## APPLICATIONS OF TIR

- Fiber optics communication
- Medical endoscopy
- Periscope (Using prism)
- Sparkling of diamond

## TOTAL INTERNAL REFLECTION

**TIR conditions**

- Light must travel from denser to rarer.
- Incident angle $i$ > critical angle $i_c$

**Relation between $\mu$ and $i_c$:** $\mu = \dfrac{1}{\sin i_c}$

## REFRACTION OF LIGHT

**Snell's law:** When light travels from medium $a$ to medium $b$, $\quad {}^a\mu_b = \dfrac{\mu_b}{\mu_a} = \dfrac{\sin i}{\sin r}$

**Refractive index,**

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}} = \frac{c}{v}$$

**Real and apparent depth**

$$\mu = \frac{\text{real depth}(x)}{\text{apparent depth}(y)}$$

## REFLECTION OF LIGHT

According to the laws of reflection, $\angle i = \angle r$

If a plane mirror is rotated by an angle $\theta$, the reflected rays rotates by an angle $2\theta$.

## SIMPLE MICROSCOPE

**Magnifying power**

For final image is formed at $D$ (least distance) $M = 1 + \dfrac{D}{f}$

For final image formed at infinity

$$M = \frac{D}{f}$$

## REFLECTING TELESCOPE

**Magnifying power**

$$M = \frac{f_o}{f_e} = \frac{R/2}{f_e}$$

Deviation of red light($\delta_R$)

Deviation of violet light ($\delta_V$)

Visible light

Angular spread

Screen

## REFRACTION THROUGH PRISM

**Relation between $\mu$ and $\delta_m$**

$$\mu = \frac{\sin \dfrac{A + \delta_m}{2}}{\sin \dfrac{A}{2}} \quad \left\{ \begin{array}{l} \text{where,} \\ \delta_m = \text{angle of minimum deviation} \\ A = \text{angle of prism} \end{array} \right.$$

or $\delta = (\mu - 1)A$ (Prism of small angle)

**Angular dispersion**

$$= \delta_V - \delta_R = (\mu_V - \mu_R)A$$

**Dispersive power,**

$$\omega = \frac{\delta_V - \delta_R}{\delta} = \frac{\mu_V - \mu_R}{\mu - 1}$$

**Mean deviation,** $\delta = \dfrac{\delta_V + \delta_R}{2}$

## RAY OPTICS

## OPTICAL INSTRUMENTS

## TELESCOPE

**Astronomical telescope**

For final image formed at $D$ (least distance) $M = \dfrac{f_o}{f_e}\left(1 + \dfrac{f_e}{D}\right)$

In normal adjustment, image formed at infinity $\quad M = f_o / f_e$

## POWER OF LENSES

**Power of lens:** $P = \dfrac{1}{f \text{ (in m)}}$

**Combination of lenses:**

Power: $P = P_1 + P_2 - d P_1 P_2$

($d$ = small separation between the lenses)

For $d = 0$ (lenses in contact)

Power: $P = P_1 + P_2 + P_3 + ...$

## THIN SPHERICAL LENS

**Thin lens formula:** $\dfrac{1}{v} - \dfrac{1}{u} = \dfrac{1}{f}$

**Magnification:** $m = \dfrac{v}{u} = \dfrac{h_i}{h_o}$

## REFRACTION BY SPHERICAL SURFACE

**Relation between object distance ($u$), image distance ($v$) and refractive index ($\mu$)**

$$\frac{\mu_{denser}}{v} - \frac{\mu_{rarer}}{u} = \frac{\mu_{denser} - \mu_{rarer}}{R}$$

(Holds for any curved spherical surface.)

**Lens maker's formula**

$$\frac{1}{f} = (\mu - 1)\left[\frac{1}{R_1} - \frac{1}{R_2}\right]$$

## REFLECTION BY SPHERICAL MIRRORS

**Mirror formula,** $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f} = \dfrac{2}{R}$

**Magnification,** $m = -\dfrac{v}{u} = \dfrac{h_i}{h_o}$

## COMPOUND MICROSCOPE

**Magnifying power,** $M = m_o \times m_e$

For final image formed at $D$ (least distance) $M = \dfrac{L}{f_o}\left(1 + \dfrac{D}{f_e}\right)$

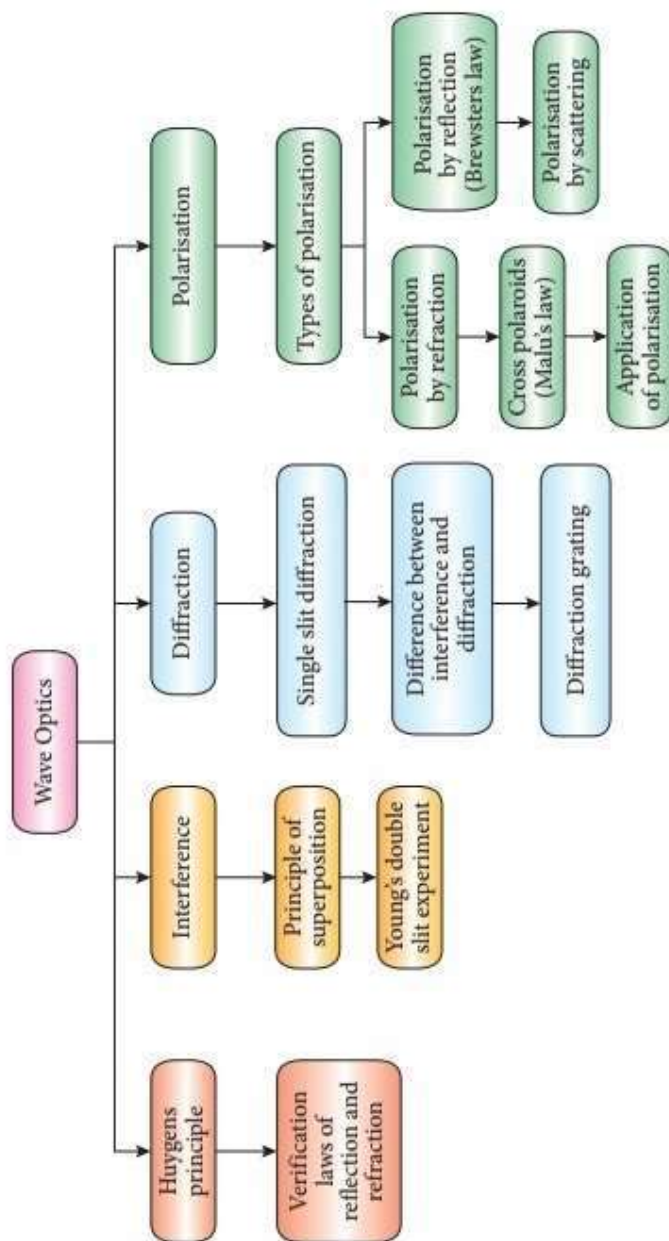For final image formed at infinity

$$M = \frac{L}{f_o} \cdot \frac{D}{f_e}$$

## TERRESTRIAL TELESCOPE

For normal adjustment $M = \dfrac{f_o}{f_e}$

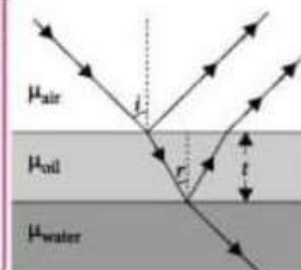Distance between objective and eyepiece $d = f_o + 4f + f_e$

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# CONCEPT MAP

Wave Optics

**Huygens principle**
→ Verification laws of reflection and refraction

**Interference**
→ Principle of superposition
→ Young's double slit experiment

**Diffraction**
→ Single slit diffraction
→ Difference between interference and diffraction
→ Diffraction grating

**Polarisation**
→ Types of polarisation
- Polarisation by reflection (Brewsters law)
  → Polarisation by scattering
- Polarisation by refraction
  → Cross polaroids (Malu's law)
  → Application of polarisation

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## REFLECTION AND REFRACTION

Law of reflection $\angle i = \angle r$ & law of refraction $\dfrac{\sin i}{\sin r} = \mu$ can be explained by Huygens wave theory.
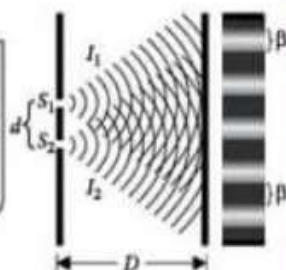
## INTERFERENCE OF LIGHT

The superposition of two coherent waves resulting in a pattern of alternating dark and bright fringes of equal width.

- Position of bright fringes $x_n = \dfrac{n\lambda D}{d}$
- Position of dark fringes $x'_n = \dfrac{(2n-1)\lambda D}{2d}$
- Fringe width $\beta = \dfrac{\lambda D}{d}$
- Ratio of slit width with intensity : $\dfrac{w_1}{w_2} = \dfrac{I_1}{I_2} = \dfrac{a_1^2}{a_2^2}$

## HUYGENS WAVE THEORY

Every point on a wavefront may be considered as a source of secondary spherical wavelets which spread out in the forward direction at the speed of light. The new wavefront is the tangential surface to all of these secondary wavelets at a later time.

Young's Double Slit Experiment

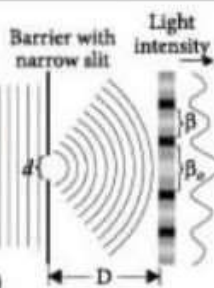Forward moving wavefront

Superposition of Light Waves

## ADDITION OF COHERENT WAVE

- Resultant intensity
$I_R = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$
for bright fringes,
$I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ at $\phi = 0°, 2\pi, 4\pi...$
for dark fringes,
$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$ at $\phi = \pi, 3\pi, 5\pi...$
for $I_1 = I_2 = I_0$ ; $I_R = 4I_0\cos^2\dfrac{\phi}{2}$

## INTERFERENCE IN THIN FILM

- For reflected Light
Maxima $\rightarrow 2\mu t \cos r = (2n+1)\dfrac{\lambda}{2}$
Minima $\rightarrow 2\mu t \cos r = n\lambda$
- For transmitted light
Maxima $\rightarrow 2\mu t \cos r = n\lambda$
Minima $\rightarrow 2\mu t \cos r = (2n+1)\dfrac{\lambda}{2}$
Shift in fringe pattern
$\Delta x = \dfrac{\beta}{\lambda}(\mu-1)t = \dfrac{D}{d}(\mu-1)t$
($t$ = thickness of film, $\mu$ = R.I. of the film)

Secondary wavelets

Single Slit Diffraction

Barrier with narrow slit

Light intensity

Huygen Fresnel Principle

Backwave (absent) (With zero intensity)

## DIFFRACTION

- Single slit experiment
  - Angular position of $n^{th}$ minima, $\theta_n = \dfrac{n\lambda}{d}$
  - Angular position of $n^{th}$ maxima, $\theta'_n = \dfrac{(2n+1)\lambda}{2d}$
  - Width of central maximum $\beta_o = 2\beta = \dfrac{2D\lambda}{d}$

## FRESNEL'S DISTANCE

Ray optics as a limiting case of wave optics
- Diffraction at circular aperture
Linear spread, $x = D\theta$
Areal spread, $x^2 = (D\theta)^2$ $\left\{\theta = \dfrac{1.22\lambda}{d}\right\}$
- Fresnel's distance : Distance at which diffraction spread is equal to the size of aperture, $D_F = \dfrac{d^2}{\lambda}$
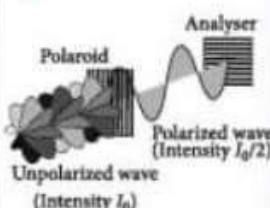- Size of Fresnel zone, $d_F = \sqrt{\lambda D}$

## RESOLVING POWER (R.P.)

The ability to resolve the images of two nearby point objects distinctly.
$$R.P. = \dfrac{1}{\text{Limit of resolution}}$$
R.P. of a microscope $= \dfrac{1}{d} = \dfrac{2\mu\sin\theta}{\lambda}$
$\theta$ = Semi vertical angle subtended at objective.
R.P. of a telescope $= \dfrac{1}{d\theta} = \dfrac{D}{1.22\lambda}$
$D$ = Diameter of objective lens of telescope.

Light as an Transverse Electromagnetic Wave

## DOPPLER'S EFFECT

- Apparent frequency received during relative motion of source and observer
$\upsilon' = \upsilon\left(1 - \dfrac{v}{c}\right)$ : (red shift)
$\upsilon' = \upsilon\left(1 + \dfrac{v}{c}\right)$ : (blue shift)
Doppler shift : $\Delta\upsilon = \pm\dfrac{v}{c}\times\upsilon$
$\Delta\lambda = \pm\dfrac{v}{c}\times\lambda \Rightarrow \lambda'-\lambda = \pm\dfrac{v}{c}\lambda$

Polaroid

Analyser

Unpolarized wave (Intensity $I_0$)

Polarized wave (Intensity $I_0/2$)
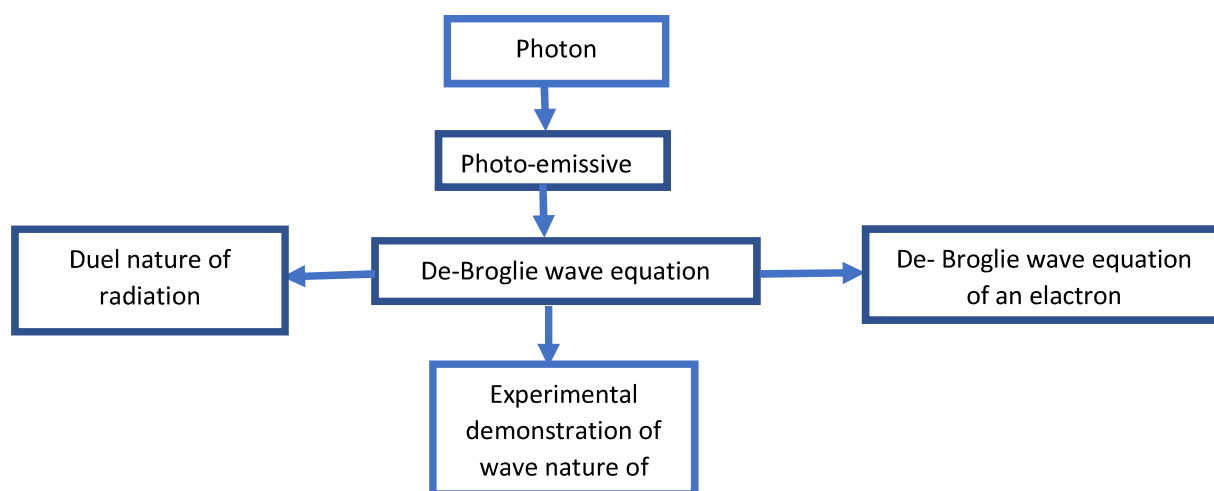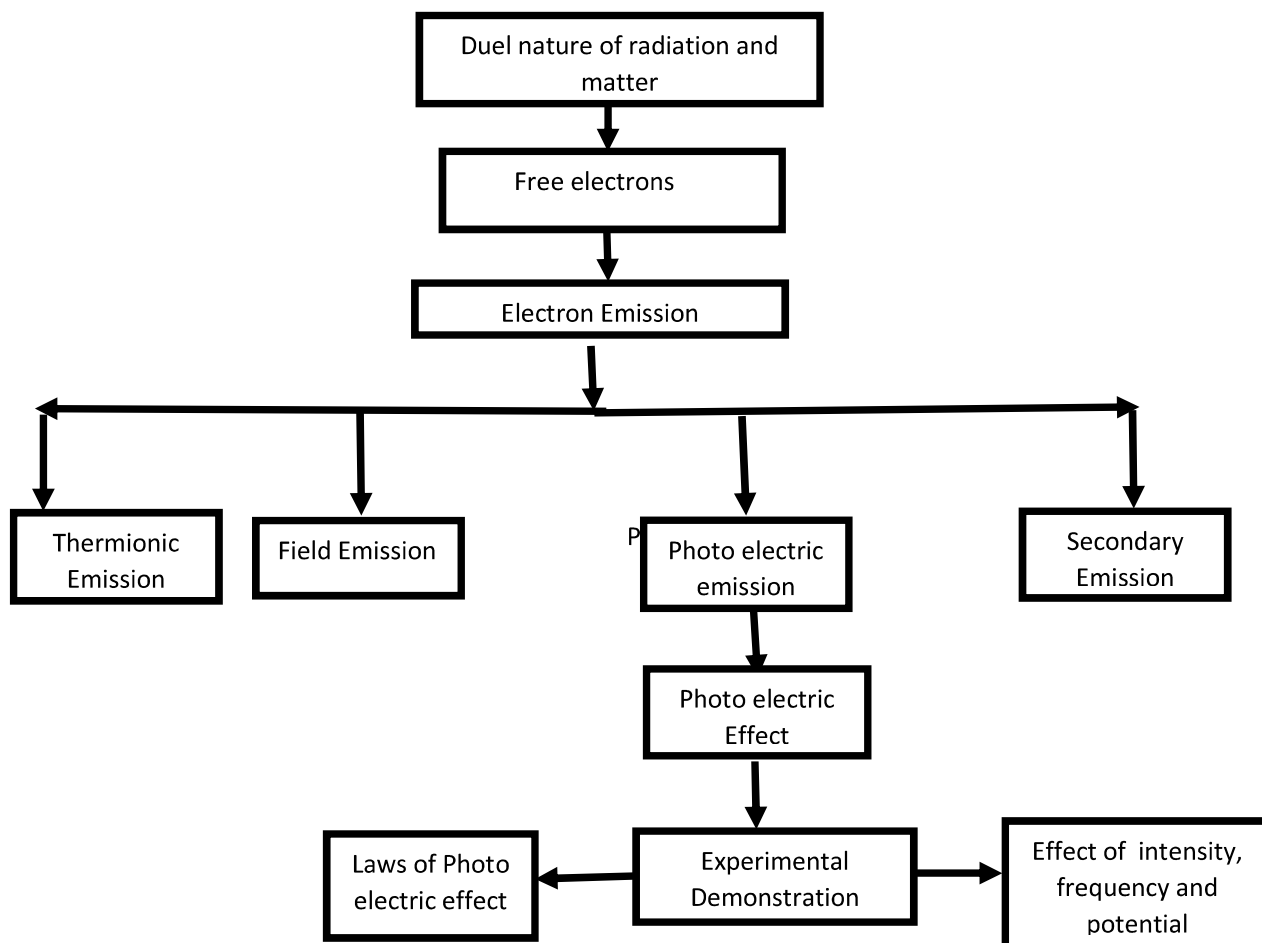
## POLARISATION OF LIGHT

Malus Law: The intensity of transmitted light passed through an analyser is
$I = I_0 \cos^2\theta$
($\theta$ = angle between transmission directions of polariser and analyser)

## POLARISATION BY REFLECTION

- Brewster's Law: The tangent of polarising angle of incidence at which reflected light becomes completely plane polarised is numerically equal to refractive index of the medium
$\mu = \tan i_p$ ; $i_p$ = Brewster's angle.
and $i_p + r_p = 90°$

$\mu_{air}$

$\mu_{oil}$

$\mu_{water}$

# Flow Chart

```
┌─────────────────────────────┐
│ Duel nature of radiation and │
│ matter                       │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│ Free electrons               │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│ Electron Emission            │
└─────────────────────────────┘
```

| Thermionic Emission | Field Emission | Photo electric emission | Secondary Emission |
|---|---|---|---|

```
                    Photo electric emission
                              │
                              ▼
                    ┌──────────────────┐
                    │ Photo electric   │
                    │ Effect           │
                    └──────────────────┘
                              │
                              ▼
```

| Laws of Photo electric effect | ◄── | Experimental Demonstration | ──► | Effect of intensity, frequency and potential |
|---|---|---|---|---|

```
┌──────────────┐
│ Photon       │
└──────────────┘
       │
       ▼
┌──────────────┐
│ Photo-emissive│
└──────────────┘
       │
       ▼
```

| Duel nature of radiation | ◄── | De-Broglie wave equation | ──► | De- Broglie wave equation of an electron |
|---|---|---|---|---|

```
                    De-Broglie wave equation
                              │
                              ▼
                ┌──────────────────────────┐
                │ Experimental demonstration│
                │ of wave nature of         │
                └──────────────────────────┘
```

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# MASTER CARD
## CHAPTER 11 DUAL NATURE OF RADIATION AND MATTER

**Photon**. It is a packet of energy. A photon of frequency v possesses energy h$\nu$.The rest mass of a photon is zero.

**Work function** of a metal. The minimum energy, which must be supplied to the electron so that it can just come out of a metal surface, is called the work function of the metal. It is denoted by W

**Photoelectric effect**. The phenomenon of ejection of electrons from a metal surface, when light of sufficiently high frequency falls on it, is known as photoelectric effect. The electrons so emitted are called photoelectrons.

**Threshold frequency**. The minimum frequency ($\nu_0$), which the incident light must possess so as to eject photoelectrons from a metal surface, is called threshold frequency of the metal. Mathematically- W = h$\nu_0$

**Laws of photoelectric effect**. 1. Photoelectric emission takes place from a metal surface, when the frequency of incident light is above its threshold frequency.

2. The photoelectric emission starts as soon as the light is incident on the metal surface.

 3. The maximum kinetic energy with which an electron is emitted from a metal surface is independent of the intensity of light and depends upon its frequency.

4. The number of photoelectrons emitted is independent of the frequency of the incident light and depends only upon its intensity.

 **Cut off potential**. It is that minimum value of the negative potential ($V_O$ ), which should be applied to the anode in a photo cell so that the photoelectric current becomes zero.

 Mathematically- e$V_o$ = $1$ /2 $mv_{max}^2$ where $v_{max}$ is the maximum velocity with which the photoelectrons are emitted Einstein's photoelectric equation. When light of frequency v is incident on a metal surface, whose work function is W (i.e. h$\nu_0$ ), then the maximum kinetic energy ($1/2$ $mv_{max}^2$ ) of the emitted photoelectrons is given by h$\nu$ = h$\nu_0$ +$1/2$ $mv_{max}^2$ e$V_O$ = hc ($1/\lambda - 1/\lambda o$ ) It is called Einstein's photoelectric equation. It can explain the laws of photoelectric emission.
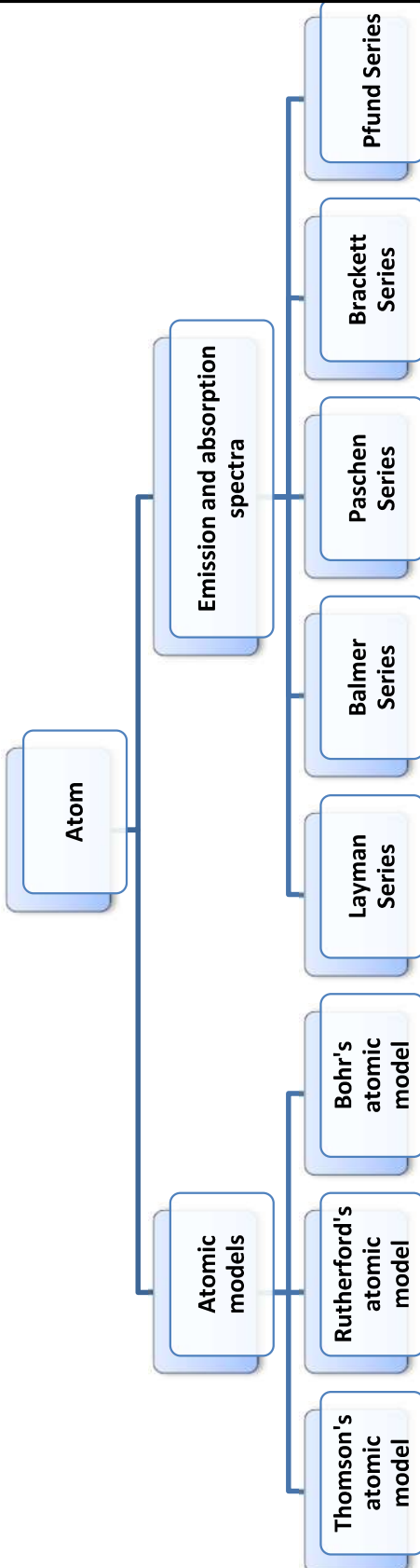
**Photoelectric cell**. A photocell is an arrangement, which produces electric current, when light falls on its cathode. de-Broglie hypothesis. Both radiation and matter have dual nature. A particle of momentum p is associated with de-Broglie wave of wavelength $\lambda = h\ p = h\ mv$ The above relation is called de-Broglie relation and the wavelength of the wave associated is called de-Broglie wavelength of the particle.

 **de-Broglie wavelength of electron**. An electron of kinetic energy E possesses de-Broglie wavelength, $\lambda = h\ \sqrt{2mE}$ If electron is accelerated through a potential difference V, so as to acquire kinetic energy E (=e V), then $\lambda = h\ \sqrt{2meV} = 12.27\ \sqrt{V}\ A\ ^\circ$

**MASTER CARD**

Light behaves as particle called photon, it is packet of energy.

$E = h\nu = h\,c/\lambda = \frac{1242}{\lambda(\text{nm})}\ eV$

Momentum of Photon
$(p = h\nu/c = h/\lambda)$

Plank's constant
$h = 6.626 \times 10^{-34}\,Js$

De-Broglie wave equation $\lambda = h/mv = h/p$,

$\lambda = h\,\sqrt{2mE}$

For electron

$\lambda = 12.27\,/\sqrt{V}$ Å

Threshold frequency. The minimum frequency ($\nu_0$), which the incident light must possess so as to eject photoelectrons from a metal surface
$\phi = W = h\nu_0$

Photoelectric effect takes place for $\nu \geq \nu_0$, $KE_{max} = h(\nu - \nu_0)$

Photon

Photoelectric Effect

Saturation Current:- The maximum value of photoelectric current is called saturation current

Work Function $\phi$ :- minimum energy required to exit an electron from metal surface

$0 \leq KE \leq h\nu - \phi$

$KE_{max} = h\nu - \phi = eV_o$

(Einstein's

Stopping Potential $V_o$:-The value of applied potential at which photoelectric current just stop is called stopping potential

# MIND MAP - ATOMS

- **Atom**
  - **Atomic models**
    - Thomson's atomic model
    - Rutherford's atomic model
    - Bohr's atomic model
  - **Emission and absorption spectra**
    - Layman Series
    - Balmer Series
    - Paschen Series
    - Brackett Series
    - Pfund Series

# ATOMS-MASTER CARD

- Radius of orbit $r = \dfrac{e^2}{4\pi\varepsilon_0 mv^2}$

- Kinetic energy of electron in its orbit $K = \dfrac{e^2}{4\pi\varepsilon_0 r}$

- Potential energy of an electron $U = -\dfrac{e^2}{4\pi\varepsilon_0 r}$

- Velocity of electron in its orbit $v = \dfrac{e}{\sqrt{4\pi\varepsilon_0 mr}}$

- Total energy of an electron in an orbit $E = \dfrac{e^2}{8\pi\varepsilon_0 r}$

**Relation between speed, total energy of an electron and its radius with respect to orbital number n:**

$$\textit{Speed of electron} \qquad v_n = \frac{1}{n}\frac{e^2}{4\pi\epsilon_0}\frac{1}{h/2\pi}$$

$$\textit{Radius of orbit} \qquad r_n = \frac{n^2}{m}\frac{h}{2\pi}\frac{4\pi\varepsilon_0}{e^2}$$

$$\textit{Bohr Radius }(n=1) \qquad r_1 = a_0 = \frac{h^2\epsilon_0}{\pi me^2} = 0.53\dot{A}$$

$$\textit{Energy for nth orbit electron} \quad E_n = \frac{-13.6}{n^2}eV$$

## Alpha particle scattering Experiment



Geiger-Marsden scattering experiment. The entire apparatus is placed in a vacuum chamber (not shown in this figure).

Schematic arrangement of the Geiger-Marsden experiment.
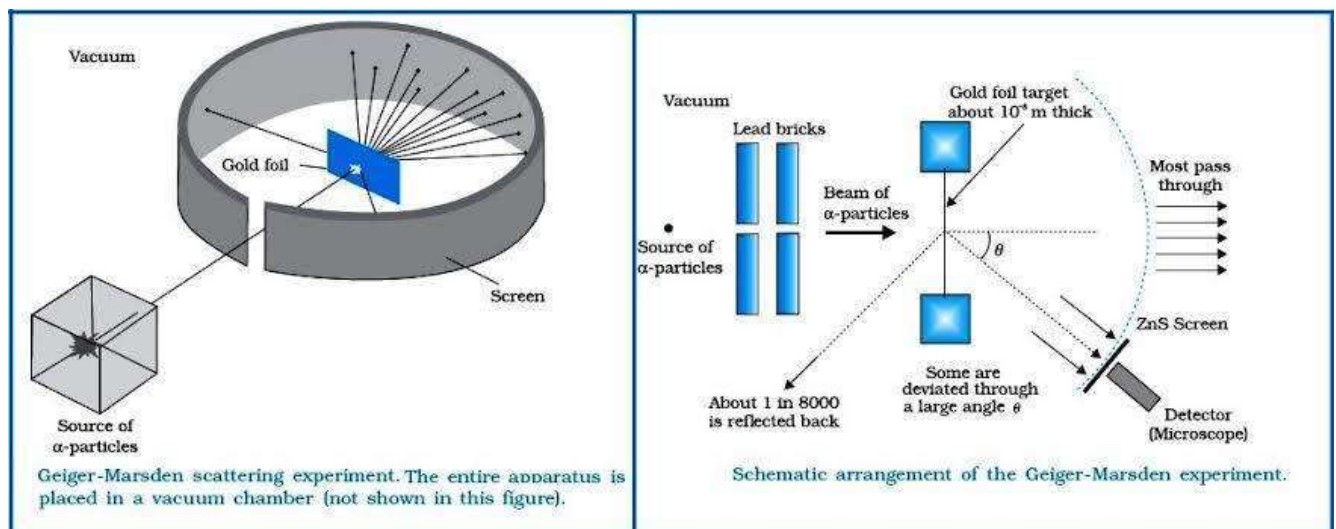
| Source of α-particles - | Radioactive element$^{214}_{83}Bi$ |
|---|---|
| Target | Very thin Gold foil ( Almost transparent) |
| Properties of Gold | Heavy metal and highest malleability |
| Screen | ZnS |

| Experimental Observations: | Conclusions: |
|---|---|
| Most of the α-particles passed roughly in a straight line | Most of the space in the atom is mostly empty |
| A very small number of α-particles were deflected | Nucleus has all the positive charges and the mass |
| Force between α-particles and gold nucleus | $F = \dfrac{1}{4\pi\varepsilon_0}\dfrac{(2e)(Ze)}{r^2}$ |

## Atomic Spectral Series:

- The atom shows range of spectral lines. Hydrogen is the simplest atom and has the simplest spectrum.
- Balmer Series: Balmer observed the first hydrogen spectral series in visible range of the hydrogen spectrum. It is known as Balmer Series.

The series of spectra for hydrogen were as follows

- Lyman Series : $\dfrac{1}{\lambda} = R\left[\dfrac{1}{1^2} - \dfrac{1}{n^2}\right]$ n=2,3,4,5….This is in UV range

- Balmer Series: $\dfrac{1}{\lambda} = R\left[\dfrac{1}{2^2} - \dfrac{1}{n^2}\right]$ where n=3,4,5… This is in visible range

- Paschen Series: $\dfrac{1}{\lambda} = R\left[\dfrac{1}{3^2} - \dfrac{1}{n^2}\right]$ n=4,5,6….This is in IR range

- Brackett Series: $\dfrac{1}{\lambda} = R\left[\dfrac{1}{4^2} - \dfrac{1}{n^2}\right]$ n=5,6,7….This is in IR range

- Pfund Series: $\dfrac{1}{\lambda} = R\left[\dfrac{1}{5^2} - \dfrac{1}{n^2}\right]$ n=6,7,8….This is in IR range

R is Rydberg's constant. The value of R is $1.097\times10^{7}m^{-1}$;

## Limitations of Rutherford model:

- **It could not explain the stability of the atom:**.
- **It could not explain the nature of energy spectrum:**

### BOHR'S MODEL AND POSTULATES:

- An electron can revolve in certain stable orbits without emission of radiant energy. These orbits are called stationary states of the atom.
- Electron revolves around nucleus only in those orbits for which the angular momentum is the integral multiple of $\dfrac{h}{2\pi}$, where, h is Planck's constant. Hence, angular momentum, $L = \dfrac{nh}{2\pi}$
- When an electron makes a transition from one of its specified non-radiating orbit to another of lower energy. When it does so, a photon of energy $h\upsilon$ is radiated having energy equal to energy difference between initial and final state.

$$h\upsilon = E_i - E_f \ \text{(where, } \upsilon \ is \ frequency\ )$$

**De-Broglie's explanation of Bohr's second postulate by quantization theory:**

- In analogy to waves travelling on a string, particle waves can lead to standing waves under resonant conditions. Resonant condition is $l = 2\pi r$ where, $l$= perimeter of orbit.

For a hydrogen atom, length of the innermost orbit is its perimeter.
Hence     $2\pi r = n\lambda$                          ……..(i)

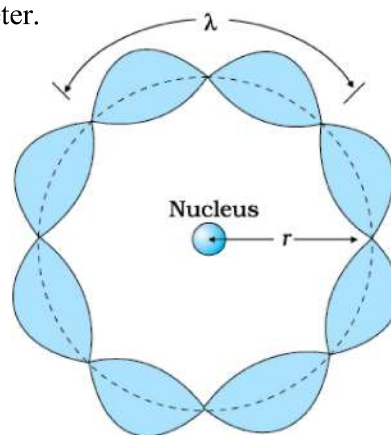According to de-Broglie's wavelength of electron,
$$\lambda = \frac{h}{p}$$
Here $p=mv$ ,  Now equation (i) can be written as

$$2\pi r = n\frac{h}{p} = n\frac{h}{mv} - - - - (ii)$$
Hence, equation (ii) can be reduced as,
$$mvr = n\frac{h}{2\pi} \quad \Rightarrow \quad L = \frac{nh}{2\pi}$$
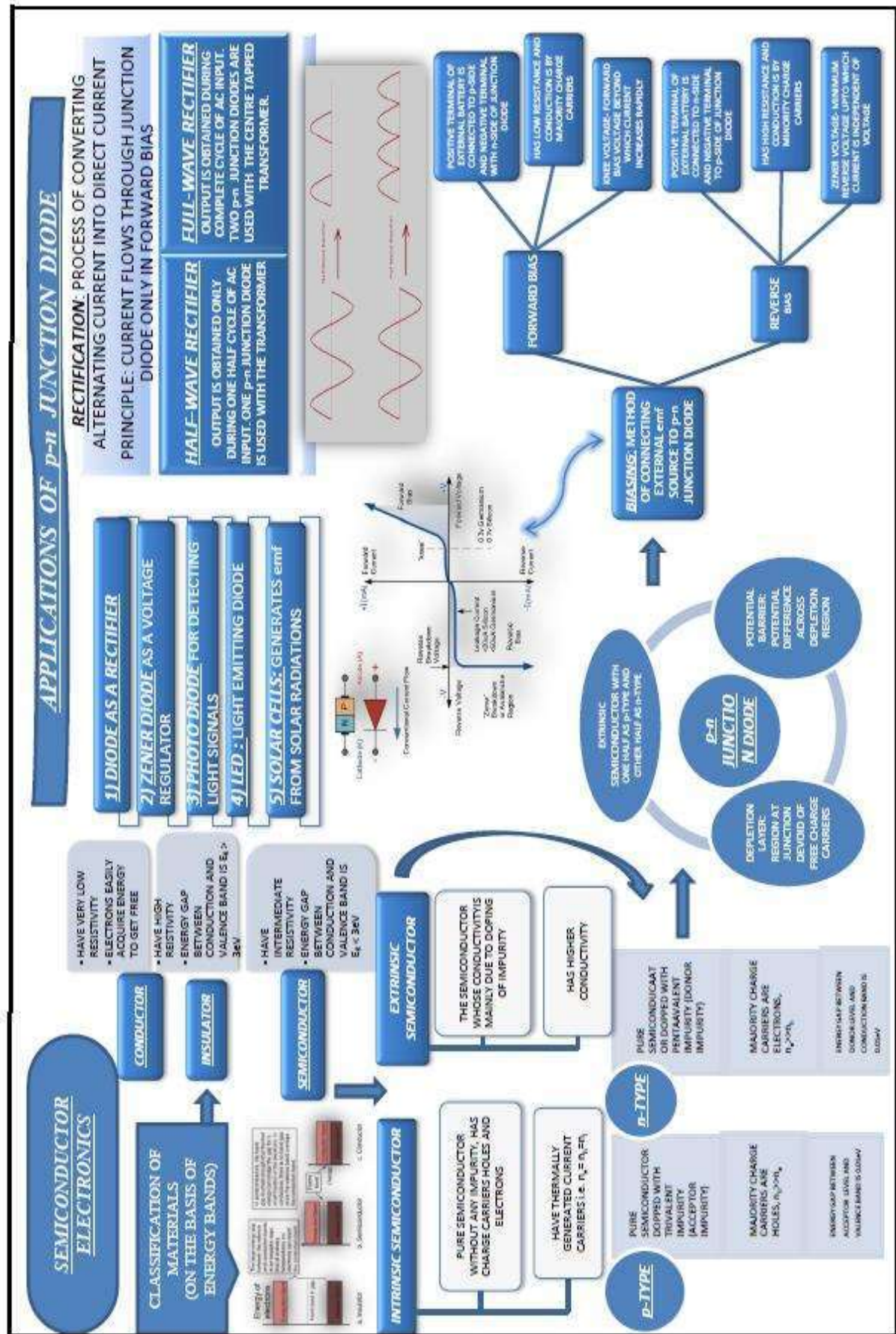This is Bohr's second postulate.

**Limitation of Bohr's atomic model:**

Bohr's model is for hydrogenic atoms. It does not hold true for a multi-electron model
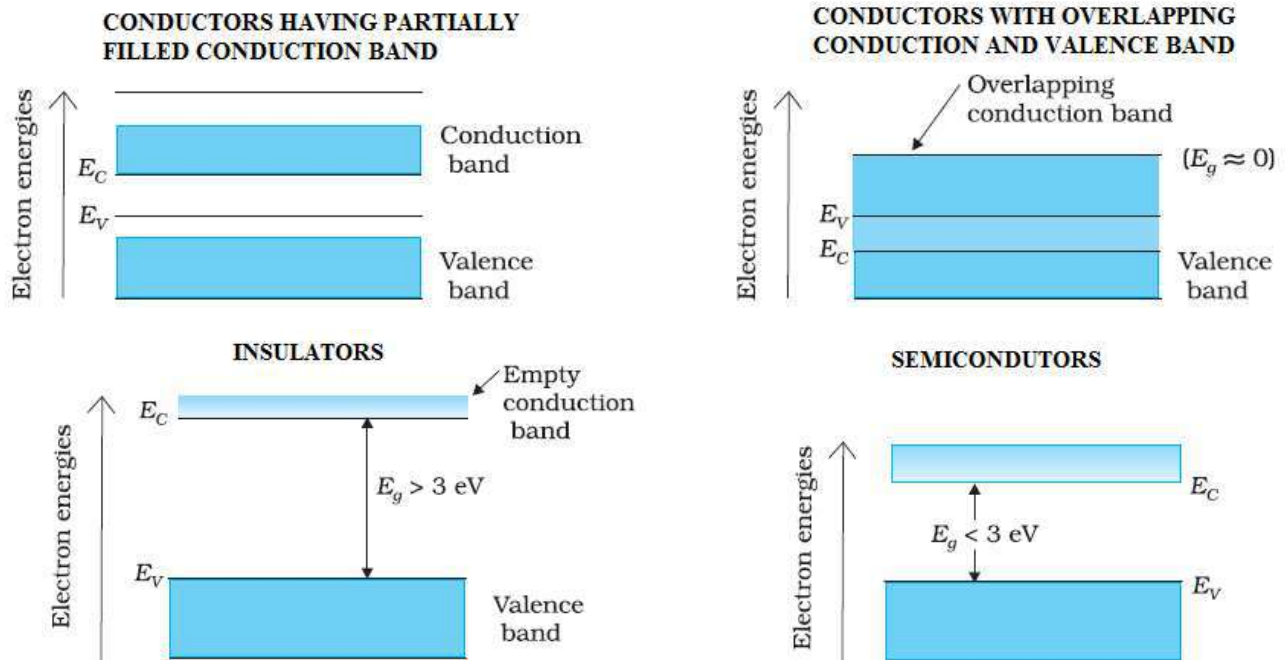
# NUCLEI
## Master Card

**Composition**
- Protons
- Neurons

**Size of Nucleus**
- $R = R_0 A^{1/3}$

**Nuclear force**
- Force among the nucleons inside nucleus

**Mass Defect**
- $\Delta M$ = Theoretical mass − Practical mass
- $\Delta M = [Zm_p + (A - Z) m_n] - M$

**Nucleus**

**Mass Energy Relation**
- $E = mc^2$

**Nuclear reactions**
- Fission
- Fusion

**Binding energy**
- If a certain number of neutrons and protons are brought together to form a nucleus of a certain charge and mass, an energy $E_b$ will be released in the process. This is called Binding Energy

**Important Graphs**

# MIND MAP

## APPLICATIONS OF p-n JUNCTION DIODE

**RECTIFICATION**: PROCESS OF CONVERTING ALTERNATING CURRENT INTO DIRECT CURRENT

**PRINCIPLE**: CURRENT FLOWS THROUGH JUNCTION DIODE ONLY IN FORWARD BIAS

**FULL-WAVE RECTIFIER**: OUTPUT IS OBTAINED DURING COMPLETE CYCLE OF AC INPUT. TWO p-n JUNCTION DIODES ARE USED WITH THE CENTRE TAPPED TRANSFORMER.

**HALF-WAVE RECTIFIER**: OUTPUT IS OBTAINED ONLY DURING ONE HALF CYCLE OF AC INPUT. ONE p-n JUNCTION DIODE IS USED WITH THE TRANSFORMER

### FORWARD BIAS
- POSITIVE TERMINAL OF EXTERNAL BATTERY IS CONNECTED TO p-SIDE AND NEGATIVE TERMINAL WITH n-SIDE OF JUNCTION DIODE
- HAS LOW RESISTANCE AND CONDUCTION IS BY MAJORITY CHARGE CARRIERS
- KNEE VOLTAGE : FORWARD BIAS VOLTAGE BEYOND WHICH CURRENT INCREASES RAPIDLY

### REVERSE BIAS
- POSITIVE TERMINAL OF EXTERNAL BATTERY IS CONNECTED TO n-SIDE AND NEGATIVE TERMINAL TO p-SIDE OF JUNCTION DIODE
- HAS HIGH RESISTANCE AND CONDUCTION IS BY MINORITY CHARGE CARRIERS
- ZENER VOLTAGE : MINIMUM REVERSE VOLTAGE UPTO WHICH CURRENT IS INDEPENDENT OF VOLTAGE

**BIASING : METHOD OF CONNECTING EXTERNAL emf SOURCE TO p-n JUNCTION DIODE**

### Applications:
1) **DIODE AS A RECTIFIER**
2) **ZENER DIODE** AS A VOLTAGE REGULATOR
3) **PHOTO DIODE** FOR DETECTING LIGHT SIGNALS
4) **LED** : LIGHT EMITTING DIODE
5) **SOLAR CELLS** : GENERATES emf FROM SOLAR RADIATIONS

### p-n JUNCTION DIODE
- EXTRINSIC SEMICONDUCTOR WITH ONE HALF AS p-TYPE AND OTHER HALF AS n-TYPE
- POTENTIAL BARRIER : POTENTIAL DIFFERENCE ACROSS DEPLETION REGION
- DEPLETION LAYER : REGION AT JUNCTION DEVOID OF FREE CHARGE CARRIERS

## SEMICONDUCTOR ELECTRONICS

**CLASSIFICATION OF MATERIALS (ON THE BASIS OF ENERGY BANDS)**

### CONDUCTOR
- HAVE VERY LOW RESISTIVITY
- ELECTRONS EASILY ACQUIRE ENERGY TO GET FREE

### INSULATOR
- HAVE HIGH RESISTIVITY
- ENERGY GAP BETWEEN CONDUCTION AND VALENCE BAND IS $E_g > 3eV$

### SEMICONDUCTOR
- HAVE INTERMEDIATE RESISTIVITY
- ENERGY GAP BETWEEN CONDUCTION AND VALENCE BAND IS $E_g < 3eV$

### EXTRINSIC SEMICONDUCTOR
- THE SEMICONDUCTOR WHOSE CONDUCTIVITY IS MAINLY DUE TO DOPING OF IMPURITY
- HAS HIGHER CONDUCTIVITY

#### n-TYPE
- PURE SEMICONDUCTOR OR DOPED WITH PENTAVALENT IMPURITY (DONOR IMPURITY)
- MAJORITY CHARGE CARRIERS ARE ELECTRONS, $n_e > n_h$
- ENERGY GAP BETWEEN DONOR LEVEL AND CONDUCTION BAND IS 0.05eV

### INTRINSIC SEMICONDUCTOR
- PURE SEMICONDUCTOR WITHOUT ANY IMPURITY, HAS CHARGE CARRIERS HOLES AND ELECTRONS
- HAVE THERMALLY GENERATED CURRENT CARRIERS i.e. $n_e = n_h$

#### p-TYPE
- PURE SEMICONDUCTOR DOPED WITH TRIVALENT IMPURITY (ACCEPTOR IMPURITY)
- MAJORITY CHARGE CARRIERS ARE HOLES, $n_h > n_e$
- ENERGY GAP BETWEEN ACCEPTOR LEVEL AND VALENCE BAND IS 0.05eV

# Chapter–14: Semiconductor Electronics: Materials, Devices and Simple Circuits

- VALANCE BAND : The energy band containing valance electrons.
- CONDUCTION BAND  The lowest unfilled energy level just above the valance band
- **FORBIDDEN GAP**  Energy gap between valance band and conduction band..



**INTRINSIC SEMICONDUCTORS:** A pure semiconductor.

Examples: Si: $1s^2, 2s^2, 2p^6, 3s^2, 3p^2$.  (Atomic No. is 14) and The energy gap in Si is 1.1 eV

Ge: $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^2$.  (Atomic No. is 32) and energy gap in Si is 1.1 eV

## MNEMONICS-TO REMEMBER NAMES OF IMPURITIES IN SEMICONDUCTORS
**BIG PAA - B**oron, **I**ndium, **G**allium **(all three are trivalent impurities)**
**P**hosphorus**, A**ntimony**, A**rsenic **(all three are pentavalent impurities)**

## ENERGY BAND DIAGRAMS IN EXTRINSIC SEMICONDUCTORS
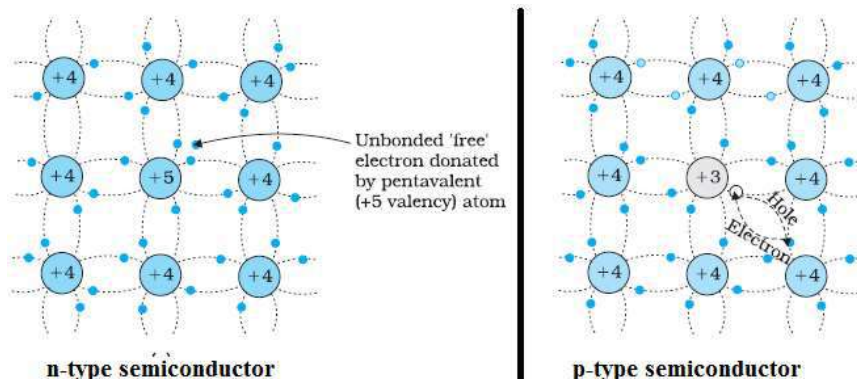
1) n-TYPE SEMICONDUCTOR
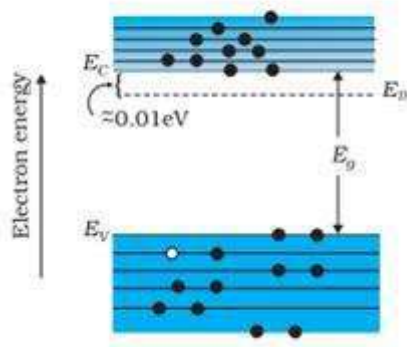
2) p-TYPE SEMICONDUCTOR
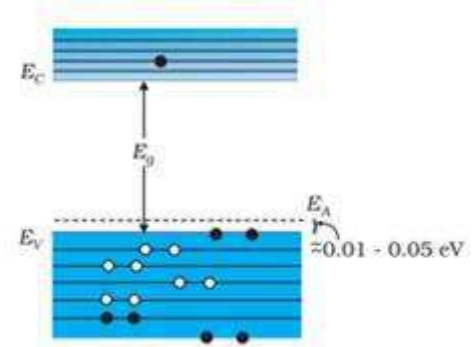
## Electrical conductivity of a semiconductor:

The conductivity of a semiconductor is determined by the mobility ($\mu$) of both electrons and holes and their concentration. Mathematically- $\sigma = e\,(n_e\mu_e + n_h\,\mu_h)$.

## P-N JUNCTION.

**Depletion layer**. It is a thin layer formed between the p and n-sections and devoid of holes and electrons. Its width is about $10^{-8}$ m. A potential difference of about 0.7 V is produced across the junction, which gives rise to a very high electric field ($= 10^6$ V/ m).

**Potential Barrier:** The difference in potential between p and n regions across the junction makes it difficult for the holes and electrons to move across the junction. This acts as a barrier and hence called 'potential barrier'. **Potential barrier for Si is nearly 0.7 V and for Ge is 0.3 V. The potential barrier opposes the motion of the majority carriers.**

**Forward biasing:**                                   **Reverse biasing:**



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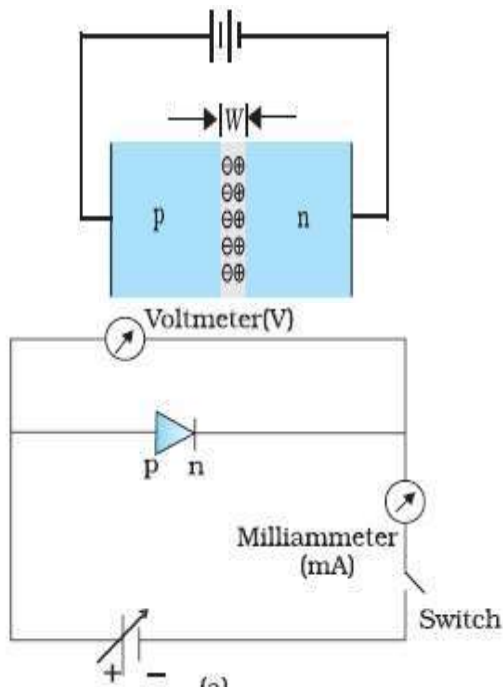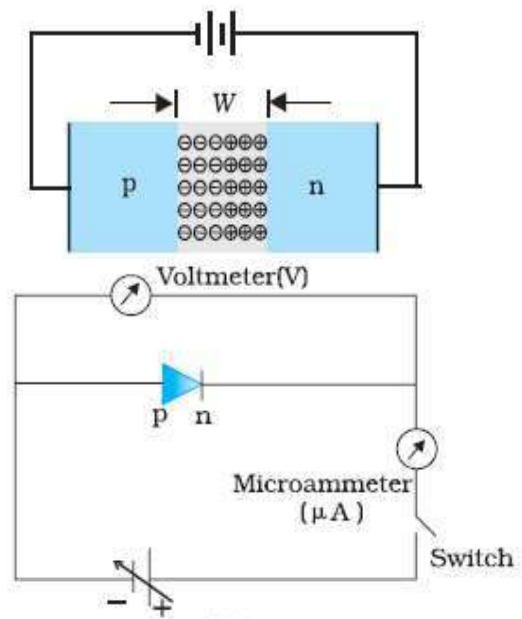
## Junction diode as rectifier:

1. **Half wave rectifier:** A rectifier, which rectifies only one half of each a.c. input supply cycle, is called a half wave rectifier. A half wave rectifier gives discontinuous and pulsating d.c. output. As alternative half cycles of the a.c. input supply go waste, its efficiency is very low.
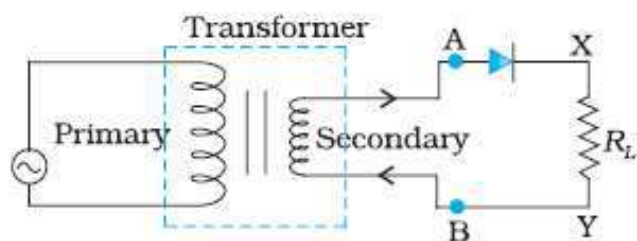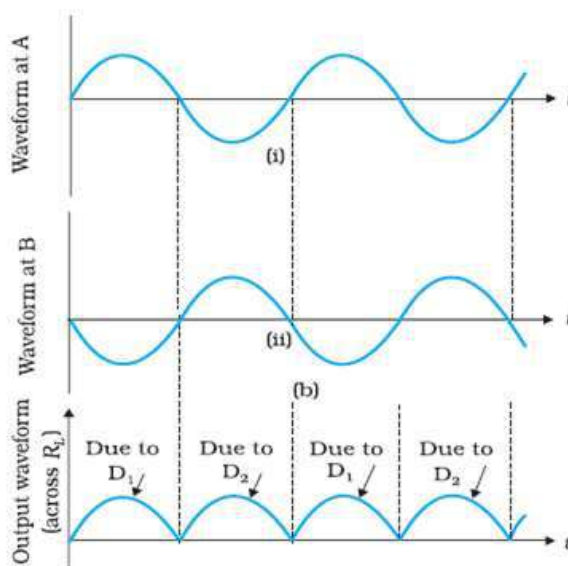


**Circuit Diagram**
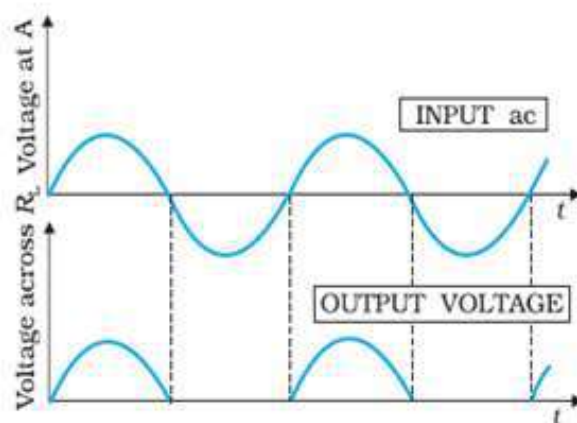
**Input- Output Waveform**

2. **Full wave rectifier:** A rectifier which rectifies both halves of each a.c. input cycle is called a full wave rectifier. The output of a full wave rectifier is continuous but pulsating in nature. However, it can be made smooth by using a filter circuit.
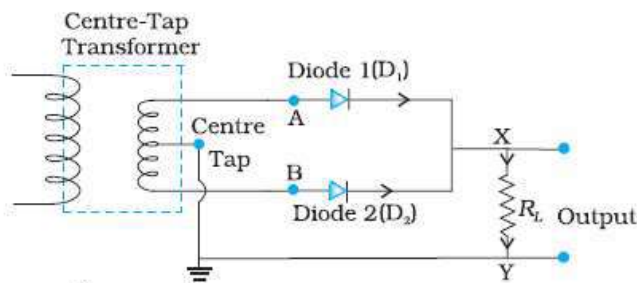


**Circuit Diagram**

**Input- Output Waveform**

# GRAPHS

## 1) I -V CHARACTERISTICS:

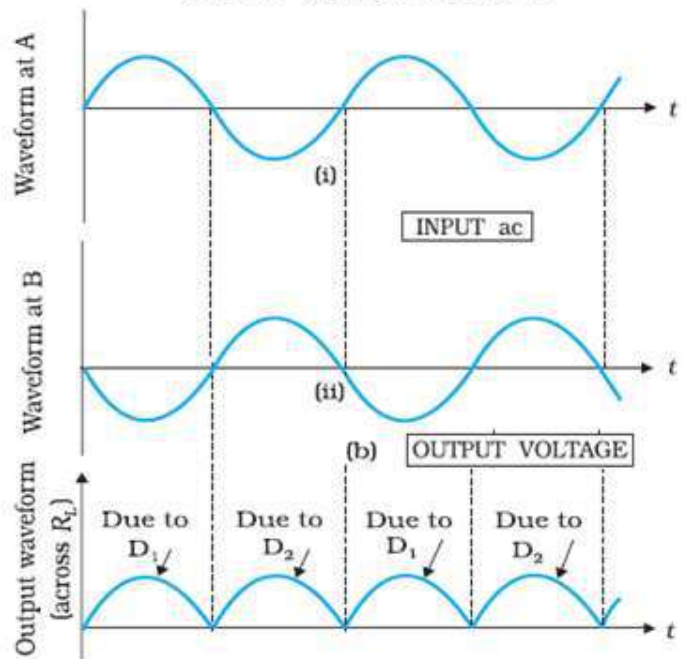### Forward Bias & Reverse Bias Characteristics of a P-N Junction Diode
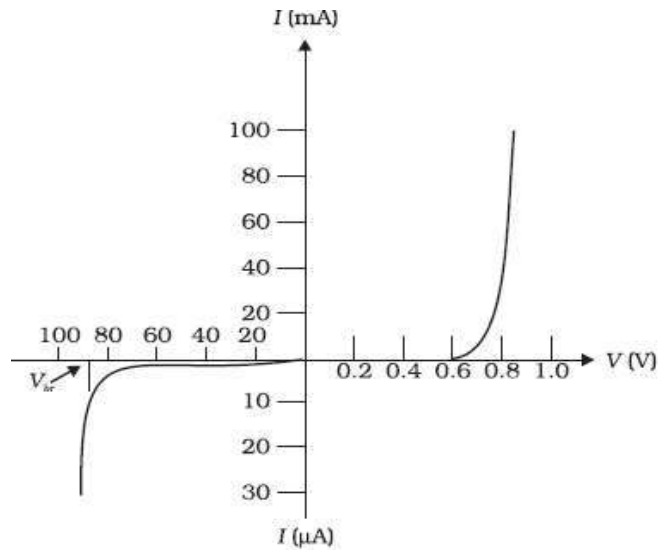


## 2) INPUT AND OUTPUT VOLTAGE GRAPHS OF
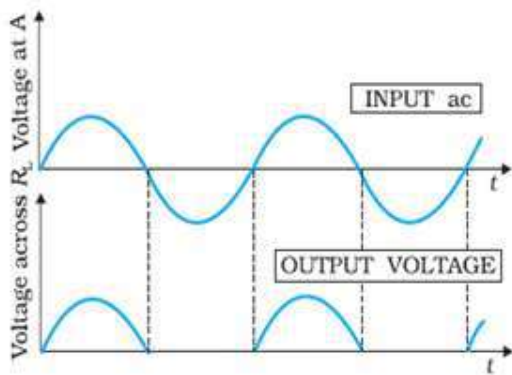
# TABLES

## 1) DIFFERENCE BETWEEN INTRINSIC AND EXTRINSIC SEMICONDUCTORS

| S.NO | INRINSIC SEMICONDUCTOR | EXTRINSIC SEMICONDUCTOR |
|---|---|---|
| 1 | Pure form of semiconductor. | Impure form of semiconductor. |
| 2 | Conductivity is low | Conductivity is higher than intrinsic semiconductor. |
| 3 | The no of holes is equal to no of free electrons | In n-type, the no. of electrons is greater than that of the holes and in p-type, the no. holes is greater than that of the electrons. |
| 4 | The conduction depends on temperature. | The conduction depends on the concentration of doped impurity and temperature. |

## 2) DIFFERENCE BETWEEN HALF WAVE AND FULL WAVE RECTIFIER

| S.NO | HALF WAVE RECTIFIER | FULL WAVE RECTIFIER |
|---|---|---|
| 1 | Only half cycle of AC is rectified. | Both cycles of AC are rectified. |
| 2 | Requires only one diode | Requires two diodes. |
| 3 | The output frequency is equal to input supply frequency. (F) | The output frequency is double of the input supply frequency. (2F) |
| 4 | The electric current through the load is not continuous | A continuous electric current flow through the load. |

# FORMULAE

1) Electron and hole concentration in a semiconductor in thermal equilibrium

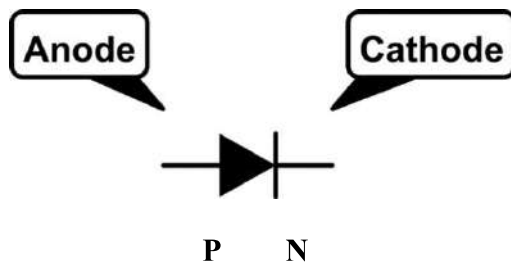   $n_e \, n_h = n_i{}^2$

2) Resistance of a Diode:
   a) Static or DC Resistance   $R_{dc} = V/I$
   b) Dynamic or AC Resistance

$$R_{a.c} = \Delta V / \Delta I$$

**1) TO REMEMBER THE P AND N SECTIONS OF A DIODE.**
   The arrow in the schematic symbol for diodes points in the direction of Conventional (positive) current flow.



**2)** Current is **unidirectional** in a diode. **It flows from anode to cathode only.** To remember this, remember the mnemonics **'ACID' (ANODE CURRENT IN DIODE)**