PVP 23

Code: 23BS1103

I B.Tech - I Semester – Regular / Supplementary Examinations
DECEMBER 2025

ENGINEERING PHYSICS
(Common for CE, ME, IT, AIML, DS)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1. a)	Infer the characteristics of LASER beam.	L3	CO2
b)	Discuss the acceptance angle of an optical fiber.	L2	CO1
c)	Describe the coordination number for SC, BCC and FCC structures.	L2	CO1
d)	Explain Miller indices.	L4	CO5
e)	Define the dielectric loss of a solid material.	L2	CO1
f)	Explain intensity of magnetization (I).	L3	CO3
g)	Calculate Debroglie's wavelength of a matter wave accelerated with a potential difference of 144 Volts.	L3	CO3
h)	List any two merits of classical free electron theory.	L4	CO5
i)	Differentiate Intrinsic and Extrinsic semiconductor.	L4	CO4
j)	Explain drift current of a semiconductor.	L4	CO4

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Develop the construction, principle and working of He-Ne laser system with neat energy level diagram.	L3	CO2	7M
	b)	List the applications of LASERs in various emerging fields.	L3	CO2	3M
		OR			
3	a)	Point out the differences between step indexed and graded indexed optical fiber.	L4	CO4	5M
	b)	Explain the optical fiber communication system with neat block diagram.	L4	CO4	5M
		UNIT-II			
4	a)	Calculate the atomic packing fraction (APF) and Void space for SCC and BCC structures.	L3	CO3	5 M
	b)	Interpret the expression for inter planner separation between any two successive (h k l) crystal planes of cubic structure.	L3	CO3	5 M
		OR			
5	a)	Explain Bragg's law of X-ray diffraction.	L4	CO5	5 M
	b)	Analyze the determination of crystal structure by using POWDER method with neat diagram.	L4	CO5	5 M

UNIT-III					
6	a)	Calculate Clausius-Mossotti relation in dielectrics.	L3	CO3	5 M
	b)	Illustrate the frequency dependence of various dielectric polarization processes with neat graph.	L3	CO3	5 M
OR					
7	a)	Deduce an expression for Bohr magneton (Atomic origin of magnetism).	L4	CO5	5 M
	b)	Distinguish Dia, Para and Ferro magnetic materials with suitable examples.	L4	CO5	5 M
UNIT-IV					
8	a)	Derive Schrodinger time dependent wave equation of a free particle.	L3	CO3	7 M
	b)	An electron is bound in 1-D infinite potential well of width $1x10^{-10}$ m. Calculate the energy value of an electron in the ground state and first excited state.	L3	CO3	3 M
OR					
9	a)	Establish an expression for electrical conductivity based on quantum free electron theory.	L4	CO5	6 M
	b)	List the postulates of Quantum free electron theory (Somerfield theory).	L4	CO5	4 M
UNIT-V					
10	a)	Demonstrate Hall effect and obtain expression for Hall coefficient (R_h).	L3	CO2	7 M

	b)	Differentiate p-type and n-type semiconductors.	L3	CO2	3 M
OR					
11	a)	Deduce an expression for electrical conductivity of a semiconductor.	L4	CO4	5 M
	b)	Develop Einstein's equation of a semiconductor.	L4	CO4	5 M

PVP SIDDHARTHA INSTITUTE OF TECHNOLOGY
(Autonomous)
I B.Tech I SEMESTER –Regular Examinations – December-2025

ENGINEERING PHYSICS (Common to Mech, Civil, IT, CSM,CSD) 23BS1103

SCHEME FOR VALUVATION

Q.No		Marks
1.	**a) Infer the characteristics of a LASER beam.** Monochromaticity, Directionality, Coherence High Intensity	2
	b) Discuss the acceptance angle of an optical fiber. The **acceptance angle** of an optical fiber is the maximum angle at which light rays, incident on the fiber's core from outside, can enter the fiber and still be propagated along the fiber by total internal reflection . Rays entering at angles greater than the acceptance angle escape from the side of the fiber . It is related to the numerical aperture (NA) by the formula $\theta_A = \sin^{-1}(NA)$ $= \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right)$	2
	c) Describe the coordination number for SC, BCC and FCC structures The coordination number is the number of nearest neighbors surrounding a central atom in a crystal lattice: Simple Cubic (SC): 6 Body-Centered Cubic (BCC): 8 Face-Centered Cubic (FCC): 12	2
	d) Miller indices are a system of notation used to describe the orientation of crystallographic planes and directions in a crystal lattice. They are defined as the reciprocals of the intercepts that a plane makes with the three crystallographic axes, cleared of fractions and written in parentheses (hkl)	2
	e) Definition of the dielectric loss of a solid material **Dielectric loss** in a solid material is the dissipation of electrical energy as heat when the material is subjected to an alternating electric field . It represents the energy lost during the polarization and depolarization cycles	2
	f) Explain intensity of magnetization **Intensity of magnetization (M):** is a measure of the extent to which a material is magnetized when placed in a magnetic field. It is defined as the net magnetic moment per unit volume of the material, measured in amperes per meter (A/m)	2

	g). Formula+ Answer $\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{144}} \approx 1.02 \times 10^{-10} m$	1+1
	h) List any two merits of classical free electron theory each carries 1 mark 1. It successfully explains Ohm's Law and the high electrical conductivity of metals 2. It accurately predicts the high thermal conductivity of metals and explains the Wiedemann-Franz law, which relates the electrical and thermal conductivity of metals	2
	i) Any two differences between intrinsic and extrinsic semiconductors. **Intrinsic semiconductors** are pure materials (like pure silicon or germanium) where the number of free electrons is naturally equal to the number of holes . **Extrinsic semiconductors** are created by adding impurities (doping) to an intrinsic semiconductor to intentionally increase the concentration of either free electrons (n-type) or holes (p-type)	1+1
	J) Definition of drift current of a semiconductor. **Drift current** in a semiconductor is the flow of charge carriers (electrons and holes) caused by the application of an external electric field . The electric field exerts a force on the charge carriers, causing them to move in a directional manner, which constitutes the drift current The magnitude of the drift current depends on the electric field strength, the concentration of charge carriers, and their mobility	2

PART-B

2*)a)* Construction+Diagram+Working ---------*3+1+3*--------*7m*

b) Any three applications .each carries 01 mark--------------1+1+1--------3m

OR

3. a) Any four diffrences -----5m

b) Diaram +Explanation ---------- 1+4---5m

UNIT – II

4a) ***Caluculation+diagrams-3+2-------------------5m***

4. b) ***Diagram+derivation ------------1+4---5m***

OR

5a) Diaram +Explanation ---------- 1+4---5m

5 b) Diaram + Explanation ---------- 1+4---5m

UNIT – III

6a) ***Derivation ----5m***

b) Diaram + Explanation ---------- 1+4---5m

OR

7 a) ***Derivation*** **origin of magnetic moment +Nuclear Magnetic momentum+ Spin Magnetic----3+1+1 -- 5m**

.b) Any Three differences ------------------5m

UNIT – IV

8a) ***Derivation of*** **time-dependent Schrödinger wave equation for a free particle.---*7m***

b) Formula+ Substution+ Answer--------------1+1+1----3M

OR

9a) ***Derivation*** **+ explanation for electrical conductivity based on quantum free electron theory** ***----------6m***

9b) Any three postulates of quantum free electron theory (Sommerfeld theory). ---------4m

UNIT-V

10 a) Definition + Diagram+ expression for the Hall coefficient. 2+1+4---------7m

10 b) Any three differences--------------3m

OR

11 **a) Deduce an expression for the electrical conductivity of a semiconductor.** → Explanation + Derivation (2 + 3) (2+3 → 5M)

11 b) Develop Einstein's equation.

↳ Derivation up to Drift & Diffusion → 2M; Einstein relation $\frac{D_p}{D_n} = \frac{\mu_p}{\mu_n}$ → 3M } → 5M

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PART-B

UNIT-I

2. a) Develop the **construction, principle, and working** of a **He–Ne laser system** with a neat **energy level diagram**. *(L3, CO2)*

Construction+Diagram+Working ---------*3+1+3*--------*7m*

HELIUM-NEON GAS LASER:

❖ This was designed by Ali Javan in the year 1961. It is a four level laser system.

❖ Using He-Ne gas laser, a continuous laser beam can be produced.

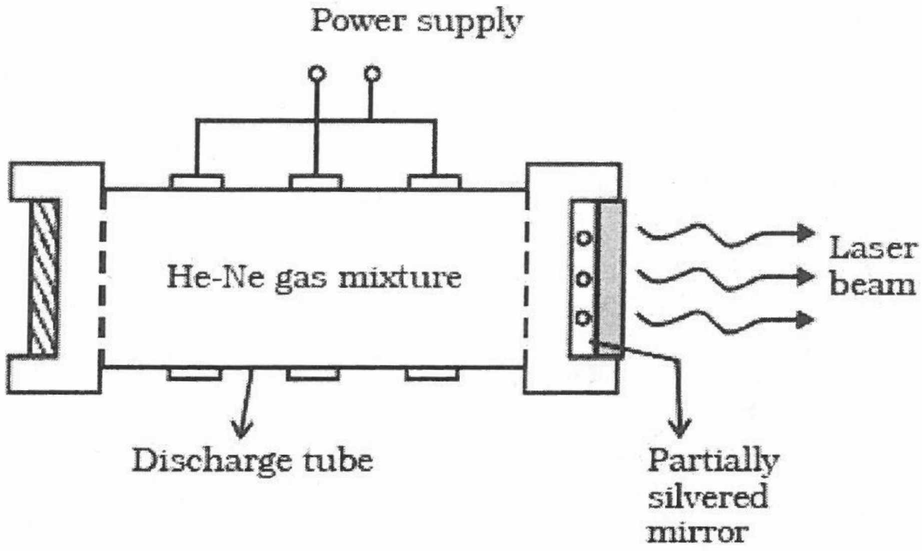
CONSTRUCTION:

❖ It consists of a long cylindrical gas discharge tube. Its length is about 100cm and diameter will be 1to 1.5cm.

❖ The tube is filled with a mixture of He and Ne gas in mixture as in the ratio **10:1**.

❖ Brewster windows made up of quartz are sealed to the tube at both ends, One of the mirror acts as perfect reflector and other as partial reflector.

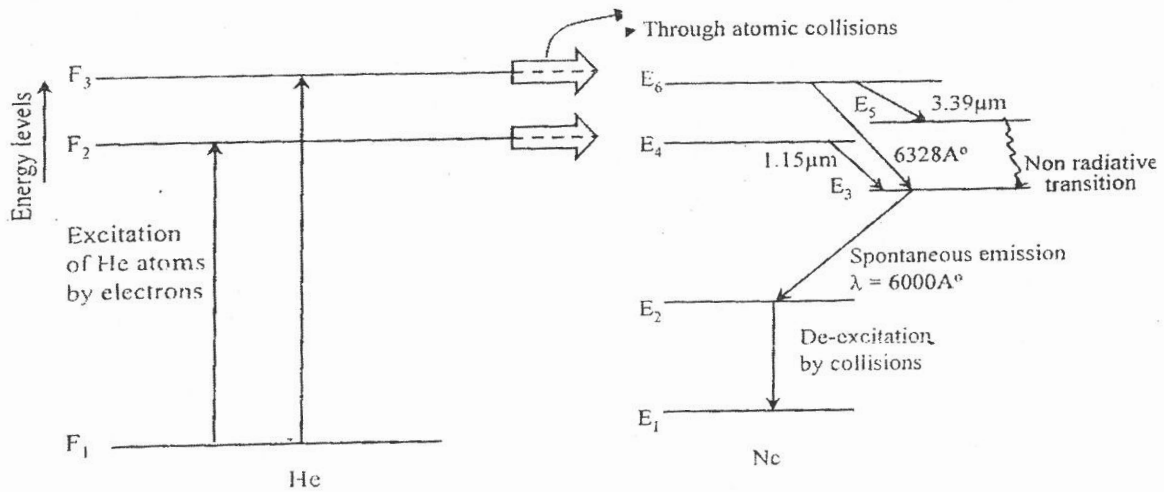
❖ About 10,000 volts is needed to ionize the gas.



Working:

❖ When a voltage of 10,000 V is applied between the electrodes, the electrons are accelerated.

❖ The accelerated electrons **collide** with He atoms and excite them to higher energy levels F_2 and F_3.



- When He atoms in levels F_2 and F_3 collide with Neon atoms in the ground level E_1, an Exchange of energy takes place.
- This results in the excitation of atoms (Ne) to the levels E_4 and E_6 .
- Due to continuous discharge, more Neon atoms are excited to the levels E_4 and E_6.
- This creates population inversion between E_4 (E_6) and the lower energy level E_3 (E_5).
- The stimulated emissions from $E_6 \rightarrow E_5$, $E_4 \rightarrow E_3$, $E_6 \rightarrow E_3$ levels leads to wavelengths 3.39 μm, 1.15 μm and 6328A^0.
- The Neon atoms undergo transition from E_2 to E_1 in the form of fast decay by spontaneous emission.
- The Neon atoms are returned E_1 by non-radiative diffusion and collision process.
- The continuous Laser output can be obtained from He-Ne Laser.

Use — He-Ne lasers are useful in making holograms and interferometric experiments

OR

2.b) List the **applications of LASERs in various emerging fields**. *(L3, CO2)*

Any three applications .each carries 01 mark--------------1+1+1--------3m

COMMUNICATION:

- As it has large band width, more data can be sent.
- More channels can be simultaneously transmitted.
- Laser has greater potential use in space crafts and submarines.
- LIDARS are used in measure of atmospheric pollutants.

COMPUTERS:

- Large amount of data can be stored in CD-ROM. Lasers are used in printing.
- To transmit memory banks from one computer to another.
- Lasers are used in CD-ROMs during recording and reading data.

INDUSTRY:

- Lasers can be used to blast holes in diamonds and hard steels. Lasers are used for cutting and drilling. Lasers are used as a source of intense heat.
- Lasers are used for welding of dissimilar metals.

SCIENTIFIC RESEARCH:

- ❖ Lasers are used to develop hidden finger prints. Lasers are used in 3-D photography called Holography.
- ❖ Lasers are used to produce certain chemical reactions.
- ❖ Lasers are used to study structure of micro organism and cells.

MILITARY OPERATION:

- ❖ High energy lasers used to destroy enemy aircrafts and missiles.
- ❖ Lasers can used as a war weapon.
- ❖ Lasers can be used for detection and ranging like RADAR.

MEDICINE:

- ❖ Lasers are used in the treatment of detached retina.
- ❖ Lasers are used in the treatment of skin diseases.
- ❖ Lasers provide bloodless surgery for operations.
- ❖ Lasers are used for elimination of moles and tumors.
- ❖ CO_2 lasers are used in the treatment of liver and lungs.

(OR)

3. a) Point out the **differences between step-index and graded-index optical fibers.** *(L4, CO4)*

Any four diffrences -----5m

STEP-INDEX FIBERS	GRADED-INDEX FIBERS
1. The refractive index of the core is **uniform** throughout and undergoes step change at the cladding interface.	1. The refractive index of the core is **Not uniform** and is varies from the axis to the cladding.
2. The diameter of the core is about 100 μ m in multimode and about 10 μ m in single mode.	2. The diameter of the core is about 50 μ m in multimode.
3. The light rays propagating in the form **meridional** rays.	3. The light rays propagating in the form **helical rays** and follows like spiral Manner.
4. Signal distortion is **more**. Due to this output signal is **broadened**.	4. 4. Signal distortion is **low** because of self 5. focusing effect. All the light rays reach 6. the end at **same time**.
5. Attenuation is **more.**	7. 5. **Attenuation** is **less**.
6. **N**umerical **A**perture is **more** for MMSI But for SMSI it is very less.	8. 6. **N**umerical **A**perture is **less**.
7. Band width is 50 MHZ for MMSI and it is >	9. 7. Band width is about 200 MHz to

1000MHz for SMSI.	600MHz.

b) **Explain the optical fiber communication system with neat Block diagram.** ***(L4, CO4)***

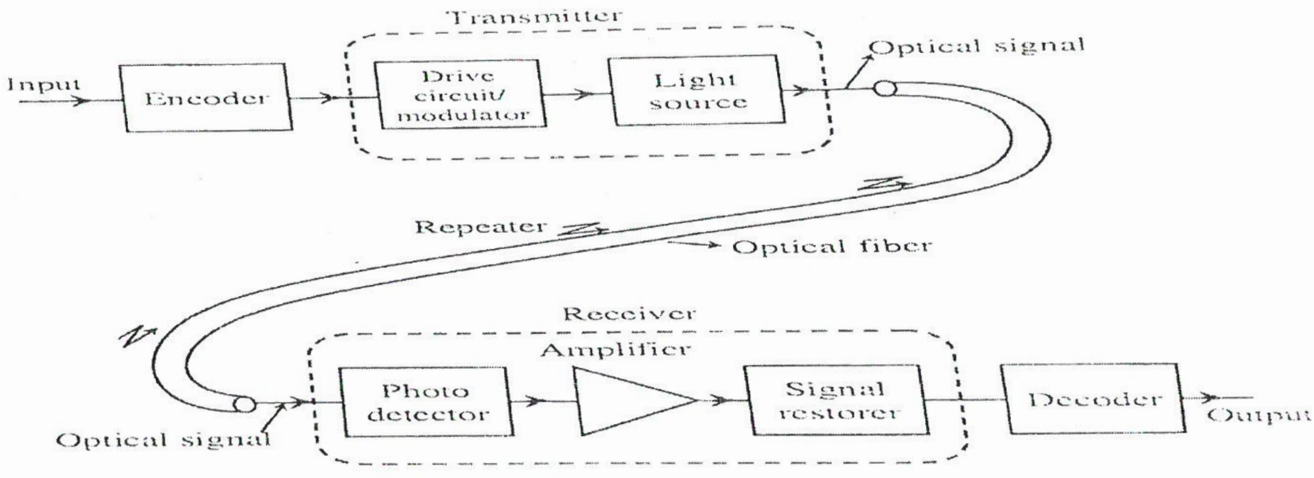
Diaram +Explanation ---------- 1+4---5m

BLOCK DIAGRAM OF AN OPTICAL FIBER COMMUNICATION (OR) FIBER OPTIC COMMUNICATION:

- ❖ Thus the optical fibers are dielectric waveguides which transmit the optical signals through them with very low attenuation.
- ❖ Thus the fiber communication system plays dominant role throughout the world.
- ❖ The important components of this system are

  1. **Transmitter 2. Receiver** and 3. **Transmission path**

- ❖ **Transmitter** consisting of optical source, input signal and modulator.
- ❖ **Receiver** consists of optical detector, demodulator and output display unit.
- ❖ Optical fiber acts as **transmission path**.



A schematic diagram of optical fiber communication system

Transmitter:

- ❖ It consists of input signal, optical source and modulator.
- ❖ **Input signal** is the information signal to be transmitted.
- ❖ It has sufficiently less energy due to low frequency.
- ❖ **Optical source** provides high frequency light signals called carrier.
- ❖ **Modulator** combines the low frequency input signal with high frequency carrier.

Transmission Path:

❖ The modulated signals from the modulator are coupled to the **fiber optic cable** which acts as transmission path.

Receiver:

❖ It consists of optical detector, Amplifier, demodulator and output display unit.

❖ The light emerging from the other end of the fiber cable is given to an optical detector.

❖ **Optical detector** converts the light signals in to electrical signals.

❖ **Amplifier** amplifies the signal to high strength. The amplified signal is given to **demodulator** which decodes the signal to get original information.

❖ These signals are given to **display unit** like **CRO**.

❖ The optical sources are **semiconductor Laser diodes** and LED.

Input signal: When we are talking the diaphragm will vibrate and thereby electrical signals are produced.

Encoder: It converts input electrical signals into digital signals.
Source: LED or Semiconductor Laser is used as source. According to input signals the source will on and off. Thus the digital signals are converted into optical signals.
Source To Fiber Connector: Source is connected to optical fibre through source to fibre Connector.
Optical Fibre: In Optical fibre the signal travels from transmitting end to receiving end by total internal reflection.
Fibre To Receiver Connector: Through fibre to receiver connector the optical fibre is connected to receiver.
Detector Or Receiver: In Detector PIN diode or Photo diode is used to convert the optical signals into digital signals.
Decoder: Digital signals are converted into electrical signals. These electrical signals are fed to the receiver. Thereby the diaphragm moves according to the signals. Thus the receivers can here the speech.
Thus the optical communication system works.

UNIT - II

4a) Calculate the **Atomic Packing Fraction (APF)** and **void space** for **SC and BCC** crystal structures. *(L3, CO3)*

Caluculation+diagrams-3+2------------------5m

STRUCTURE AND PACKING FRACTION OF SIMPLE CUBIC:

❖ The simplest and easiest structure is simple cubic structure. There are 8 corner atoms situated at the eight corners of the unit cell. The corner atoms touch each other.

❖ Each corner atom touches 6 atoms. Hence each atom is surrounded by 6 equidistant nearest neighbours hence the coordination number is 6.

❖ Each corner atom contributes 1/8th to the unit cell, the effective number of atoms to the unit cell is one. Hence the unit cell is primitive cell. This structure is a loosely packed one.

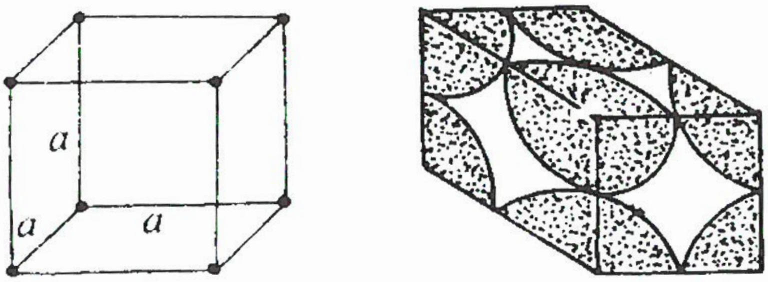


Fig: unit cell of simple cubic structure

ATOMIC PACKING FACTOR IN SC STRUCTURE:

Let 'r' be the radius of atom. 'a' be the lattice parameter.(a=2r)
The effective no of atoms per unit cell = 1 i.e. $N_e=1$
Volume of unit cell=a^3

Volume of atom = $\frac{4}{3}\Pi r^3$

Atomic packing factor = volume of atom / volume of unit cell = $\frac{4}{3}\Pi r^3 / a^3$

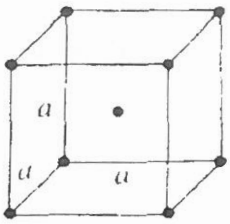
On substituting r =a/2 (or) a = 2r
we get Atomic Packing Fraction = Π/6 = 0.523 = 52 %
Atomic Packing Fraction of simple cubic structure is 0.523 = 52%
Ex: Polonium

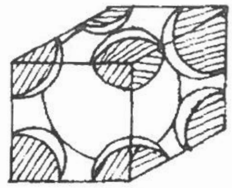
STRUCTURE AND PACKING FRACTION OF BODY CENTERED CUBIC (BCC):

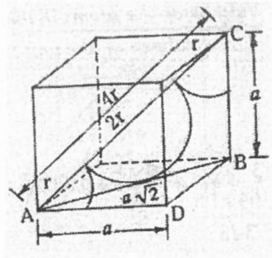
❖ There are 8 atoms at the corners of the unit cell and one atom at the center. The corner atoms do not touch each other but each corner atom touches the central atom.

❖ Since the corner atom at the center touches eight corners of the unit cell, hence the coordination number is 8.

❖ The effective number of atoms in the unit cell = $8X\frac{1}{8}+1$= 2 atoms/cell







ATOMIC PACKING FACTOR IN BCC STRUCTURE:

Let 'r' be the radius of atom. 'a' be the lattice parameter.

From the right triangle ABC, $AC^2 = AB^2 + BC^2$

$$AC^2 = 2a^2 + a^2 = 3a^2$$

$$AC = \sqrt{3}\, a \quad \text{----(1)}$$

And also from the figure body diagonal AC = 4r -----(2)

From equations (1) and (2), we have $\sqrt{3}\, a = 4r \Rightarrow a = 4r/\sqrt{3}$

The effective no of atoms per unit cell = 2 i.e. $N_e = 2$

Volume of unit cell=a^3

Volume of atom=$\frac{4}{3}\Pi r^3$

Atomic packing factor = volume of atoms/volume of unitcell = $\frac{2 \times (4/3\Pi r^3)}{a^3} = \frac{8/3\,\Pi r^3}{(4r/\sqrt{3})^3}$

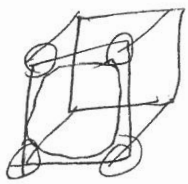
$$= \frac{\sqrt{3}}{8}\Pi = 0.68 = 68\%$$

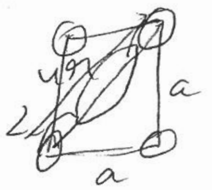
Atomic Packing Fraction OF BCC structure is 0.68 or 68%

Ex: Tungsten, Sodium, Iron and chromium

STRUCTURE AND PACKING FRACTION OF FACE CENTERED CUBIC (FCC):

❖ It has eight atoms at the corners of the unit cell and six atoms at the centres of six faces of the cube.





❖ Each atom at the corner is shared by eight unit cells and each atom at the centre of the face is shared by two unit cells. The no. of atoms per unit cell = 8× (1/8) + 6× (1/2) = 4 atoms/cell

❖ The unit cell of FCC structure is non-primitive. For the atom at the centre of the faces there are 12 atoms at the same distance. Hence the Co-ordination number is 12.

ATOMIC PACKING FACTOR IN FCC STRUCTURE:

From the figure it is clear that AC = √2a and also AC = 4r.

Hence its face diagonal = 4r = ×a ⇒ a = 2 √2 r

a = 2√2 × r

Packing factor = volume of atoms / volume of unit cell = v/V

$$= \frac{4 \times \left(4/3\Pi r^3\right)}{a^3} = \frac{(16/3)\Pi r^3}{\left(2\sqrt{2.r}\right)^3}$$

$$= \frac{\pi}{3\sqrt{2}} = 0.74 = 74\%$$

In FCC structure, 74% of its volume is occupied by the atoms and the remaining 26% is empty. FCC has the highest packing density. It is tightly packed than SC, BCC Structures.

Ex: Cu, Al and Ag have this type of structure.

Conclusion: FCC is most closely packed of all three structures

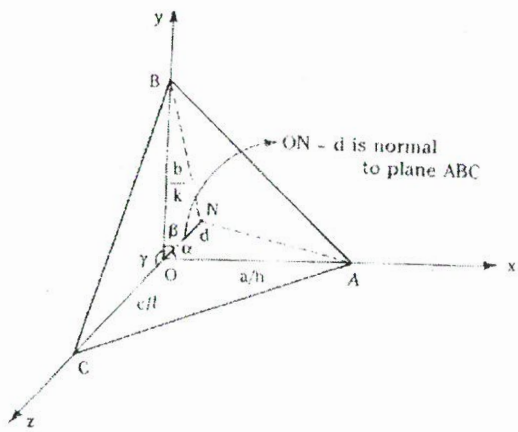
4. b) Interpret the expression for **inter-planar separation** between any two successive (hkl) planes of a **cubic crystal structure**. *(L3, CO3)*

Diagram+derivation -----------1+4---5m

DISTANCE OF SEPARATION BETWEEN SUCCESSIVE (h k l) PLANES:

❖ Let us consider a rectangular co-ordinate system with origin 'o' at any of the lattice points. Construct a plane ABC. Let (h k l) be the miller indices of the plane ABC.

❖ The direction of the plane is given by a normal drawn to the plane passing through the origin.



ABC is a plane, '*d*' is inter planar separation

❖ Let ON be the normal drawn to the plane ABC such that 'ON' =d. Let the normal makes angles α, β, γ with X, Y and Z axes.

❖ OA, OB and OC be the intercepts of the plane ABC.

X-intercept OA =a/h. Y-intercept OB=b/k.

Z- Intercept OC=c/l.

❖ From the figure $\cos\alpha$ =ON/OA= d/(a/h) = dh/a.

$\cos\beta$ = ON/OB=d/(b/h) = dk /b.

$\cos\gamma$ = ON/OC=d/(c/h) = dl /c.

❖ From the cosine rule $\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$ $d^2h^2/a^2 + d^2k^2/b^2 + d^2l^2/c^2 = 1$.

$$\Rightarrow d^2 = \frac{1}{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}} \qquad \Rightarrow d = \frac{1}{\sqrt{\frac{h^2}{a^2}+\frac{k^2}{b^2}+\frac{l^2}{c^2}}}$$

❖ For a simple cube a=b=c, $d=\frac{a}{\sqrt{h^2+k^2+l^2}}$.

OR

5a) Explain **Bragg's law of X-ray diffraction.** *(L4, CO5)*

Bragg's law :

Diaram +Explanation ---------- 1+4---5m

❖ W.L.Bragg and W.H.Bragg gave a simple relation relating the *θ, λ, d [wavelength of the incident radiation .the angular positions of the scattered beams and interplanar spacing d].*

❖ **Statement:** When a monochromatic beam of X-rays is incident on a crystal planes, each atom acts as a source of scattering radiation of the same wavelength. The rays interfere constructively or destructively will depend up on the path difference between the reflected rays .These two rays reinforce each other and produce an intense spot.

PROOF:

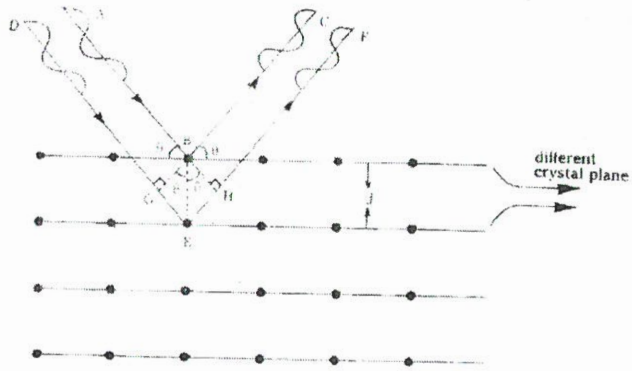


Fig. 3.8. Different planes and diffraction rays in a single crystal

- ❖ Let us consider a crystal of equidistant parallel planes with interplanar spacing d.
- ❖ Consider a monochromatic beam of X-ray of wavelength λ is incident of an angle θ to the atomic planes.
- ❖ The 'dot' represents the position of atoms Consider a ray AB incident on plane I at an atom B and reflected to C in the direction BC.
- ❖ Another ray DE incident on plane II at an atom E, and reflected to F in the direction EF.
- ❖ Draw two normals BG & BH from B on to the lines DE and EF respectively.
- ❖ The path difference between the two rays ABC and DEF is (GE+EH).
- ❖ From ΔBGE, $\sin\theta = GE/BE = GE/d \Rightarrow GE = d \sin\theta$.
- ❖ From ΔBHE, $\sin\theta = EH/BE = EH/d \Rightarrow EH = d \sin\theta$.
- ❖ Path difference = GE+EH = $2d \sin\theta$.
- ❖ Bragg's law states that the X-rays reflected from different parallel planes of a crystal interfere constructively when the path difference is integral multiple of the wavelength of X-rays. i.e. $2d \sin\theta = n\lambda$.

5

b) Analyze the **determination of crystal structure using the powder method** with a neat diagram. *(L4, CO5)*

Diaram + Explanation ---------- 1+4---5m

Powder method: (debye-Schrrer method)

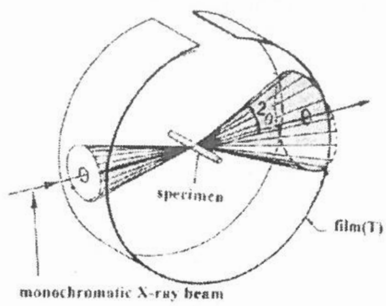
This is the only method which can be used with large classes of substance which are microcrystalline.In this method instead of using a simple crystal a fine crystal powder is used.

Principle:-

The basic principle in this powder technique is since millions of tiny crystalline have all possible random orientations, several values of θ and d are available to the incident X-ray beam.

Experimental arrangement:

This method is used to determining the structure of solids which are in the form of tiny crystalline powder. The powdered sample is pasted on a thin wire and placed along the axis of cylindrical shaped photographic films at its centre.



X-rays from a suitable source are passed through a filter which absorbs all the wavelengths except one wavelength thus monochromatic beam is produced by passing through the fine slits S1and S2.

As there is large number of randomly oriented crystallites in the powder, many possible orientations of this set of planes will be present and the reflected rays will be in the form lying on the surface of the cone.

The reflected rays (beams) will emerge out in all the directions inclined at an angle 2θ with the direction of the incident beam.

They form a cone whose semi vertical angle is 2θ and the apex of the cone is the point of contact of X-rays with the specimen.

For a fixed value of n, there will be several values of θ and d that satisfies Bragg's condition.

For each combination, the cone of reflection is formed.

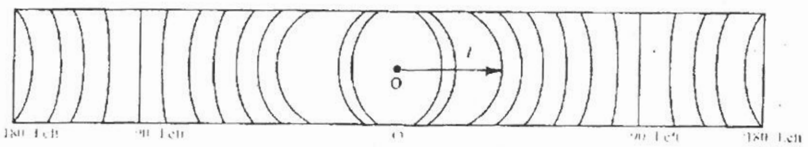
If 'l'is the distance from 0 to A, and R is the radius of the camera, then is

$\theta = l/2R \ (2\theta = l/R)$

If S is the length of the screen then we can write $4\theta = S/R \Rightarrow \theta = S/4R$

Paralle $\theta_1 = S_1/4R$, $\theta_2 = S_2/4R$ and so on.

The following figure shows the diffraction cones marked as arcs on the film strip.



Lines on the powder photograph film

UNIT - III

6 a) Derive the **Clausius–Mossotti relation** in dielectrics. *(L3, CO3)*

derivation ----5m

Clausius Mosotti Equation

The relation is in between the microscopic property called molecular Polaris ability and macroscopic property called dielectric constant.

The dipole moment $\bar{P}_m$ or $\bar{P}_i$ induced in the molecule to the local field or polarizing field E_L or E_m that is

$$\alpha = \frac{P_i}{E_i} \text{ or } \frac{P_m}{E_m}$$

$$P_i = \alpha E_i \qquad \text{or} \qquad P_m = \alpha E_m$$

If there are N number molecules per and volume of the dielectric then the polarization $\bar{p}$ is given by

$$\bar{p} = N\bar{P}_i = N\alpha\bar{E}_L \qquad \ldots(1)$$

According to lorentz equation the polarizing field acting on a single atom or molecule of a non-polar dielectric in macroscopic field $\bar{E}$ is

$$\bar{E}_L = \bar{E} + \frac{\bar{P}}{3\epsilon_0}$$

Therefore

$$\bar{p} = N\alpha \; \bar{E} + \frac{P}{3\epsilon_0}$$

Now $\qquad P = n\alpha E_{loc} = n\alpha\left[E + \frac{P}{3\varepsilon_0}\right]$

Also $\qquad \chi_e = \frac{P}{3\varepsilon_0} = \frac{n\alpha\left[E + \frac{P}{3\varepsilon_0}\right]}{\varepsilon_0 E} = n\alpha\left[\frac{1}{\varepsilon_0} + \frac{P}{3\varepsilon_0^2 E}\right]$

or $\qquad \chi_e = n\alpha\left[\frac{1}{\varepsilon_0} + \frac{\chi_e}{3\varepsilon_0}\right] \Rightarrow \chi_e = \frac{n\alpha}{\varepsilon_0}\Big/\left(1 - \frac{n\alpha}{3\varepsilon_0}\right)$

Now, we know that

$$\varepsilon_r = 1 + \chi_e$$

$\therefore \qquad \varepsilon_r = 1 + \frac{n\alpha}{\varepsilon_0}\Big/\left(1 - \frac{n\alpha}{3\varepsilon_0}\right) = \frac{1 + \frac{2n\alpha}{3\varepsilon_0}}{1 - \frac{2n\alpha}{3\varepsilon_0}}$

On rearranging, we have $\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{n\alpha}{3\varepsilon_0}$.

6. **b)** Illustrate the **frequency dependence of various dielectric polarization processes** with a neat graph. *(L3, CO3)*

Diaram + Explanation ---------- 1+4---5m

Polarization Mechanisms & Frequencies :

1. **Electronic Polarization**: Very fast (optical frequencies, ~10^{15} Hz); electrons lag electric field but the cloud adjusts instantly, contributing at all frequencies.
2. **Ionic (Atomic) Polarization**: Slower (~10^{13} Hz, infrared); ions shift relative to each other, contributing at higher frequencies than dipoles.
3. **Dipolar (Orientation) Polarization**: Even slower (~10^{6} Hz, electrical frequencies); permanent dipoles align with the field, but lag significantly at high frequencies, causing large loss peaks.
4. **Space-Charge (Maxwell-Wagner) Polarization**: Slowest (~10^{2} Hz, power frequencies); charge carriers migrate to interfaces, ceasing to respond at high frequencies, contributing most at very low frequencies.

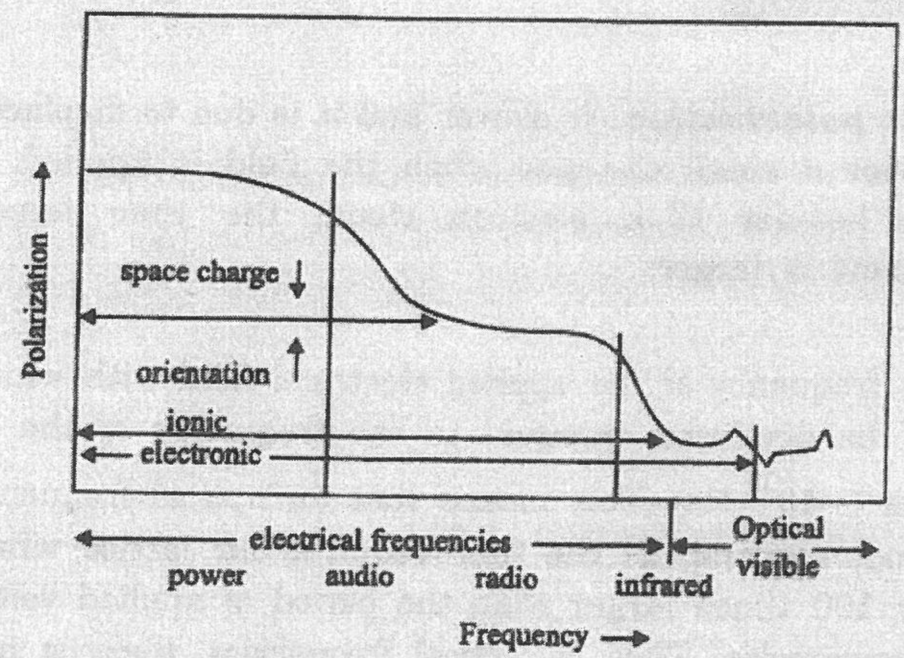


Fig. 1.9 Frequency dependence of various polarisation processes

OR

7 **a)** Deduce an expression for the **Bohr magneton** (atomic origin of magnetism). *(L4, CO5)*

Derivation **origin of magnetic moment +Nuclear Magnetic momentum+ Spin Magnetic---- 3+1+1 -- 5m**

ORIGIN OF MAGNETIC MOMENT:

♠ The magnetic moment in a material due to the orbital motion and spinning motion of electrons in an atom.

♠ when a magnetic moment is obtained through the motion of electrons in various orbits of an atom, it is called **orbital magnetic moment**.

♠ In an atom, every two electrons will form a pair and they have opposite spins. Thus resultant spin magnetic moment is zero.

♠ But in magnetic materials like iron, cobalt, nickel, there are unpaired electrons.

♠ This unpaired electrons contributes **spin magnetic moment**.

♠ These unpaired electron spins are responsible for ferro and paramagnetic behavior of materials.

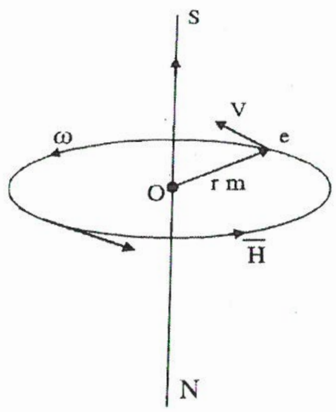
♠ The value of spin magnetic moment is larger than orbital magnetic moment.

<u>Note:</u> Magnetic moment arises due to

1) Magnetic moment due to orbital motion of the electron:

♠ The revolving and rotating electrons constitute current loops.

Each loop is like a magnet with one face as a north pole and Other face as a south pole. consider an electron moving in a circular orbit of radius r angular velocity 'ω' With Current produced due to this Motion is given by I = $\frac{q}{t} = \frac{e}{T}$ where T is the time taken to complete one revolution.



the magnetic moment associated with this electron is $\mu = iA = \frac{e}{T}\pi r^2$. Where πr^2 is area of the circular orbit.

♠ we know that $\omega = 2\pi n = \frac{2\pi}{T} \Rightarrow T = \frac{2\pi}{\omega}$.

$$\therefore \mu = \frac{e\pi r^2}{2\pi}\omega = \frac{er}{2}(r\omega) = \frac{erv}{2} \text{------ (1)}(\because linear velocity v = r\omega)$$

♠ In case of circular motion, Angular momentum L = mvr ⇒ vr = L/m.

From equa-----(1), $\mu_l = \frac{eL}{2m} \Rightarrow \frac{\mu_l}{L} = \frac{e}{2m}$

♠ The ratio of orbital magnetic moment μ_l to the angular momentum L is known as

Gyromagnetic ratio. $\therefore \mu_l = \frac{e}{2m}L$ ------ (2)

♠ According to quantum theory, the angular momentum is given by $L = l\frac{h}{2\pi}$ ----- (3)

From (2) and (3). We get $\mu_l = \frac{e}{2m}\frac{lh}{2\pi} = \left[\frac{eh}{4\pi m}\right]l$ ------- (4) (l is orbital quantum number).

Here $\left[\frac{eh}{4\pi m}\right]$ is known as **Bohr magneton.**

$\therefore \mu_l = \mu_B l$

Its value is given by $\mu_B = \left[\frac{eh}{4\pi m}\right] = 9.27X10^{-24}$ A-m^2

Note: Bohr magneton is the fundamental unit for magnetic moment.

2) MAGNETIC MOMENT DUE TO SPIN MOTION:

♠ An electron spins around itself which produces spin magnetic moment. According to quantum theory, the spin angular momentum is $+\frac{h}{4\pi}$ or $-\frac{h}{4\pi}$.

♠ The relation between spin angular momentum' S' and spin magnetic moment μ_s is given by $\mu_s = \frac{e}{m_s}S = \left[\frac{eh}{4\pi m}\right] = \mu_B \Rightarrow \mu_s = \mu_B$

Thus spin magnetic moment is Bohr magneton.

3) MAGNETIC MOMENT DUE TO SPIN OF PROTON:

♠ Magnetic moment due to nucleus spin is given by $\mu_n = \left[\frac{eh}{4\pi m_p}\right]$

Where m_p is the mass of proton. $\mu_n = 5.05X10^{-27}$A-m^2

♠ The value μ_n is small compare to μ_B. So this contribution can be neglected.

7) b) **Distinguish between** diamagnetic, paramagnetic, and ferromagnetic materials **with suitable examples.** ***(L4, CO5)***

Any Three differences ------------------5m

CLASSIFICATION OF MAGNETIC MATERIALS:

- Magnetic materials are classified on the basis of magnetic properties of the **atomic dipoles** and the interaction between them.
- ♠ If the atoms of an element possess net moment, they act as **magnetic dipoles**.
- ♠ Based on the nature and degree of response to the external magnetic fields, materials are classified into different magnetic materials.
- ♠ Based on the values of relative permeability and magnetic susceptibility χ_B the materials are classified into **Dia**, **Para** and **Ferro** magnetic materials.
- ♠ Materials which lack permanent dipoles are called **diamagnetic**.
- ♠ If the permanent dipoles do not interact among themselves, the material is **paramagnetic**.
- ♠ If the interaction among permanent dipoles is strong then the material is **Ferromagnetic** material.
- ♠ If the permanent dipoles line up in anti parallel the material is **anti**-ferromagnetic.
- ♠ Based on the nature of magnetization curve (Hysterisis), ferromagnetic are divided into **soft** and **hard** magnetic materials.

DIAMAGNETIC MATERIALS:

- ♠ The substances which are repelled by magnetic are called **diamagnetic** materials.
  Ex :- Antimony, Bismuth, Copper, etc.,
- ♠ The atoms in the diamagnetic material contains as many electrons orbiting in clockwise as in anticlockwise direction.
- ♠ Thus **net magnetic moment is zero** in these materials.

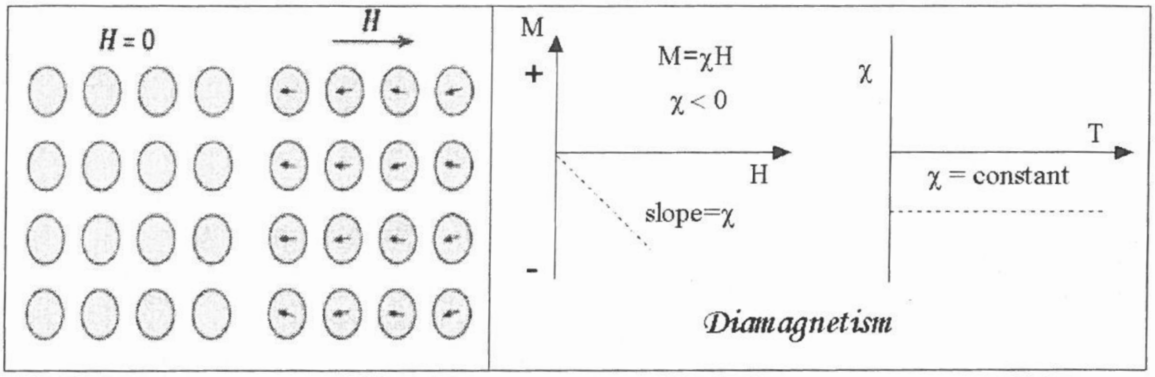
PROPERTIES:

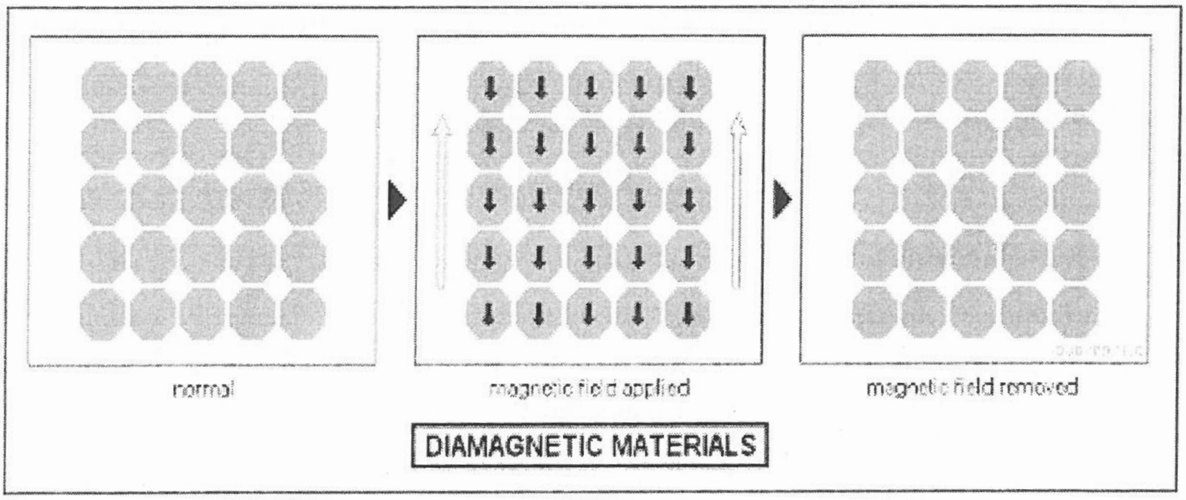
- ♠ The induced magnetic moment is always in the opposite direction of the applied field.
- ♠ Permanent dipoles are absent.
- ♠ When placed in a magnetic field, the magnetic lines of force are repelled.
- ♠ In a non uniform magnetic field they move from stronger part to weaker part of field.
- ♠ If it is suspended freely it comes to rest perpendicular to the direction of field.

♠ The magnetic lines of force shows less performance to pass through the substance than through the air, so relative permeability μ_r is less than 1.

♠ The susceptibility χ_B is small and negative.

♠ The diamagnetic susceptibility is independent of temperature.



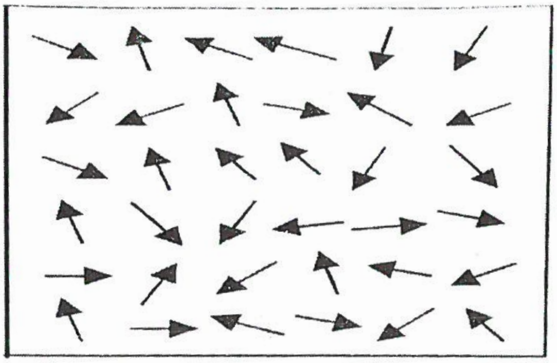


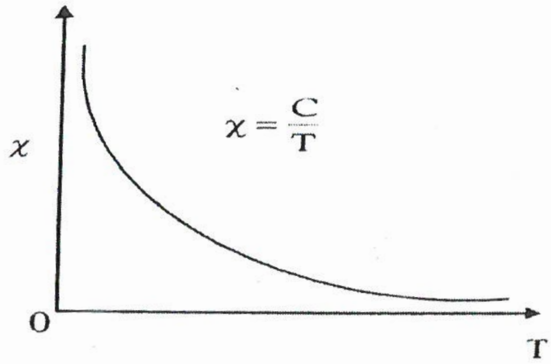
PARA MAGNETIC MATERIALS:

♠ The substances which are attracted by the magnet are called **paramagnetic**.

♠ The **induced magnetism** is the source of Para magnetism.

Ex :- Aluminum, Platinum, Tungsten, Nitrogen





PROPERTIES:

♠ The spin of unpaired electrons is responsible for paramagnetic behavior of materials.

♠ The induced magnetism is in the direction of applied magnetic field.

♠ In each atom there is a resultant magnetic moment even in the absence of field.

♠ But due to thermal agitations, orientation is random. Thus the material is unmagnified.

♠ When placed in a non-uniform magnetic field, they move from weaker part to stronger part of the field.

♠ If it is suspended freely it comes to rest in the field direction.

♠ The magnetic lines of force shows little more performance to pass through the substance than through air. So μ_r is greater than 1.

♠ Susceptibility χ_B is small and positive.

♠ The paramagnetic susceptibility is inversely proportional to temperature. i.e., $\chi_m \propto \frac{1}{T}$

♠ Spin alignment is as shown in the figure.

Note: **Weiss** formulated the following relation from the Curie's law as

$$\chi_B = \frac{C}{T-\theta}$$ where θ is **Curie** temperature.

If T< θ, paramagnetic become diamagnetic.

FERROMAGNETIC MATERIALS:

♠ The substances which are strongly attracted by magnets are called **ferromagnetic** Materials.

Ex :- Iron, Nickel, Cobalt

♠ Ferromagnetism is a phenomenon by which **spontaneous magnetization** occurs when $\boxed{T \le \theta}$ and so even in the absence of applied field.

PROPERTIES:

♠ These materials acquire strong magnetism in the direction of applied field.

♠ In non-uniform magnetic field they move from weaker to stronger part of the field.

♠ When it is suspended freely after some time it comes to rest in the field direction.

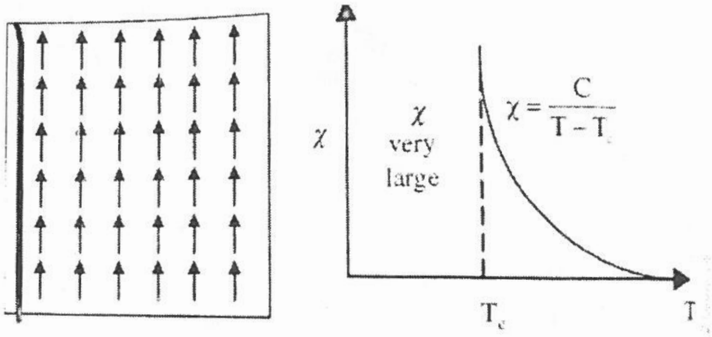
♠ The magnetic lines of force shows more performance to pass through the substance than through air, so permeability is large. i.e., $\boxed{\mu_r >> 1}$.

♠ Susceptibility χ_B is large and positive.

♠ When heated these materials turn into paramagnetic materials above a temperature known as **CURIE TEMPERATURE.**

♠ The stronger effect of ferromagnetism is explained on the basis of magnetic dipole **domains.**

♠ Spin alignment is parallel in the same direction.



Variation of susceptibility with temperature is shown in the above figure.

UNIT – IV

8. **a)** Derive the **time-dependent Schrödinger wave equation** for a **free particle.** *(L3, CO3)*

Derivation ---7m

Time dependent schrodinger wave Equation may be obtained by Elimination of 'E'

$$\nabla^2\psi + \frac{2m}{\hbar^2}[E-V]\psi = 0$$

$$\psi = \psi_0 e^{-i\omega t}$$

$$\frac{\partial\psi}{\partial t} = -i\omega\psi_0 e^{-i\omega t}$$

$\omega = 2\pi n$

$E = h\nu$

$$\frac{\partial \psi}{\partial t} = \frac{-2\pi i E}{h}\psi \qquad (\hbar = h/2\pi)$$

$$\frac{\partial \psi}{\partial t} = \frac{-iE}{\hbar}\psi$$

$$\frac{\partial \psi}{\partial t} = \frac{-iE}{\hbar}\psi \times \frac{i}{i}$$

$$E\psi = i\hbar \frac{\partial \psi}{\partial t}$$

Substituting Eqn ①

$$\nabla^2\psi + \frac{2m}{\hbar^2}\left[i\hbar\frac{\partial\psi}{\partial t} - V\psi\right] = 0$$

$$\nabla^2\psi = -\frac{2m}{\hbar^2}\left[i\hbar\frac{\partial\psi}{\partial t} - V\psi\right]$$

$$-\frac{\hbar^2}{2m}\nabla^2\psi + V\psi = i\hbar\frac{\partial\psi}{\partial t}$$

$$\left[-\frac{\hbar^2}{2m}\nabla^2 + V\right]\psi = \left(i\hbar\frac{\partial}{\partial t}\right)\psi \Rightarrow E\psi = V\psi$$

8 **b)** An electron is bound in a **one-dimensional infinite potential well** of width 1×10−10m Calculate the **energy of the ground state and first excited state.** *(L3, CO3)*

Formula + Substitution + Answer (1+1+1) → 3m

Sol:- $E = \frac{n^2h^2}{8mL^2}$

$L = 1\times10^{-10}m$; $m = 9.1\times10^{-31}kg$

$$E_1 = \frac{1^2\times(6.626\times10^{-34})^2}{8\times9.1\times10^{-31}\times(1\times10^{-10})^2} \simeq 6.024\times10^{-19}J$$

$$E_2 = \frac{2^2h^2}{8mL^2} \simeq 2.409\times10^{-18}J$$

OR

9a) Establish an expression for **electrical conductivity based on quantum free electron theory**. *(L4, CO5)*

→ Electrical conductivity According to Quantum free electron Theory, The electron move freely in a solid with constant potential, (V=0)

(Assuming V = 0)

$$-\frac{\hbar^2}{2m}\nabla^2\psi = E\psi \rightarrow (1)$$

$$\psi = \psi_0 \exp^{(ikx)}$$

$$\frac{\partial^2\psi}{\partial x^2} = -K_x^2\psi$$

||ly

$$\nabla^2\psi = -K^2\psi \longrightarrow (2)$$

substituting (2) in (1)

$$-\frac{\hbar^2}{2m}\nabla^2\psi = E\psi$$

$$-\frac{\hbar^2}{2m}\times -K^2\psi = E\psi$$

$$E = P^2/2m$$

$$E = \frac{\hbar^2K^2}{2m};\quad K = \frac{n\pi}{L} \Rightarrow E = \frac{n^2h^2}{8mL^2}$$

→ When an external electrical field is applied electron produces a force $-eE$

$$-eE = dP/dt$$

$$P = h/\lambda = \frac{h}{2\pi}\times\frac{2\pi}{\lambda} = \hbar K$$

$$-eE = \frac{d}{dt}[\hbar K] = \hbar\frac{dK}{dt}$$

$$dK = -\frac{eE}{\hbar}\times dt$$

$$P = mv = \hbar K \Rightarrow \Delta v = \frac{\hbar}{m}\Delta K$$

$$\Delta v = \frac{\hbar}{m}\times\left(-\frac{eE}{\hbar}\right)\times dt$$

$$\Delta v = -\frac{eE\tau}{m}$$

$$J = \sigma E$$

$$J = nev_d \Rightarrow ne\Delta v$$

$$J = -ne\times eE\tau \Rightarrow J = \frac{ne^2\tau}{m}\times E$$

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

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

'σ' is known as electrical conductivity

9b) List the **postulates of quantum free electron theory (Sommerfeld theory).** *(L4, CO5)*

1. In a metal the available free electrons are fully responsible for electrical conduction.

2. The electrons move in a constant potential inside the metal.

3. Electrons have wave nature, the velocity and energy distribution of the electron is given by Fermi-Dirac distribution function.

4. The loss of energy due to interaction of the free electron with the other free electron.
5.Electron's distributed in various energy levels according to Pauli Exclusion Principle.

Unit-v

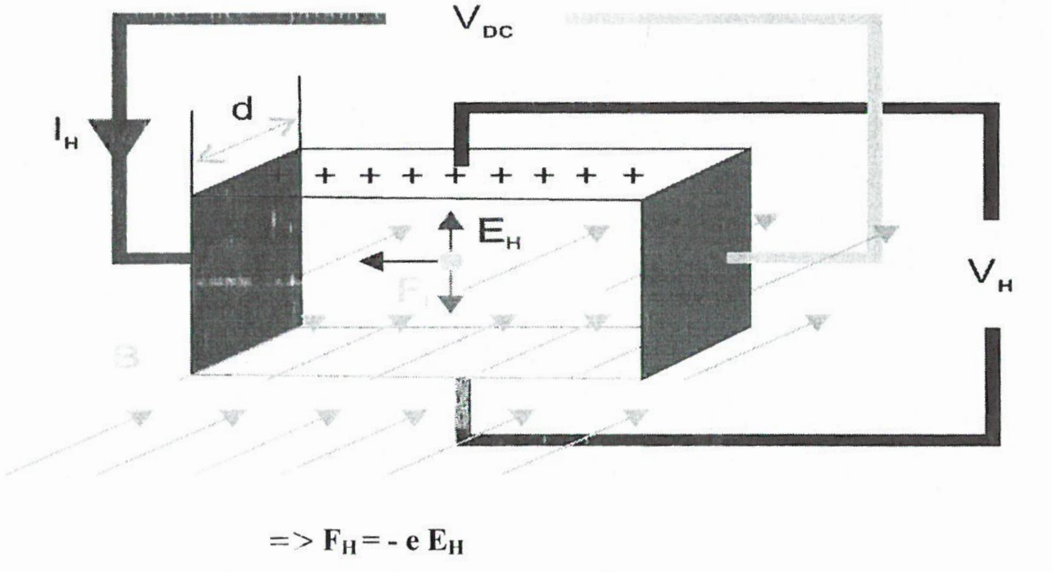
10. **a)** Demonstrate the **Hall effect** and obtain an expression for the **Hall coefficient**. *(L3, CO2)*

HALL EFFECT:

When a slab of metal or semiconductor carrying current is placed in a transverse magnetic field, a potential difference is produced in the direction normal to both current and magnetic field. This phenomenon is called 'Hall Effect' and the generated voltage is known as 'Hall Voltage'.

Consider a slab of conductor in which a current I is flowing in the positive x-direction. Let a magnetic field 'B' is applied along the Z- direction then the electrons experience a Lorentz force given by

$$F_L = - B.e.V_d \qquad V_d \text{ - drift velocity}$$



$$=> F_H = - e\, E_H$$

At equilibrium position the two forces acting on electrons are equal.

i.e $F_L = F_H$

$$=> e\, E_H = - B.e.V_d$$

OR

11 a) Deduce an expression for the **electrical conductivity of a semiconductor**. *(L4, CO4)*

In semiconductor, the total current is sum of holes and electrons.

Total current = Electrical current + Hole current

Electrical current density $J_e = nev_e = ne\mu_n E$

Hole current density $J_h = pev_h = pe\mu_p E$

$J = J_e + J_h = nev_e + pev_h$

$J = ne\mu_e E + pe\mu_p E$

$J = E[ne\mu_e + pe\mu_p]$

$J = \sigma E \Rightarrow \boxed{\sigma = ne\mu_e + pe\mu_p}$

11 b) Develop **Einstein's equation**. *(L4, CO4)*

The relation b/w Diffusion co-efficient & mobility is known as Einstein's Equation.

Under Equilibrium condition, Drift current is equal to Diffusion current.

Drift current $= (\Delta n) \times e \times \mu \times E$

Diffusion current $= \frac{-d(\Delta n)}{dx} \times D_n \times e$

$\Delta n \times e \times \mu \times E = \frac{d \Delta n}{dx} \times D_n \times e$

$\Delta n = \frac{d \Delta n}{dx} \times \frac{D_n}{\mu \times E} \rightarrow (1)$

$F = (\Delta n) \times e \times E$

According to kinetic theory of gases

$F = kT \, d\left(\frac{\Delta n}{dx}\right) \rightarrow (2)$

Comparing (1) = (2) $\quad \frac{D_n}{\mu_n} = \frac{kT}{e}$

Ily $\quad \frac{D_p}{\mu_p} = \frac{kT}{e}$

$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} \Rightarrow \frac{D_n}{D_p} = \frac{\mu_n}{\mu_p} \Rightarrow \boxed{D \propto \mu}$

The current density $\mathbf{J = - n\, e\, V_d}$

$\mathbf{V_d = - J/ne}$ **or** $\mathbf{E_H = - JB/ne}$

The Hall Effect is described in terms of the Hall coefficient R_H

$$\Rightarrow R_H = -1/ne$$

$$\Rightarrow E_H = R_H.\, JB$$

$$\Rightarrow R_H = E_H / J\,B = -1/ ne$$

Determination of Hall Coefficient:

The Hall electric field per unit current density per unit magnetic induction is called Hall Coefficient

(R_H).

If 'w' is the width of the sample across which Hall Voltage V_H is measured by

$\mathbf{E_H = V_H / w}$ $\quad\Rightarrow \mathbf{R_H = E_H / J\,B = V_H / J\,B\,w}$

If 't' is the thickness of the sample, then its cross section is 'wt' and the current density,

$\mathbf{J = I / wt}$ $\quad\Rightarrow \mathbf{V_H = R_H.I.B / t}$

$\Rightarrow R_H = V_H.t / IB$

10 b) Differentiate between p-type and n-type semiconductors. ***(L3, CO2)***

S. No.	n-type Semiconductor	p-type Semiconductor
1	When a **pentavalent impurity** is added to an intrinsic semiconductor, an **n-type semiconductor** is formed.	When a **trivalent impurity** is added to an intrinsic semiconductor, a **p-type semiconductor** is formed.
2	The impurity is called a **donor impurity** because it donates free electrons.	The impurity is called an **acceptor impurity** because it accepts electrons.
3	**Majority charge carriers** are electrons.	**Majority charge carriers** are holes.
4	**Minority charge carriers** are holes.	**Minority charge carriers** are electrons.
5	The **donor energy level** lies very close to the bottom of the **conduction band**.	The **acceptor energy level** lies very close to the top of the **valence band**.
6	The **Fermi energy level decreases** with an increase in temperature.	The **Fermi energy level increases** with an increase in temperature.