9	a)	Explain the concept of density of states.	L3	CO3	2 M
	b)	Explain Fermi energy and Fermi Dirac distribution function. Illustrate the effect of temperature on the distribution.	L4	CO5	8 M
		UNIT-V			
10	a)	Derive an expression for the carrier concentration of P-type Extrinsic semiconductor.	L4	CO4	6 M
	b)	Explain Insulators, semiconductors, conductors according to origin of energy band theory.	L3	CO2	4 M
		OR			
11	a)	Define Hall effect. Derive an expression for the Hall coefficient.	L4	CO4	6 M
	b)	Explain Drift, Diffusion currents.	L3	CO2	4 M

Code: 23BS1203

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

ENGINEERING PHYSICS
(Common for EEE, ECE, CSE)

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)	Describe the properties or characteristics of LASER.	L2	CO1
1.b)	State the basic principle used in optical fiber for transmission of light.	L1	CO1
1.c)	Establish a relation between the atomic radius(r) and the interatomic distance (a) for a Face centered cubic unit cell.	L3	CO3
1.d)	Illustrate any two applications of X-ray diffraction studies.	L3	CO3
1.e)	Develop the following relation $P= \varepsilon_0 (\varepsilon_r -1) E$.	L4	CO5
1.f)	Deduce the relation $B = \mu_0 (M+H)$.	L3	CO3
1.g)	Show that De-brogile wavelength $\lambda = h/P$.	L3	CO3
1.h)	Discuss the salient features of classical free electron Theory.	L3	CO3

1.i)	Illustrate the energy level diagrams for intrinsic and extrinsic (P-type, N-type) semiconductors.	L4	CO4
1.j)	List any two applications of Hall effect.	L1	CO1

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Demonstrate construction and working mechanism of He-Ne Laser with suitable diagram.	L3	CO2	6 M
	b)	Distinguish spontaneous and stimulated emissions.	L4	CO4	4 M
		OR			
3	a)	Obtain an expression for numerical aperture of an optical fiber in terms of refractive indices of core and cladding.	L3	CO2	5 M
	b)	An optical fiber has the core and cladding refractive indices 1.45 and 1.44 respectively. Find the acceptance angle of optical fiber. 9.78	L4	CO4	5 M
		UNIT-II			
4	a)	Show that FCC is the most closely packed of the three cubic structures by working out the packing fractions.	L3	CO3	6 M
	b)	Copper has FCC structure and the atomic radius is 0.1278nm. Calculate the inter planar spacing for (110) plane.	L4	CO5	4 M

0.2556

		OR			
5	a)	Explain Bragg's law for the reinforcement of diffracted X-rays from a set of planes.	L4	CO5	4 M
	b)	Illustrate Laue's method with a neat diagram for the determination of crystal structure.	L3	CO3	6 M
		UNIT-III			
6	a)	Define the term relative permittivity. Derive an expression for Clausius-Mosotti equation.	L4	CO5	5 M
	b)	Discuss the Electronic polarization and derive the Electronic polarizability.	L3	CO3	5 M
		OR			
7	a)	Differentiate between hard and soft magnetic materials? Explain their applications.	L4	CO5	5 M
	b)	Explain the important features of ferromagnetic materials?	L3	CO3	5 M
		UNIT-IV			
8	a)	Derive Schrodinger's Time independent wave equation for a free particle of mass 'm' and energy 'E'.	L3	CO3	6 M
	b)	Calculate the De Broglie's wave length associated with a proton moving with a velocity of 1/10th of velocity of light. (mass of proton = 1.67 x 10^{-27}kg). 1.32×10^{-4}	L4	CO5	4 M
		OR			

I B.Tech II Semester Regular/ Supplementary Examination May, 2025 PVP 23

SCHEME OF VALUATION

CODE: 23BS12C

I/IV B-Tech Regular
May-25

ENGNIEERING PHYSICS PART-A.

(1)(a) Four characteristics $-4\times\frac{1}{2} = 2$

(b) Principle + Explanation/diagram = 1+1 = 2

(c) Formula + Answer $(r = \frac{a}{2\sqrt{2}})$ = 1+1 = 2

(d) Two applications = 2×1 = 2

(e) Formula + Ans (Derivation) = 1+1 = 2

(f) Formula + Ans (Derivation) = 1+1 = 2

(g) Energy Eq + Derivation = 1+1 = 2

(h) Any two features of classical free e theory = 2×1 = 2

(i) Intrinsic + Extrinsic diagrams 1+1 = 2

(j) Any two application of Hall effect = 2×1 = 2

PART-B.

(2) (a) Construction 2M
Diagram + Energy level 2M = 6M
Working 2M

(b) Four Diff 4×1 = 4M

(3) (a) Def - 1M.
Dia - 1M. = 5M
Derivation - 3M

(b) Given data - 1 = 5M
Formula - 1
Sub - 1
Calc Ans - 2

(4) (a) S.C - 2M, B.C.C - 2M, F.C.C - 2M 6M

(b) Data + Formula + cal + Ans - 4M 4M

5) (a) Statement - 1M, Dia - 1M. & Exp e derivation - 2M = 4M

(b) Diagram - 2M, Explanation & Adv - 4M = 6M

6) a) Permittivity - 1M.
Derivation - 4M. - 5M

(b) Electronic polarization - 1M
Diagm + Derivation - 4M - 5M

7) (a) Any 5 diff of Soft & Hard magnetic materials 5×1 = 5M
(b) Any 5 Points in Ferro magnetic materias 5×1 = 5M

---

8) (a) wave length - 1M.
Quantum Mech - 1M - 6M
Derivation - 4M

(b) Given data - 1M
Formula - 1M - 4
substitution - 1M
Answer - 1M

(9) (a) Density of States Def - 1M
Formula - 1M } 2M

(b) Fermi energy - 2M
Fermi dirac distribution - 2M
Graph & Cases - 4M

---

(10) (a) upto Fermi energy - 3M
Final expression - 3M } 6M

(b) origin - 1M,
Conductor, Semi Conductor & Insulator 3×1 = 3M } 4M

11) (a) statement for Hall effect - 1M, Diagram - 1M
Hall Coefficient Derivation - 4M } 6M

(b) Drift current - Def + explanat - 2M
Diffusion current - Def + explanation - 2M } 4M

I B.Tech – II Semester – Regular Examination [PVP-23]
ENGINEERING PHYSICS

23BS1203

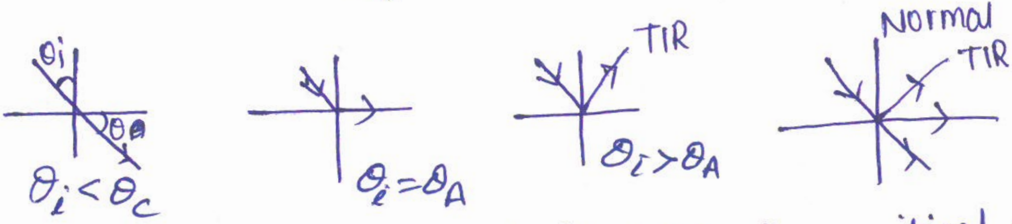
1.a) Describe the properties or characteristics of LASER. $(4 \times 1/2 = 2m)$

Ans. characteristics of laser:

1) monochromatic 2) unidirectionality 3) coherence 4) Brightness

1.b) State the basic principle used in optical fiber for transmission of light.

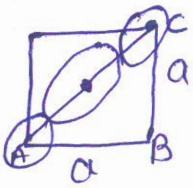
Ans. Total Internal Reflection – Principle $(1+1=2m)$



incident angle is greater than critical angle $(\theta_i > \theta_c)$

1.c) Establish a relation between the atomic radius (r) and the interatomic distance (a) for a Face centred Cubic unit cell.

Ans.



$$AC^2 = AB^2 + BC^2$$
$$\Rightarrow (r+2r+r)^2 = a^2 + a^2$$
$$\Rightarrow (4r)^2 = 2a^2$$
$$\Rightarrow 16r^2 = 2a^2$$
$$\Rightarrow r = \frac{a}{2\sqrt{2}}$$

1.d) Illustrate any two applications of X-Ray diffraction studies [ANY TWO] $2 \times 1 = 2M$

Ans. App:- ① To identify defects in solids

② ~~Drug~~ Crystal structure determined.

③ Interplanar spacing

④ to find glancing angle.

1.e) Develop the following relation $P = \varepsilon_0(\varepsilon_r - 1)E$.

Ans. Relation b/w dielectric constant & susceptability

wkt $D = \varepsilon E$

$= \varepsilon_0 \varepsilon_r E$ – ①

Relation b/w D, E & P is

$D = \varepsilon_0 E + P$ ②

Equation ① ②

$\varepsilon_0 \varepsilon_r E = \varepsilon_0 E + P$

Divide with $\varepsilon_0 E$

$\varepsilon_r = 1 + \frac{P}{\varepsilon_0 E}$

$(\varepsilon_r - 1) = \frac{P}{\varepsilon_0 E}$

$$\boxed{P = \varepsilon_0(\varepsilon_r - 1)E}$$

1(f)

1.f) Deduce the relation $B = \mu_0(M+H)$.

Ans. $B = \mu_0 [M+H]$

WKT $B = \mu H$ $\quad [\mu = \mu_0 \mu_r]$

$= \mu_0 \mu_r H$ $\quad$ Adding and subtraction $\mu_0 H$

$$B = \mu_0 \mu_r H - \mu_0 H + \mu_0 H$$

$$= \mu_0 H [\mu_r - 1] + \mu_0 H$$

wkt $\chi = \frac{M}{H}$

$M = \chi H = (\mu_r - 1) H$ $\quad [\text{wkT } \chi = \mu_r - 1]$

$$B = \mu_0 H + \mu M$$

$$\boxed{B = \mu_0 (H+M)}$$

1.g) Show that De-broglie wavelength $\lambda = h/p$

Ans. $\lambda = \frac{h}{p}$

wkt $E = h\nu$ −① [from plank's Quantum theory of radiation]

$E = mc^2$ −② [Energy-mass relation]

① = ②

$h\nu = mc^2$ $\quad [\nu = \frac{c}{\lambda}]$

$\frac{hc}{\lambda} = mc^2$

$$\lambda = \frac{h}{mc} = \frac{h}{mv} = \frac{h}{p}$$

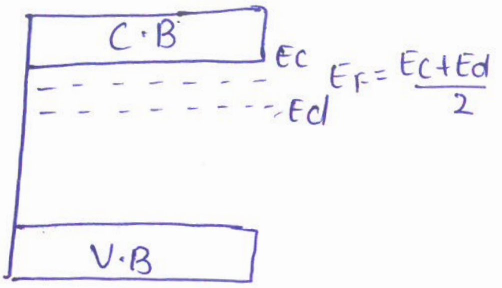
1.h) Discuss the salient features of classical free electron theory.

Ans. Salient features of classifal free electron theory [Any two 2×1=2]

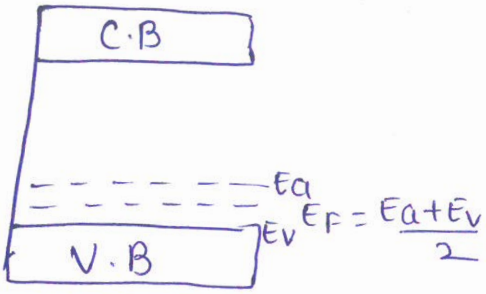
1) In metals there in large no. of free e^-, moving freely in all possible directions.
2) The free e^- in the metal are assumed to behave like gas molecules obeying the laws of kinetic theory of gases.
3) It verifies ohm's law.
4) It explains mechanism of electrical conductivity and thermal conductivity.

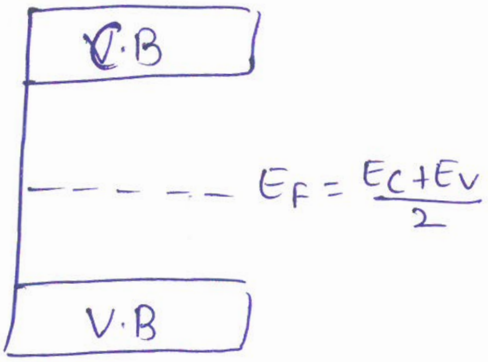
1.i.) Illustrate the energy level diagrams for intrinsic and extrinsic (P-type, N-type Semiconductor

Ans. N-type



P-type





Intrinsic Semiconductor

1.j.) List any two applications of Hall effect.

[2×1=2]

Ans. App. of Hall effect:

① The sign of charge carriers can be determined [P-type(or) N-type]

② Magnetic field can be measured by knowing V_H and R_H.

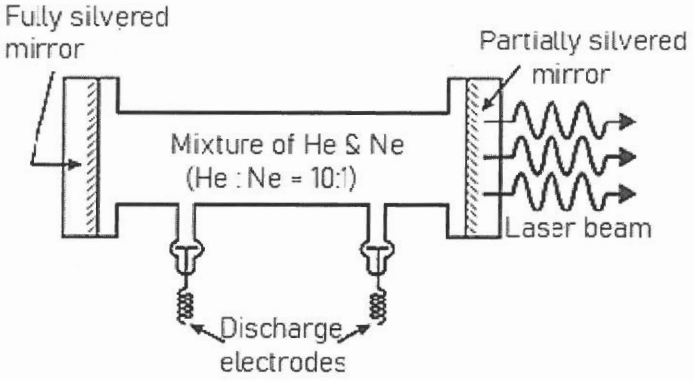
③ Carrier density / carrier concentration can be calculated.

Part B

2)a)

[2+2+2=6M]

A helium-neon (He-Ne) laser consists of a glass tube filled with a mixture of helium and neon gases, typically in a 10:1 ratio. Electrical discharge is used to excite the helium atoms, which then collide with neon atoms, causing them to jump to higher energy levels. The excited neon atoms emit photons, leading to laser action.



He - Ne LASER

Construction:

Active material:

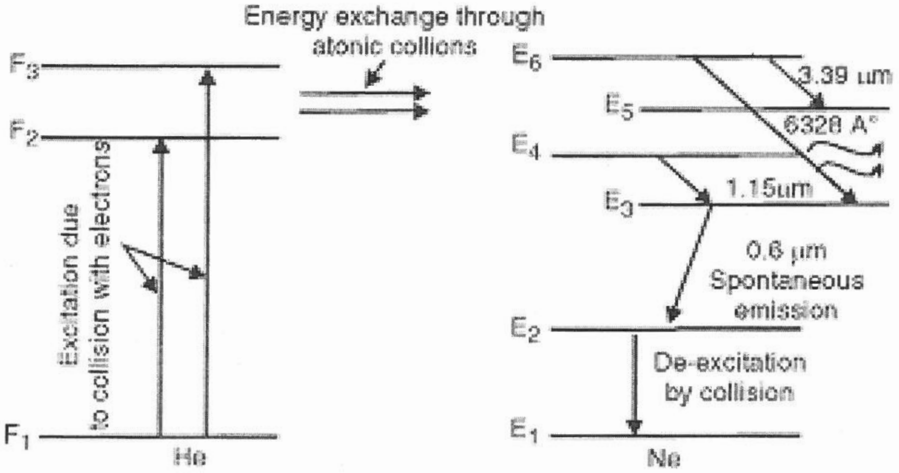
The He-Ne laser utilizes a glass tube containing a mixture of helium and neon gases. The ratio of helium to neon is typically 10:1. The majority carriers are helium and minority carriers are neon.

Resonating system:

The tube is placed between two mirrors. One mirror is partially silvered (output) and the other is fully silvered (high reflector). Laser beam emitting only on partially reflector side.

Excited system :

An electrical discharge is passed through the gas, exciting the helium atoms.



Working:

Excitation: An electrical discharge excites the helium atoms.

Energy Transfer:

Excited helium atoms collide with neon atoms, transferring energy to the neon atoms and causing them to jump to higher energy levels.

Population Inversion:

Neon atoms accumulate in specific excited states (metastable states) due to collisions, creating a state of population inversion.

Stimulated Emission:

As excited neon atoms decay to lower energy levels, they spontaneously emit photons. These photons stimulate further emissions, creating a coherent, amplified light beam.

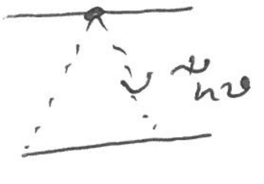
Laser Beam:

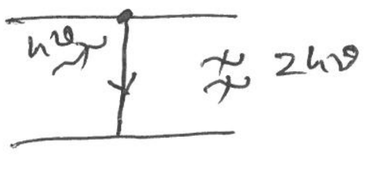
The stimulated emission of photons generates a laser beam with a specific wavelength (632.8 nm in air). .

Advantages: It emits continuous laser beam.
It is used in communication system.

2) b) $4 \times 1 = 4M$

Spontaneous emission	Stimulated emission
1. The atom jumps excited state to ground state	The atom jumps excited state to ground state
2. No incident photon is required	incident photon is required
3. Single photon is emitted	Double photon is emitted
4. Incoherent radiation	coherent radiation
5. Postulated by Bhor	Postulated by Einstein
6. Random direction	Same direction
7. diagram	





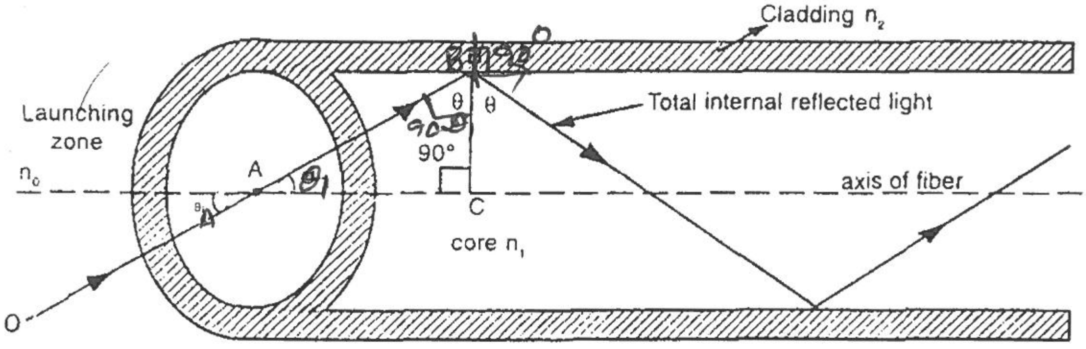
3) a)

NUMERICAL APERTURE:

[1+1+3 = (5M)]

Numerical aperture represents s the light gathering capacity of an optical fiber.

It is defined as the sine of the acceptance angle. i.e., NA= sinθ_A



Let the refractive indices of core and cladding are n_1 and n_2.

The ray refracts at an angle α_r and strikes the core-cladding interface at angle θ.

If $\theta > \theta_c$, the light ray gets totally reflected.

At pt 'O'

According to Snell's law, $\Rightarrow n_0 \sin \theta_A = n_1 \sin \theta_1$

$\Rightarrow n_0 \sin \theta_A = n_1 \sin (90 - \theta_1)$ (∵ [illegible])

$\Rightarrow \sin \theta_A = \frac{n_1}{n_0} \cos\theta$ — ①

At pt B.

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$n_1 \sin[90-\theta_1] = n_2 \sin 90$

$n_1 \cos\theta_1 = n_2$

$\cos\theta_1 = \frac{n_2}{n_1}$ — ②

$$\sin\theta_A = \frac{n_1}{n_0}\left[1-\cos^2\theta_1\right]^{1/2}$$

we

$$= \frac{n_1}{n_0}\sqrt{1-\frac{n_2^2}{n_1^2}}$$

$$= \frac{n_1}{n_0}\frac{\sqrt{n_1^2-n_2^2}}{n_1}$$

$$= \frac{\sqrt{n_1^2-n_2^2}}{n_0} \quad — ③$$

Numerical aperture of an optical fiber can be defined as NA= **sin θ_A** = $\frac{\sqrt{n_1^2 - n_2^2}}{n_0}$

$n_0 = 1$ for air

$$\boxed{NA = \sin\theta_A = \sqrt{n_1^2-n_2^2}}$$

3)b) $N\cdot A = \sqrt{n_1^2 - n_2^2} = \sqrt{(1.45)^2 - (1.44)^2}$ [1+1+1+2=5M]

$= \sqrt{2.1025 - 2.0736}$

$= \sqrt{0.0289}$

$\theta_A = \sin^{-1}(\sqrt{n_1^2 - n_2^2}) =$ ~~0.17~~ $\sin^{-1}(0.17) = 9^\circ.78'$

4) a)

{3×2=6M}

Packing faction: for Simple cube:

Lattice constant, $a = 2r$

Number of atoms in the Unit Cell = 1

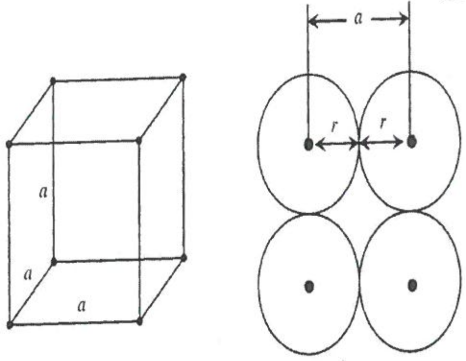
The volume occupied by atom in the unit call $\vartheta = 1 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi r^3$

The volume of unit cell $v = a^3$

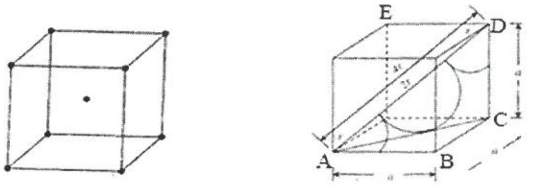
Packing fraction (or) density of packing of simple

Cubic unit cell (PF) = $\frac{\text{volume ocupied by atoms}(v)}{\text{volume of unit cell}(V)}$

$$= \frac{\frac{4}{3}\pi r^3}{a^3} = \frac{4\pi r^3}{3(2r)^3} = \frac{\pi}{6} = 0.52 = 52\%$$



Unit cell of a simple cubic structure



Unit Cell of a Body centered cubic structure

Packing fraction: for Body centered cube

Length of the body diagonal AD= 4r

$\therefore AD^2 = AC^2 + CD^2$

$AD^2 = AB^2 + BC^2 + CD^2$

$AD^2 = a^2 + a^2 + a^2$

$(4r)^2 = 3a^2$

$4r = \sqrt{3}a \Rightarrow a = \frac{4}{\sqrt{3}} r$

Lattice constant $a = \frac{4}{\sqrt{3}} r$

Number of atoms in the Unit Cell = 2

Volume occupied by the atoms in unit cell is $\vartheta = 2 \times \frac{4}{3}\pi r^3$

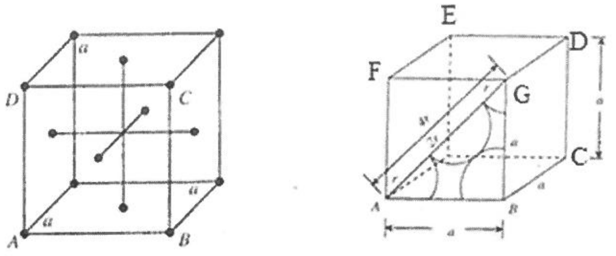
Volume of unit cell $= a^3$

$$\text{Atomic packing fraction} = \frac{\text{volume occupied by atoms}}{\text{Volume of unit cell}}$$

$$= \frac{2\times\frac{4}{3}\pi r^3}{a^3} = \frac{2\times4\times\pi r^3}{3\times(\frac{4}{\sqrt{3}}r)^3} = \frac{2\times4\times\pi r^3\times3\cdot\sqrt{3}}{3\times4\times4\times4\times r^3}$$

$$= \frac{\sqrt{3}\pi}{8} = 0\cdot68 = 68\%$$

Packing faction: for Face centered cube



Unit Cell of a Face centered cubic structure

Volume occupied by the atoms in FCC unit cell is $\vartheta = 4 \times \frac{4}{3}\pi r^3$

Volume of unit cell=a^3

From Fig,

$$AG = 4r$$

$$AG^2 = AB^2 + BG^2$$

$$(4r)^2 = a^2 + a^2$$

$$(4r)^2 = 2a^2$$

$$4r = \sqrt{2}a$$

$$a = 2\sqrt{2}\ r$$

Lattice constant $a = 2\sqrt{2}\ r$

Number of atoms in the Unit Cell = 4

Volume occupied by atoms in unit cell $\vartheta = 4 \times \frac{4}{3}\pi r^3$

Volume of unit cell V=a^3

$$\text{Atomic packing fraction} = \frac{\text{volume occupied by atoms}}{\text{Volume of unit cell}}$$

$$= \frac{4 \times \frac{4}{3}\pi r^3}{a^3} = \frac{4\times4\times\pi r^3}{3\times(2\sqrt{2}\,r)^3} = \frac{4\times4\times\pi r^3}{3\times8\times2\sqrt{2}\times r^3} = \frac{\pi}{3\sqrt{2}} = 0.74 = 74\%$$

4) b) Copper has FCC structure and the atomic radius is 0.1278nm. Calculate the inter planar spacing for (110) plane

[1+1+1+1=4M]

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

$$r = \frac{a}{2\sqrt{2}} \Rightarrow a = 2\sqrt{2}r$$

$$= 2\sqrt{2}\times0.1278$$

$$d = \frac{2\sqrt{2}\times0.1278}{\sqrt{1+1+0}}$$

$$= 2\times0.1278$$

$$= 0.2556nm$$

5) a)

Bragg's law:

[1+1+2=4M]

Statement

Bragg's law states that the path difference between the two reflected X-rays by the crystal planes should be an integral multiple of wave length of incident X-rays for producing maximum or constructive interference.

Path difference = n λ

Let us consider a set of parallel lattice planes of a crystal separated by a distance d apart. Suppose a narrow beam of X-rays of wave length λ be incident upon these planes at an angle θ as shown in the figure. Consider a ray PA reflected at the atom A in the direction AR from plane 1and another ray QB reflected at another atom B in the direction of BS. The path difference between the two rays is (CB+BD). When the path difference between the two rays is an integral multiple of X-rays wavelength, the constructive interference phenomenon will occur.

Thus the condition for constructive interference is

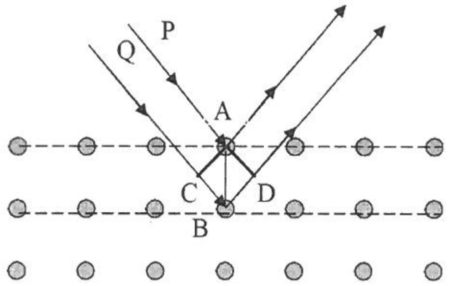
$$(CB+BD)=n\lambda$$

From ΔABC $\quad \sin\theta = \frac{CB}{AB} = \frac{CB}{d}$

$$CB = d\sin\theta$$

From ΔABD $\quad \sin\theta = \frac{BD}{AB} = \frac{BD}{d}$

$$BD = d\sin\theta$$



$$(CB+BD) = 2d\sin\theta$$

$$2d\sin\theta = n\lambda$$

Where $n = 1,2,3$............etc for first order, second order, third order ....etc

5) b)

Laue's method:

[2+4=6M]

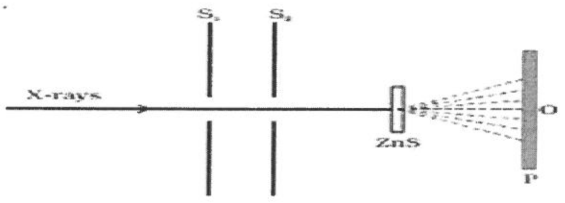


Fig (a) Laue experimental set up

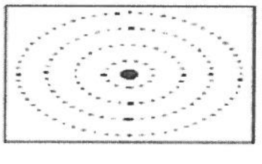


Fig (b) Laue spot

Von Laue, in 1913, suggested that a crystal can act as a three dimensional grating for an X-ray beam. The experimental arrangement used to produce diffraction in X-rays by Laue is shown in Fig (a). X-rays from the X-ray tube is collimated into a fine beam by two slits S_1 and S_2. The beam is now allowed to pass through a zinc sulphide (*ZnS*) crystal. The emergent rays are made to fall on a photographic plate P.

The diffraction pattern so obtained consists of a central spot at O and a series of spots arranged in a definite pattern about O as shown in Fig b. The central spot is due to the direct beam, whereas the regularly arranged spots are due to the diffraction pattern from the atoms of the various crystal planes. These spots are known as Laue spots.

To find imperfection or defects in crystal by using Laue's method.

6) a) Relative permittivity or **Dielectric Constant** :- it is defined as the ratio of the permittivity of the medium to the permittivity of the free space.

[1+4=5M]

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

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

$$\alpha = \frac{Pi}{E_L} \text{ or } \frac{P_m}{E_m}$$

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

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

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

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

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

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

Now, we know that

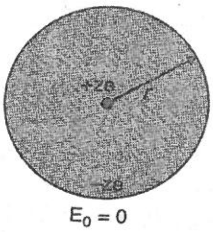
$$\varepsilon_r = 1 + \chi_e$$

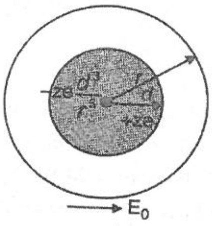
$\therefore$ $$\varepsilon_r = 1 + \frac{n\alpha}{\varepsilon_0}\bigg/\left(1 - \frac{n\alpha}{3\varepsilon_0}\right) = \frac{1 + \frac{2na}{3\varepsilon_0}}{1 - \frac{2na}{3\varepsilon_0}}$$

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

6) b) [1+1+3 = 5 M]

Electronic polarisation: opposite displacement of positively charged nucleus and electron cloud of an atom in opposite direction to the applied field.





Consider a nucleus of charge Ze surrounded by an electron cloud of charge –Ze symmetrically distributed in a sphere of radius R. The charge density is given by

$$\rho = \frac{CHARGE}{VOLEME} = \frac{-Ze}{\frac{4}{3}\pi R^3} \text{ --------1}$$

When an electric field E is applied, a Lorentz force acting on an electron cloud is

$$F = -ZeE$$

Hence nucleus and electron cloud are pulled apart. Thus establishing a columbic force.

At equilibrium distance x, these two forces balance each other. The negative charge in the sphere of radius x is

$$= \frac{4}{3}\pi x^3 \rho$$

$$= \frac{4}{3}\pi x^3 \frac{-Ze}{\frac{4}{3}\pi R^3}$$

$$= \frac{-Zex^3}{R^2}$$

Columbic force of attraction F = $\frac{1}{4\pi\varepsilon_0}$ Ze $\frac{-Zex^3}{R^3x^2}$ $\Rightarrow$ F=- $\frac{1}{4\pi\varepsilon_O}\frac{(Ze)^2 x}{R^3}$ -------- (3)

Lorentz force F = ZeE -------- (4)

Under equilibrium condition $F_L = -F_C$

$$\frac{1}{4\pi\varepsilon_O}\frac{(Ze)^2 x}{R^3} = ZeE$$

$$E = \frac{zex}{4\pi\varepsilon_0 R^3} \quad \text{------------- (5)}$$

We can write dipole moment $\mu_e = Zex$

We also know that $\mu_e = \alpha_e E$

Hence α_e E = Zex

$$E = \frac{Zex}{\alpha_e} \quad \text{------------------- (6)}$$

Equating 5 and 6 we get

$$\alpha_e = 4\pi\varepsilon_0 R^3$$

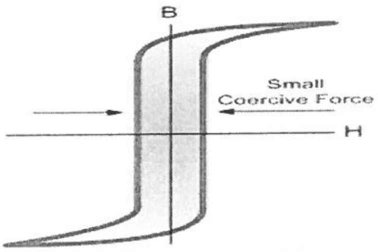
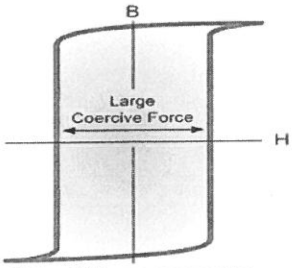
So it is proportional to volume of the atom.

$$\boxed{\alpha_e = 4\pi\varepsilon_O R^3}$$

~~7a)~~ 7) a)

Soft And Hard Magnetic Materials:

[5×1=5M]

SOFT MAGNETIC MATERIALS	HARD MAGNETIC MATERIALS
 "Soft" Ferromagnetic Material	 "Hard" Ferromagnetic Material
1.The figure shows nature of hysteresis loop of soft materials	1. The figure shows nature of hysteresis Loop of hard materials.
2. These materials can be easily Magnetized and demagnetized.	2.These materials cannot be easily Magnetized and demagnetized.
3.They have small hysteresis loss due to small area of loop.	3.They have large hysteresis loss due to large area of loop.
4.In these materials the domain wall Movement is easier. Even for a small change in applied field there is a large change in the magnetization.	4.In these materials the domain wall movement is difficult because of presence of impurity and defects.
5.The **coercivity** and **retentivity** are small.	5.The **coercivity** and **retentivity** are large.
6.They have high value of **susceptibility** and **permeability**.	6.They have small value of **susceptibility** and **permeability**.
7. The magnetostatic energy is very small since these are free from irregularities.	7. Because of presence of impurities and defects the mechanical strain is more. The magneto static energy is more.
APPLICATIONS: 1. These are used as magnetic core for direct current applications.	**APPLICATIONS:** These are used to prepare Permanent magnets.

~~7b)~~ 7) b)

[5×1 = 5M]

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 $\boxed{T \leq \theta}$ 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.

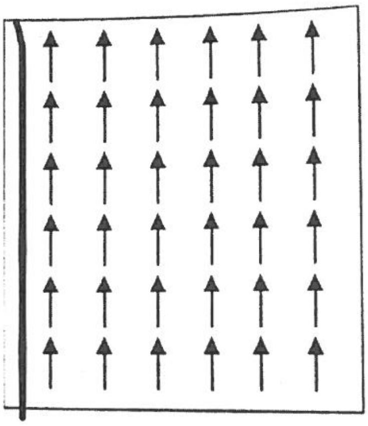
When it is suspended freely after some time it comes to rest in the field direction.

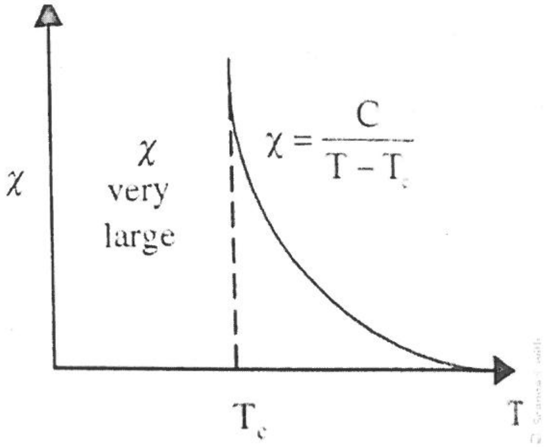
The magnetic lines of force show more performance to pass through the substance than through air, so permeability is large. i.e., $\boxed{\mu_r >> 1}$.

Susceptibility χ_B is large and positive.

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

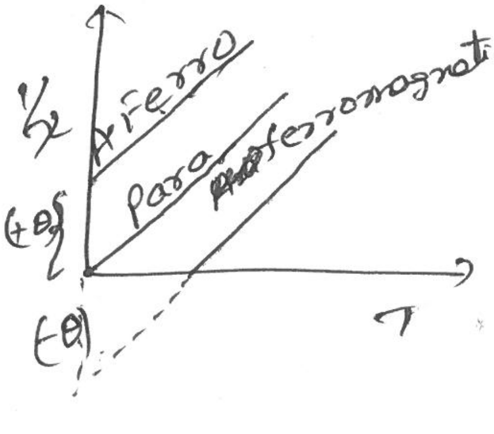
Spin alignment is parallel in the same direction.





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

$\frac{1}{\chi}$ vs T



$$\chi = \frac{C}{T - T_c}$$

$$\frac{1}{\chi} = \frac{T}{C} - \frac{T_c}{C}.$$

$$\boxed{y = mx - c.}$$

8)a) Derive Schrodinger's Time independent wave equation for a free particle of mass 'm' and energy 'E'

[2+2+2=6M]

"TIME INDEPENDENT SCHRODINGER WAVE EQUATION:" "The time - independent Schrodinger wave equation is a fundamental equation in quantum mechanics. It describes the stationary states of a quantum system and is derived by separating variables from the full, time dependent Schrödinger equation."

wave length $\lambda = \frac{h}{mv} = \frac{h}{p}$ - ①

In classical mechanism the wave eq is $\psi = A \sin \omega t$

In Quantum mechanis the wave eq is $\psi = A \sin \omega x$

$\psi = A \sin \frac{2\pi}{\lambda} x$

diff twice w.r.t. to x

$$\frac{\partial \psi}{\partial x} = A \cos \frac{2\pi}{\lambda} x \left[\frac{2\pi}{\lambda}\right]$$

$$\frac{\partial^2 \psi}{\partial x^2} = -A \sin \frac{2\pi}{\lambda} x \left[\frac{2\pi}{\lambda}\right]^2$$

$$= \frac{-4\pi^2}{\lambda^2} \psi$$

$$\boxed{\frac{1}{\lambda^2} = -\frac{1}{4\pi^2 \psi} \cdot \frac{\partial^2 \psi}{\partial x^2}}$$

we know that $E = KE + PE$

$$E = K.E + V$$

$$E - V = \frac{1}{2} m v^2 \times \frac{m}{m}$$

$$= \frac{p^2}{2m}$$

$$(E - V) = \frac{1}{2m} \frac{h^2}{\lambda^2}$$

$$= \frac{h^2}{2m} \left[\frac{-1}{4\pi^2 \psi} \frac{\partial^2 \psi}{\partial x^2}\right]$$

$$\frac{8m\pi^2 (E-V)\psi}{h^2} = -\frac{\partial^2 \psi}{\partial x^2}$$

$$\frac{\partial^2 \psi}{\partial x^2} + \frac{8m\pi^2}{h^2}(E - V)\psi = 0$$

$\left[\hbar = \frac{h}{2\pi}\right]$

$$\boxed{\frac{\partial^2 \psi}{\partial x^2} + \frac{2m}{\hbar^2}(E - V)\psi = 0}$$

[1+1+1+1=4M]

(8)
(b)

$v = \frac{1}{10} \times 3 \times 10^8$
$= 3 \times 10^7$ m/sec

$$\lambda = \frac{h}{mv} = \frac{6.625 \times 10^{-34}}{1.67 \times 10^{-27} \times 3 \times 10^7} = 1.32 \times 10^{-14}$$

$$\boxed{\lambda = 1.32 \times 10^{-4}}$$

9) a)

Density of States: "It is defined as the no. of States present per given energy range"

$$Z(E)\,dE = \frac{4\pi}{h^3}(2m)^{3/2}\,E^{1/2}\,dE$$

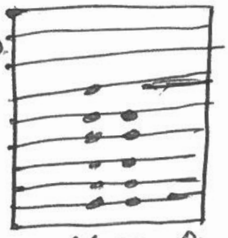
[1+1=2M]

b) Fermi Energy Level

[2+2+4=8M]

The Fermi energy level is the highest energy level occupied by electrons in a solid at absolute zero (0K).

Below fermi energy level filled with electrons.
Above fermi energy level is empty. E_F



At T=0°K.

The Fermi function f(E) gives the probability that a given available electron energy state will be occupied at a given temperature. the Fermi-Dirac distribution function

$$f(E) = \frac{1}{e^{(E - E_F)/kT} + 1}$$

The change in the electron distribution among energy levels for $T > 0$ K can be seen by plotting the Fermi–Dirac distribution function. If we let $E = E_F$ and $T > 0$ K, then Equation ([redacted]) becomes

$$f_F(E = E_F) = \frac{1}{1 + \exp(0)} = \frac{1}{1+1} = \frac{1}{2}$$

The probability of a state being occupied at $E = E_F$ is $\frac{1}{2}$. Figure [redacted] shows the Fermi–Dirac distribution function plotted for several temperatures, assuming that the Fermi energy is independent of temperature.

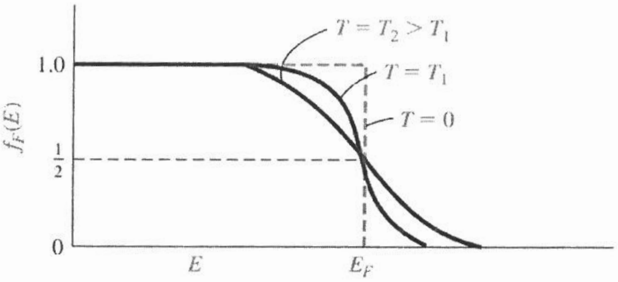


Figure [redacted] | The Fermi probability function versus energy for different temperatures.

10)a) Carrier concentration of p-type extrinsic semi-conductor:

[2+2+2=6 M]

We know that density of holes in valence band is

$$p = 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_v - E_F}{k_B T}\right)$$

$$N_a F(E_a) = \frac{N_a}{1 + \ exp\ \left(\frac{E_a - E_F}{K_B T}\right)}$$

When $E_a - E_F \gg K_B T$

$$N_a F(E_a) = N_a exp\ \left(\frac{E_a - E_F}{K_B T}\right)$$

The number of electrons present in the acceptor level is equal to the density of holes.

So,
$$2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_v - E_F}{k_B T}\right) = N_a\ exp\ \left(\frac{E_a - E_F}{K_B T}\right)$$

$$exp\left(\frac{E_v + E_a - 2E_F}{k_B T}\right) = \frac{N_a}{2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}}}$$

$$\left(\frac{E_v + E_a - 2E_F}{k_B T}\right) = log\ log\ \frac{N_a}{2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}}}$$

$$E_F = \frac{E_v + E_a}{2} - \frac{k_B T}{2} log\ log\ \frac{N_a}{2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}}}$$

So substituting E_F in density of holes

Then equation becomes $p = 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_v - \frac{E_v + E_a}{2} - \frac{k_B T}{2} loglog \frac{N_a}{2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}}}}{k_B T}\right)$

$$= 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\ exp \left(\frac{E_v - E_a}{2k_B T} + \frac{1}{2} log\ log \frac{N_a}{2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}}}\right)$$

$$= 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\ exp \left(\frac{E_v - E_a}{2k_B T} + log\ log \frac{N_a^{\frac{1}{2}}}{2^{\frac{1}{2}}\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{\frac{3}{4}}}\right)$$

$$p = (2N_d)^{\frac{1}{2}}\left(\frac{2\pi\, m_h^* k_B T}{h^2}\right)^{\frac{3}{4}} exp\left(\frac{E_v - E_a}{2k_B T}\right)$$

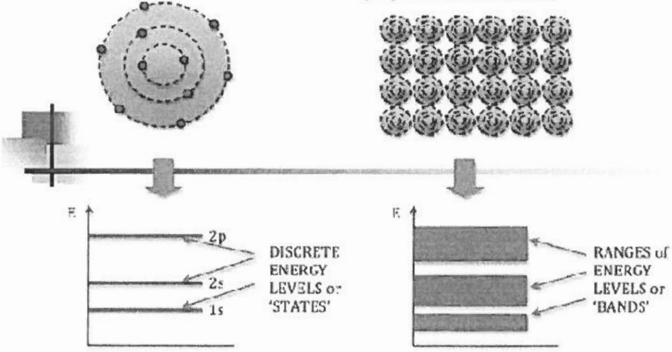
This is an equation for carrier concentration in p-type.

10) b) Origin of Energy Band

[1+1+1+1 = 4M]

In an isolated atom, the electrons are tightly bound and have discrete, sharp energy levels.When two identical atoms are brought closer the outermost orbits of these atoms overlap and interact. When the wave functions of the electrons of the different atoms begin to overlap considerably, the energy levels corresponding to those wave functions split into two as in below Fig.If more atoms are brought together more energylevels are formed and for a solid of N atoms, each of the energy levels of an atom splits into N levels of energy.The levels are so close together that they form an almost continuous band. The width of this band depends on the degree of overlap of electrons of adjacent atoms and is largest for the outermost atomic electrons.

In a solid many atoms are brought together so that the split energy levels form a set of bands of very closely spaced levels with forbidden energy gaps between them as shown in fig.There are two energy bands called valence and conduction bands. The band corresponding to the outer most gaps between these two allowed bands is called forbidden energy gap or band gap since electrons can't have energy values within the forbidden energy gap.



According to the width of the gap between the bands and band occupation by electrons, all solids can be classified broadly into three groups, namely conductors, semiconductors and insulators.

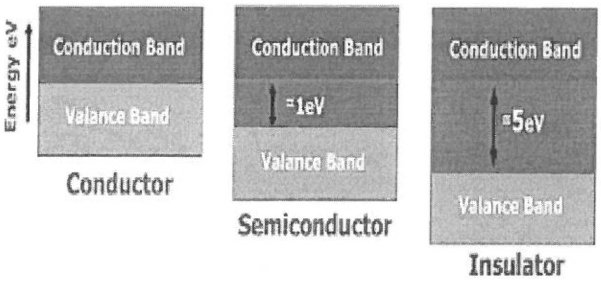


Fig: Classification of Solids on the basis of electricity Conduction

Conductors: - They have very high electrical conductivity and large no. of mobile charge carriers or free electrons which carry electric current. When temperature of conductors increased, its resistivity also increases. They have positive temperature coefficient of resistance. eg.. Cu, Ag, Al, Au etc… And Gold is the best conductor of electricity

Semi-conductors: -

Semiconductors are those materials whose conductivities lie between conductors and insulators. They have poor conductivity than conductors and higher than insulators. Therefore, they are neither good conductors nor good insulators. When temp of a semiconductor is increased, its resistivity decreases or conductivity increases. At higher temp, a semiconductor conducts better.

Therefore, the semiconductors have negative temp coefficient of resistance.

For e.g: Si, Ge, gallium, Arsenic, etc.

Insulators: - Insulators are those materials which are bad conductors of electivity. i.e, they have very high resistivity because they have no charge carriers or free electrons to carry electric current.

For eg: Glass, quartz, rubber, bake lite etc.

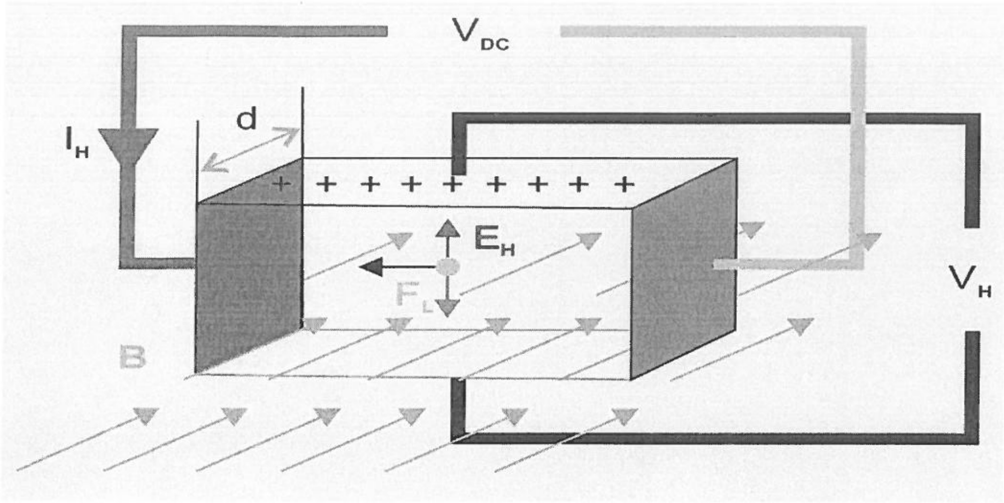
11) a) HALL **EFFECT:**

[1+ 2+3 =6M]

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

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



Applying the Fleming's left hand rule, the force exerted on the electrons is in the negative y-direction. As a result, the density of electrons increases in the lower end of the material due to which its bottom surface becomes negatively charged.

On the other hand, the loss of electrons from the upper end causes the top edge of the material to become positively charged. Hence, potential V_H called Hall Voltage appears between the upper and lower surfaces of the semi conductor, which establishes on electric field E_H called the Hall Electric field. The electric field E_H exerts an upward force F_H in the electron.

$$\Rightarrow F_H = -e E_H$$

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

i.e $F_L = F_H \Rightarrow e E_H = -B.e.V_d$

$$\Rightarrow E_H = B V_d$$

The current density $J = -n e V_d$

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

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

$$E_H = V_H / w \qquad \Rightarrow R_H = E_H / J B = V_H / J B w$$

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

$$J = I / wt \qquad \Rightarrow V_H = R_H.I.B / t$$

$$\Rightarrow R_H = V_H.t / IB$$

11) b) **Drift current:**

[2 + 2 = 4M]

When an electric field E is applied across a semi-conductor, every charge carrier experience a force due to electric field and drifts in the direction of the force.

Thus, a charge carrier acquires an average velocity which is called the drift velocity and it gives rise to the drift current.

The total current due to the holes and electrons in the presence of applied electric field is called as drift current.

$J = \sigma E$ E – applied electric field

$J = ne\, v_d$ v_d – drift velocity,

$\Rightarrow\ J = ne\, \mu E$ μ - mobility

$J_n = ne\, E\, \mu_e$, & $J_p = p\, e\, \mu_h\, E$

Total drift current density, $J_{drift} = J_{n\,(drift)} + J_{p\,(drift)}$

Diffusion Current:

The motion of charge carriers from region of higher concentration to the region of lower concentration leads to a current called Diffusion current.

In general, the concentration of charge carriers varies with distance in a semiconductor, this constitutes a concentration gradient.

The diffusion current is proportional to the concentration gradient.

The concentration gradient is denoted by (dn/dx) in case of electrons and (dp/dx) in case of holes.

The electron flux at any point due to diffusion is proportional to the concentration gradient.

$J_n(\text{diffusion}) = e.\ D_n.(dn/dx)$

$J_p\ (\text{diffusion}) = e\ D_p.(dp/dx)$

$J\ (\text{diffusion}) = e.\ D_n.(dn/dx)\ \text{--}\ e\ D_p.(dp/dx)$