PVP 23

Code: 23BS1103

I B.Tech - I Semester – Regular Examinations - JANUARY 2024

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)	Define pumping and population inversion.	L2	CO1
1.b)	What are critical angle and acceptance angle?	L2	CO1
1.c)	Why are x-rays diffracted by crystals?	L3	CO3
1.d)	How many Bravais lattices are possible for tetragonal crystal system? Mention the lattice parameters for the same system.	L3	CO3
1.e)	Define orientational polarization. Give examples.	L3	CO3
1.f)	Define magnetic field intensity and magnetization.	L2	CO1
1.g)	Write down two properties of wave function.	L3	CO3
1.h)	Differentiate between classical and quantum particles.	L3	CO3
1.i)	Define Fermi level. What is its importance?	L4	CO4
1.j)	What is Hall coefficient? Mention one application of Hall effect.	L3	CO2

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Explain absorption, spontaneous and stimulated emission of radiation with suitable energy diagram.	L2	CO1	6 M
	b)	Calculate the critical angle and acceptance angle for a step index fiber in which the refractive index of core is 1·53 and the refractive index of cladding is 2.5 % less than that of core.	L3	CO2	4 M
OR					
3	a)	Explain the construction and working principle of He-Ne LASER.	L3	CO2	5 M
	b)	Explain the different mechanisms of losses in optical fibre.	L2	CO1	5 M
UNIT-II					
4	a)	Calculate the packing fraction of FCC structure with suitable diagram.	L3	CO3	6 M
	b)	Draw the planes of Miller indices (110), (111), (001) and (112).	L4	CO5	4 M
OR					
5	a)	Explain the construction and working of x-ray diffraction method by Laue. Mention its applications.	L3	CO3	5 M
	b)	Derive an expression for the inter-planar spacing (d_{hkl}) between the planes (hkl) for a cubic lattice of lattice constant a.	L3	CO3	5 M

UNIT-III					
6	a)	Derive the relation between susceptibility (χ) and relative permeability (μ_r) of a magnetic material.	L3	CO3	5 M
	b)	Classify different types of magnetic materials with suitable examples and mention their properties.	L4	CO5	5 M
OR					
7	a)	The electronic polarizability of the Ar atom is 1.7×10^{-40} F.m^2. What is the static dielectric constant of Ar gas at 300 K if the dielectric contains 1.67×10^{27} atoms/m^3.	L4	CO5	5 M
	b)	Explain the formation of domains and domain walls in magnetic materials.	L3	CO3	5 M
UNIT-IV					
8	a)	Obtain an expression for the Schrodinger's time independent one-dimensional equation for an electron of mass m moving in a potential $V(x)$.	L3	CO3	6 M
	b)	A proton and electron have the same de Broglie wavelength. Calculate the ratio of velocities of proton and electron. Which particle is moving faster?	L4	CO5	4 M
OR					
9	a)	Write down the postulates of quantum free electron theory.	L3	CO3	4 M
	b)	Derive an expression for electrical conductivity (σ_e) based on quantum free electron theory.	L3	CO3	6 M

UNIT-V					
10	a)	Differentiate among conductors, semiconductors and insulator based on band theory.	L4	CO4	4 M
	b)	Define intrinsic and extrinsic semiconductors with suitable examples. Explain the formation of p-type and n-type semiconductors with suitable diagrams.	L3	CO2	6 M
OR					
11	a)	Calculate the carrier concentration of n-type semiconductor.	L3	CO2	8 M
	b)	Write down the Einstein's equation and explain it.	L3	CO2	2 M

PVP SIDDHARTHA INSTITUTE OF TECHNOLOGY
(Autonomous)
I B.Tech I SEMESTER –Regular Examinations –JANUARY 2024

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

SCHEME FOR VALUVATION

PART-A

1.

a	**Definition of pumping+ population Inversion**	**1+1-2M**
b	**Definition of Critical angle+ Acceptance angle**	**1+1-2M**
c	The X-rays get diffracted by a crystal because the wavelength of X-rays is similar to the inter-atomic spacing in the crystals	**2M**
d	For tetragonal systems are $a=b\neq c$ and $\alpha=\beta=\gamma$.	**2m**
e	**Definition +exampes**	**2m**
f	Magnetic field intensity (H) +The magnetization	**2M**
g	.Any two properties	**2M**
h	**Any one difference**	**2m**
i	**Definition**	**2M**
j	Hall coefficient (R H). $R_H = V_H.t$ / application	**2M**

UNIT-I

1. a) Explanation of Absorption, spontaneous, stimulated Emission ---2+2+2--------6M

b) FORMULA+ SSOLUTION ------------- 2+2------4M

OR

3. a) Diagram+ construction and working of He-Ne laser -----1+4M
b) Mentioning various losses +Explanation of Any losses in optical fiber---1+4

UNIT-II

4. a) Diagram+ explanation+**caluculation--------------------1+2+3-6M**
4. b) Draw the planes of Miller indices (110), (111), (001) and (112)- 1+1+1+1 -4M

OR

5.a) Diagram+/explanation of laue method ------------- 1+4 --------5M

5.b) Derivation of Interplanar distance ---------5M

Unit-III

6.a) Derivation of Susceptibility and relative permeability ---------- 5M

6.b) list of various magneticmaterials and mention any two properties 2+4-----6M

OR

7.a) formula + solution ---------2M+3M

b) Diagram+ Definition+ Explanation ------------- 1M+1M+4M

UNIT-IV

8.a) derivation of Scrodinger Time independent wave equation------------6M

b) formula + solution ---------1M+3M

OR

9)a) Any four postulates of Quantum free electron theory -4M

9).b) Derivation of electrical conductivity based on quantum free electron theory—6M

UNIT-IV

10 a) Any two Differences between conductors, semiconductors, insulators-------- 4M

b) Definition of Inrinsic, extrinsic semiconductor + explanation of p-type and n type semiconductor 2 M +4 M

OR

11 a) Derivation of N- Type semiconductors- --8M

b) Write the Einstein relation ----2M

PVP SIDDHARTHA INSTITUTE OF TECHNOLOGY
(Autonomous)
I B.Tech I SEMESTER –Regular Examinations –JANUARY 2024

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

SCHEME FOR VALUVATION

PART-A

1.

a	**Definition of pumping+ population Inversion** pumping is a process in which external energy is used to raise (or "pump") electrons from a lower energy level in an atom or molecule to a higher one. **population Inversion** the number of atoms in the ground state (N_1) is larger than the number ofatoms in the higher energy state (N_2) i.e., $N_1>N_2$.	**1+1-2M**
b	**Definition of Critical angle+ Acceptance angle** **Critical angle:** The angle of incidence for which the angle of refraction is 90 degrees is called as the critical angle $\operatorname{Sin}\theta_c = \frac{n_2}{n_1}$ **Acceptance angle:** **Acceptance angle** is the maximum angle of incidence at the end face of an optical fiber for which the light ray will propagate within the optical fiber $\sin(\theta_A) = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$	**1+1-2M**
c	The X-rays get diffracted by a crystal because the wavelength of X-rays is similar to the inter-atomic spacing in the crystals	**2M**
d	For tetragonal systems are $a=b\neq c$ and $\alpha=\beta=\gamma$. Tetragonal crystal systems arranged into simple cubic,body centered cubic	**2m**
e	Orientational polarization arises when there is a permanent dipole moment in the material. Materials such as HCl and H_2O will have a net permanent dipole moment because the charge distributions of these molecules are skewed.	**2m**

f	Magnetic field intensity (H) at any point in the magnetic field is defined as the force experienced by the unit north pole at that point. The SI unit of magnetic field intensity is Ampere/meter (A/m). The magnetization of a material M can be defined as net magnetic moment for that material per unit volume. Mathematically, $M = \frac{m_{net}}{V}$	**2M**
g	wave function is a mathematical description of a quantum state of a particle as a function of momentum, time,,position, and spin. The symbol used for a wave function is a Greek letter called psi, **Ψ**. **Ψ** should be continuous and single-valued.	**2M**
h	1.classical theory describes the nature of macroscopic level, whereas quantum theory describes the nature of microscopic level. .2. classical theory, the free electrons in a metal have random motions with equal probability in all directions. But according to quantum theory, the free electrons occupy different energy levels, up to Fermi level at 0 K. So, they possess different energies and hence they possess different velocities. **3. If any others**	**Any one difference-2m**
i	The highest energy level that an electron can occupy at the absolute zero temperature is known as the Fermi Level, The Fermi level lies between the valence band and conduction band because at absolute zero temperature, the electrons are all in the lowest energy state.	**2M**
j	Hall coefficient (R H) is defined as the ratio between the induced electric field and to the product of applied magnetic field and current density . $R_H = V_H.t / IB$ Applications: 1. Determination of type of semiconductor whether it is p-type or n-type. The carrier concentration can be calculated	**2M**

UNIT-I

2. a) **Explanation of Absorption, spontaneous, stimulated Emission ---2+2+2--------6M**

ABSORPTION:- If the electrons are excited to the higher energy level from ground level by absorbing energy is called as absorption.

- The process of particle transfer from normal state to a higher energy state is termed as excitation. The process is called

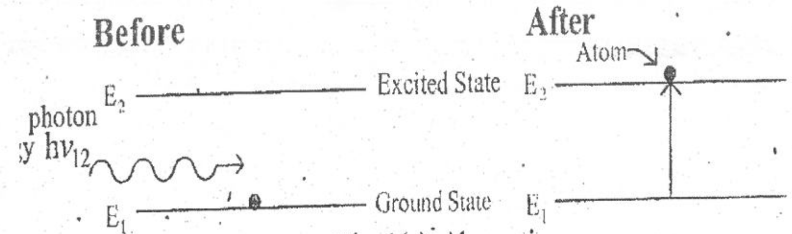
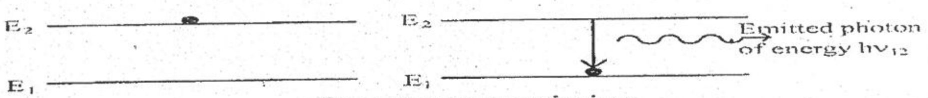


Fig. 1(a): Absorption

SPONTANEOUS EMISSION:-

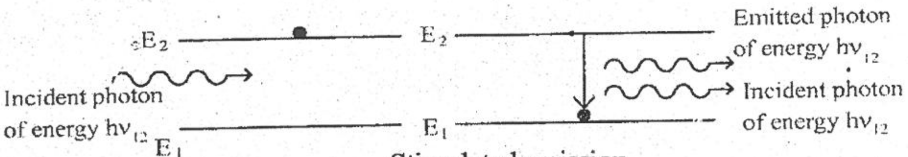
- The atoms in the excited state can remain for a short time 10^{-8} seconds is known as life time.
- The process of returning of an electron from the excited state to ground state by itself After the completion of life time is **S**pontaneous **e**mission.
- It is incoherent. Example is light from electric bulb. It was postulated by **Bohr.**



Spontaneous emission

STIMULATED EMISSION:-

- The transition from a higher energy state to a lower energy state when radiation of same frequency is incident on an atom in the excited state is **stimulated emission.**
- The electron under transition releasing a **photon** of the **same frequency** as that ofincident radiation. Example is **Laser** light. In this emission a double photon energy isemitted.



Stimulated emission

b) GIVEN DATA+ Formula+ Solution -------------- 1+1+2------4M

Refractive Index of core n_1 =1.53

Refractive Index of cladding n_2 =2.5% n_1 $= \frac{2.5 \times 1.53}{100} = 0.03825 \Rightarrow 1.53 - 0.0382$ $= 1.491$

$= n_1 - 2.5\% n_1$

Critical angle = $\sin\theta_c = \frac{n_2}{n_1} = \frac{1.491}{1.53} \Rightarrow \theta_c = \sin^{-1}\left(\frac{1.491}{1.53}\right)$

$\theta_c = 75.93$

Acceptance angle = sin (θ_A) $= \frac{\sqrt{n_1^2 - n_2^2}}{n_0} = \sin\theta_A = \sqrt{(1.53)^2 - (1.491)^2}$

$\sin\theta_A = \sqrt{2.3409 - 2.223}$

$\sin\theta_A = \sqrt{0.1179} = 0.3433$

$\theta_A = \sin^{-1}(0.3433)$
$= 20.07$

$\theta_A = 20.07$.

OR

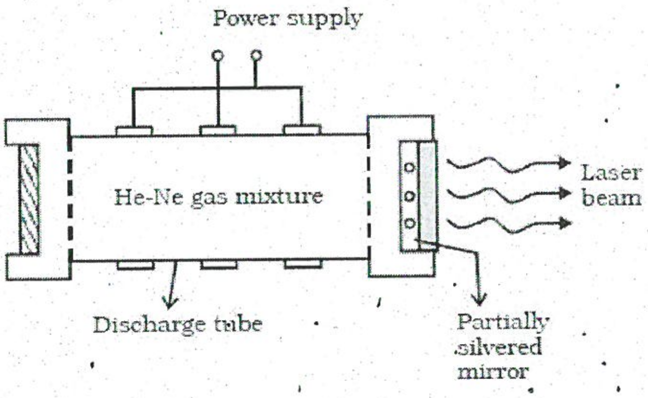
3. a) Diagram+ construction and working of He-Ne laser -----1+4M

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.

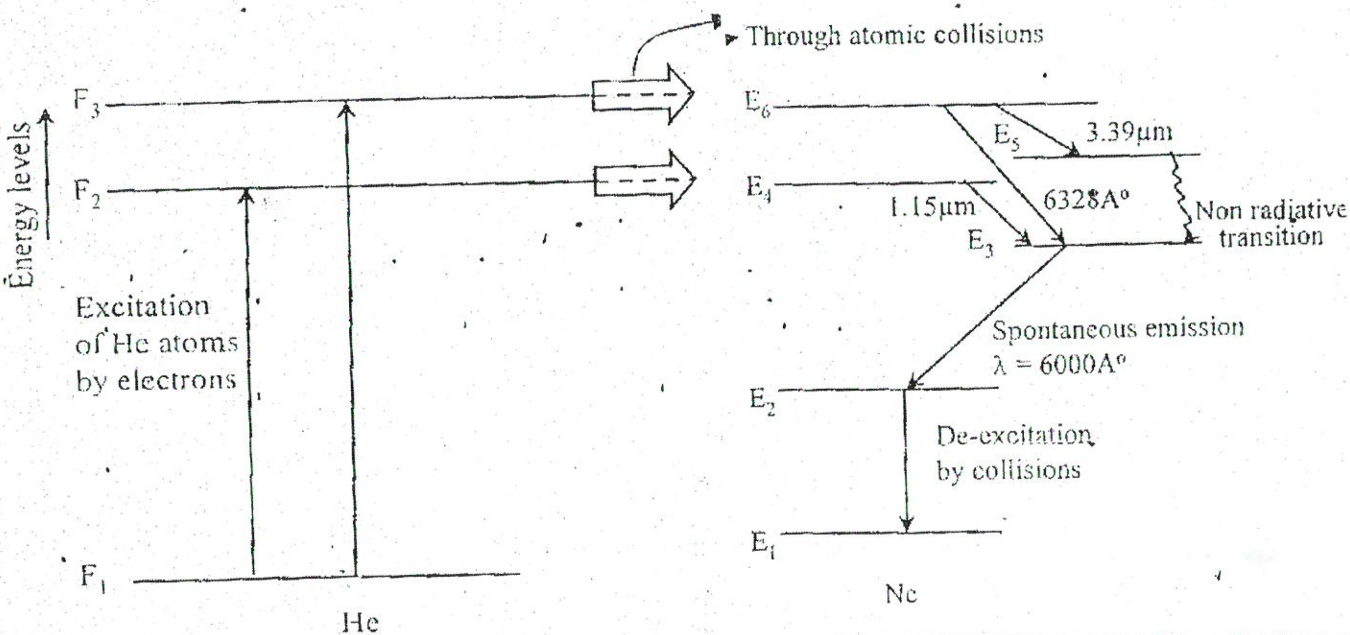
CONSTRUCTION:

- 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

  $3.39\ \mu m,\ 1.15\ \mu m\ and\ 6328A^0$.

- 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

b) Mentioning various losses + Explanation losses in optical fiber---1+4

Optical Fiber Losses consist of absorption loss, and scattering loss , connector loss, and bending loss and their explanation

Absorption loss is a significant type of loss in optical fiber that occurs when light is absorbed by the material of the fiber, which can be caused by impurities in the fiber or by the natural absorption of the material itself.

Scattering loss is a phenomenon where light waves interact with small particles or inhomogeneities in the glass lattice of the fiber, causing the light to scatter in different directions

Any other give marks

The transmission loss or attenuation in an optical fiber is very important in the optical fiber communication. Different mechanisms are responsible for the signal attenuation.

- Due to attenuation, the output power is always less than the input power.
- It is a function of fiber materials, wavelength and length of the fiber.
- The attenuation coefficient of the signal is given by

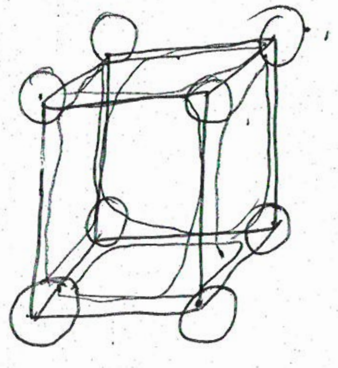
$$\boxed{\alpha = \frac{10}{L}\log\frac{P_i}{P_0}\ \text{dB/Km}}$$ where L is length of the fiber.

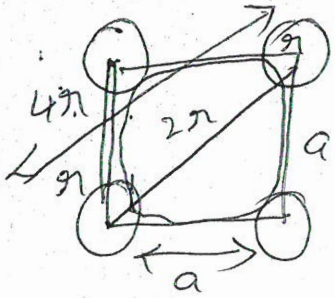
UNIT-II

4. a) Diagram+ explanation+**caluculation---------------------1+2+3-6M**

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

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

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

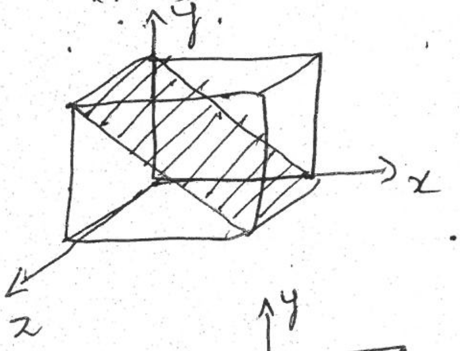
$$= \frac{4\times\left(4/3\Pi r^3\right)}{a^3} = \frac{(16/3)\Pi r^3}{\left(2\sqrt{2}.r\right)^3}$$

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

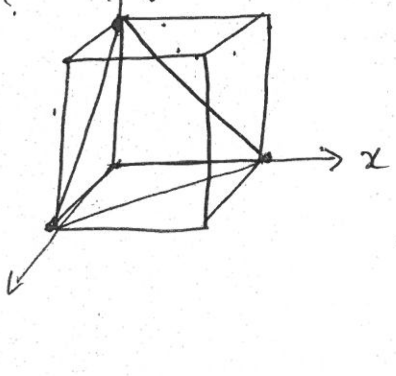
In FCC structure, 74% of its volume is occupied by the atoms and the remaining 26% is empty. FCC has the highest packing density. It is tightly packed than SC, BCC Structures.

4. b) Draw the planes of Miller indices (110), (111), (001) and (112)- 1+1+1+1 -4M

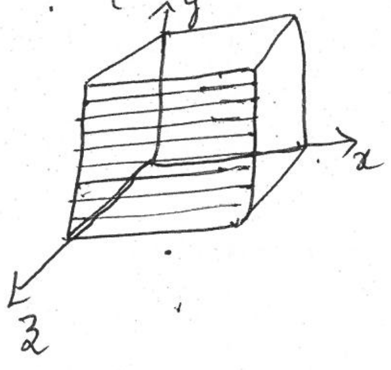
(110)

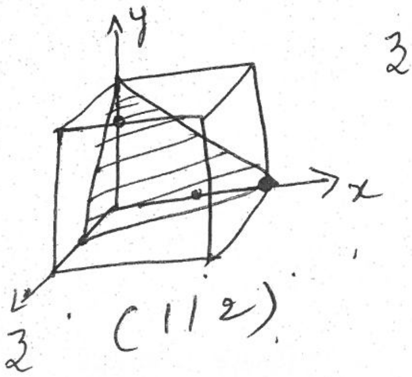


(111)



(001)





(112)

OR

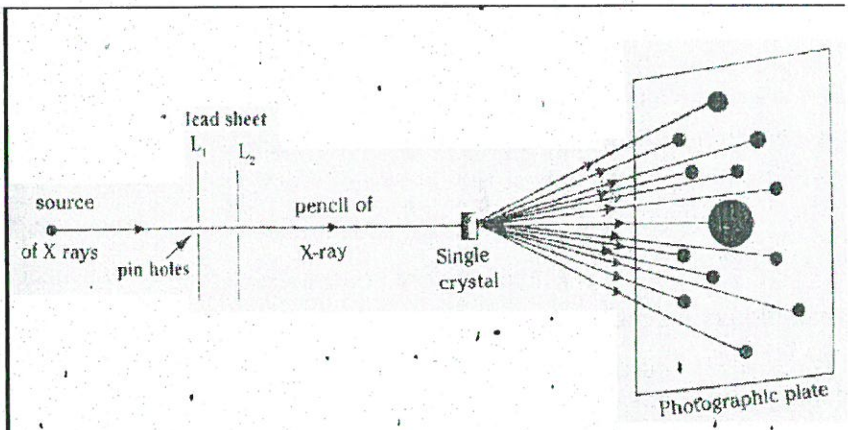
5.a) Diagram+ explanation of laue method -------------- 1+4 --------5M

LAUE METHOD:-

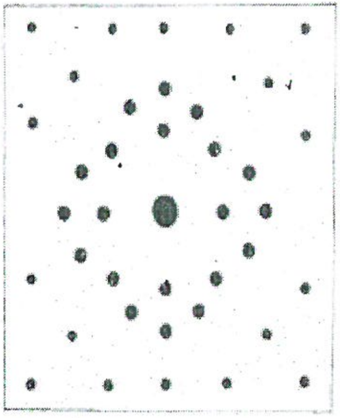
- In this method, the crystal is held stationary in the beam of X-rays. A crystal is imagine to possess different set of planes with different orientations and different interplanar spacing.
- For any values of θ and d, each reflecting plane in the crystal will select particular wavelength λ such that diffraction can occur.
- The resulting diffraction pattern is recorded on a photographic plate.

Experimental Arrangement:-

- A beam of X-rays in the wave length range 0.2A° to 2A° is made to incident on a crystal.
- These X-rays are produced from a suitable source. Before passing through the crystal, the X-rays are limited to a fine pencil by a slit system (lead diaphragms).
- The size of the pinhole should be small to get sharp interference pattern. The smallest is the diameter, the sharper is the interference.
- The laue method employs white radiation which is usually obtained from the tungsten target at about 60,000 volts.



Laue diffraction arrangement and Laue spots



Laue pattern of cubic crystal

- X-rays are then made to fall on the crystal then penetrate in to the crystal. Each reflecting

  plane will select the wave length which it can be diffract.

- The diffraction pattern consists of a bright central spot and a large number of spots

  arranged symmetrically about the central spot.

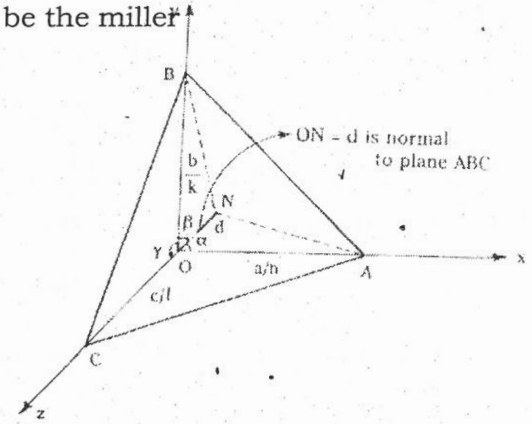
Applications:-

- To check the orientation of crystal planes.
- To study the defects in solids

5.b) Derivation of Interplanar distance ---------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.



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

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

- 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/1.

- From the figure Cosα =ON/OA= d/(a/h) = dh/a.

  Cos β = ON/OB=d/(b/h) = dk /b.

Cos γ = 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, $d = \frac{a}{\sqrt{h^2+k^2+l^2}}$.

Unit-III

6.a) Derivation of Susceptibility and relative permeability ---------- 5M

Relation Between μ_r and χ_B :

$$B \ \alpha \ H$$

$$B = \mu H$$

$$B = \mu_0 \mu_r H$$

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

$$B = \mu_0 H + \mu_0 H (\mu_r - 1)$$

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

Where M is the magnetization

$$B = \mu_0 (H + M)$$

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

$$\text{relative permeability } \mu_r = \frac{\mu}{\mu_0} \rightarrow \frac{B/H}{B/(H+M)}$$

$$\mu_r = \frac{H + M}{H}$$

$$\mu_r = 1 + \frac{M}{H}$$

$$\mu_r = 1 + \chi_m$$

6.b) list of various magnetic materials and mention any two properties 2+4-----6M

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.

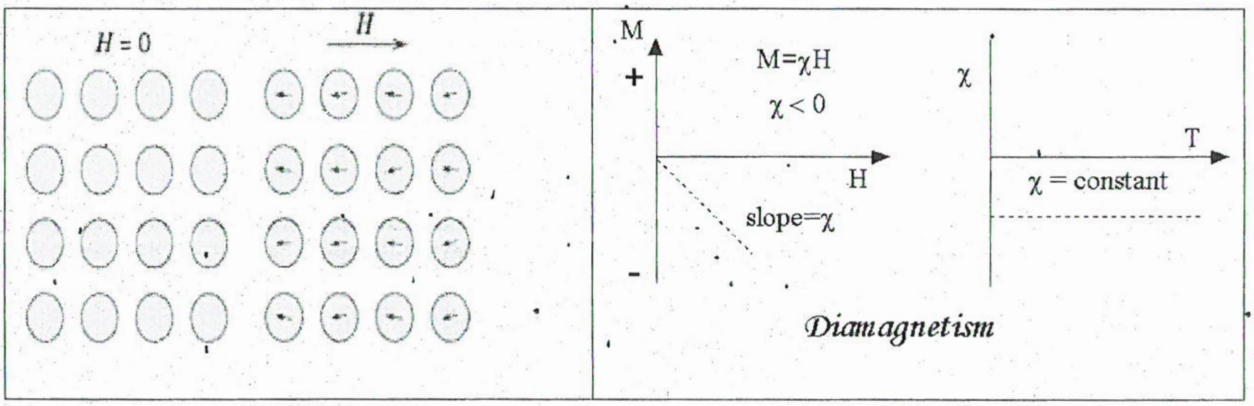
DIAMAGNETIC MATERIALS:

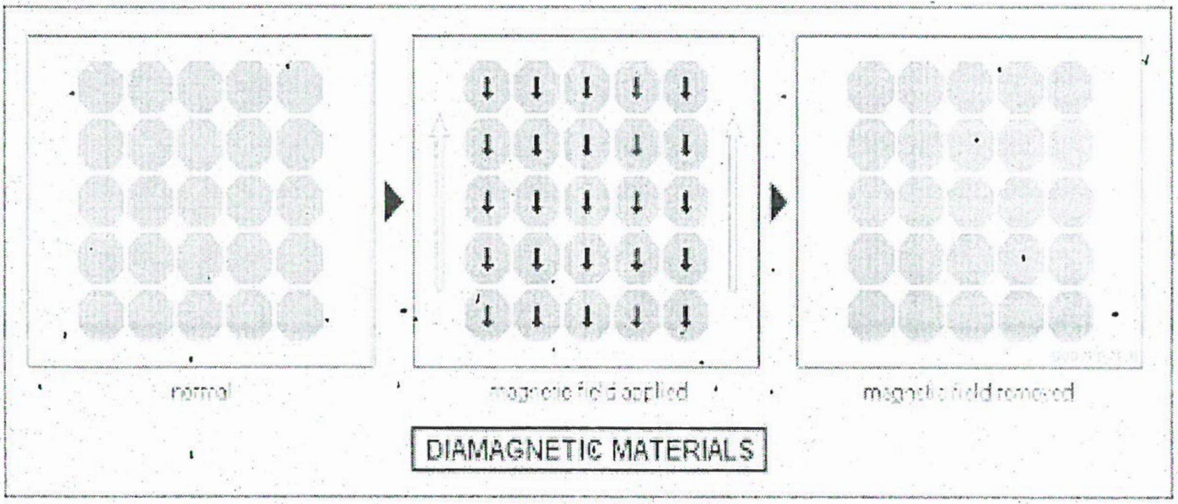
- The substances which are repelled by magnetic are called **diamagnetic** materials.

  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.



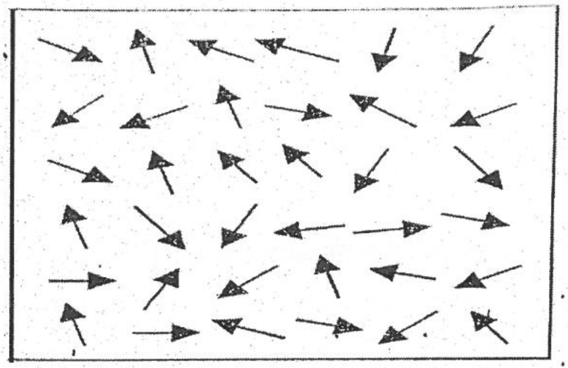


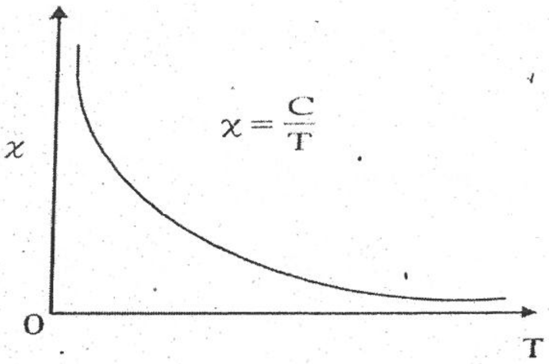
PARA MAGNETIC MATERIALS:

♠ 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., $\boxed{\chi_m \propto \frac{1}{T}}$

- Spin alignment is as shown in the figure.

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

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

If $T<\theta$, paramagnetic become diamagnetic.

FERROMAGNETIC MATERIALS:

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

  Ex :- Iron, Nickel, Cobalt

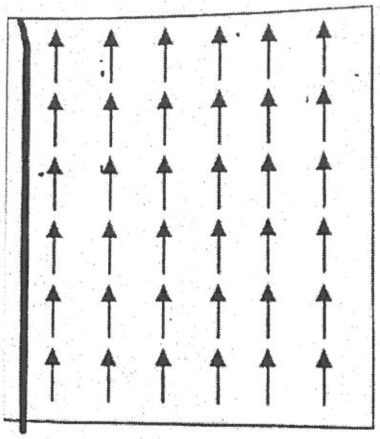
- Ferromagnetism is a phenomenon by which **spontaneous magnetization** occurs when $\boxed{\mathbf{T} \le \theta}$ and so even in the absence of applied field.

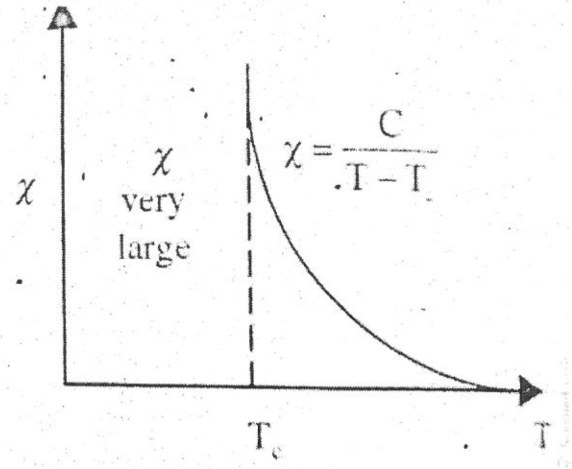
PROPERTIES:

- 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

OR

7.a) formula + solution ---------2M+3M

A) Electronic polarizability $\alpha_e = 1.7\times10^{-40}\ F.m^2$

$N = 1.67\times10^{27}$ atoms/m^3

$$\alpha_e = \frac{\varepsilon_0(\varepsilon_r - 1)}{N}$$

$$\varepsilon_r = \frac{N\alpha_e}{\varepsilon_0} + 1$$

$$\varepsilon_r = 1 + \frac{1.67\times10^{27}\times1.7\times10^{-40}}{8.85\times10^{-12}}$$

$$\varepsilon_r = 1 + \frac{2.839\times10^{-1}}{8.85} = 1 + 0.032 \quad \boxed{\varepsilon_r = 1.032}$$

b) **Diagram+ Definition+ Explanation ------------- 1M+1M+4M**

<u>DOMAIN THEORY OF FERROMAGNETISM:</u>

♠ **Weiss** proposed the concept of domains in 1907 to explain the hysteresis effect of ferromagnetic.

♠ A region of ferromagnetic material where all the magnetic moments are aligned in the same direction is called **domain** varying from 10^{-9} to 10^{-5} m^3

♠ Each domain contains about 10^{17} to 10^{21} atoms which are spontaneously magnetized.

♠ In each domain spontaneous magnetization is due to parallel alignment of all magnetic dipoles. The direction of spontaneous magnetization varies from domain to domain.

♠ These domains are oriented randomly so that the net magnetic moment is always zero.

♠ Each domain posses dipoles aligned in the same direction.

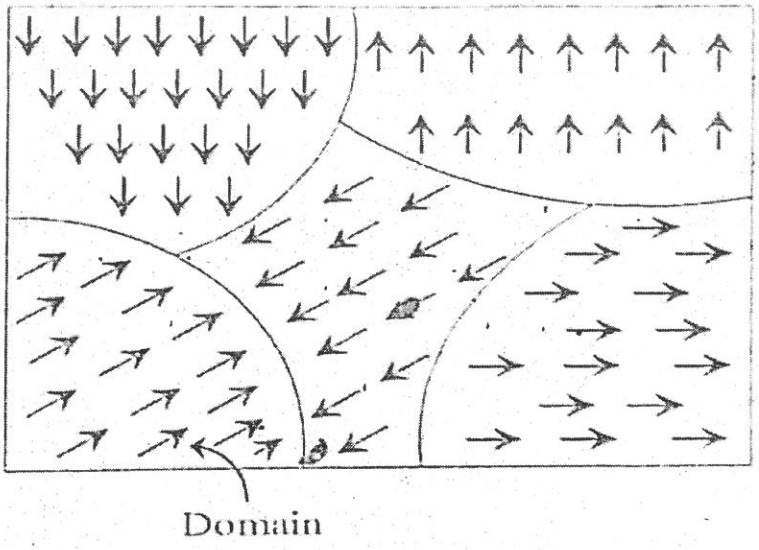
♠ When magnetic field is applied the domains may tend to rotate in the direction of B

♠ Thus magnetic material will be strongly magnetized

by the external magnetic field induction B.

♠ In ferromagnetism the adjacent atomic dipoles are interact with **exchange coupling**.

The resultant magnetization may hence be zero or nearly zero. When an external field is applied there are two possible ways of alignment of a random domain.



1. Displacement of Boundaries of the domains:

The domains which are oriented favourable with respect to the external magnetizing field increases in size while those oriented opposite to the external field are reduced as shown in Fig.(b). Fig.(a) shows domain arrangement in a ferromagnetic specimen when no magnetic field is applied.

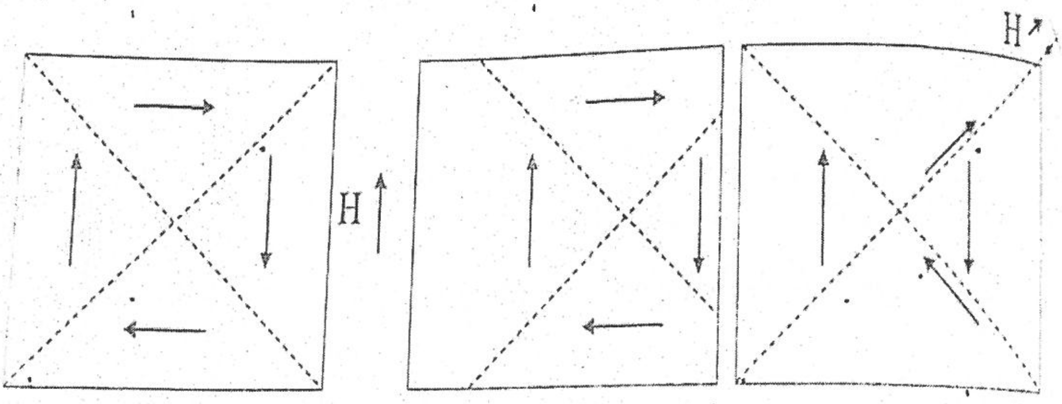


Fig (a) Ferromagnetic domains (b) Domain magnetization by wall movement

(c) Domain magnetization by rotation.

2. Rotation of Domains:

Domain rotate until their magnetic moments are aligned more or less in he direction of external magnetic field as shown in fig.(c). When the external magnetic field is weak the specimen is magnetized mostly by the boundary displacement. In the strong magnetic field, the magnetization takes place mostly by the rotation of domains.

When the domain vectors are oriented parallel to the direction of field, the stage is called as saturation limit. On the removal of external field the boundaries do not move completely back to their original position and hence the specimen is not completely demagnetized. i.e there still remains some residual magnetism. At high temperatures, the domains are broken up and the ferromagnetic material becomes paramagnetic.

UNIT-IV

8.a) Derivation of Scrodinger Time independent wave equation------------6M

Schrodinger's Wave Equations :-

Time-Independent Schrodinger's wave Equation :-

In 1925, Schrodinger gave mathematical theory known as wave mechanics to describe the dual nature of matter.

Consider a particle of mass 'm' moving with velocity 'v' along x-direction.

$$\psi(x) = A \sin \omega t \qquad \omega = 2\pi n \, ; \, t = x/v$$

$$\psi(x) = A \sin \frac{2\pi v}{\lambda} \times \frac{x}{v} \qquad n = \frac{v}{\lambda}$$

$$\psi(x) = A \sin \frac{2\pi}{\lambda} . x \longrightarrow ①$$

Differentiating Eqn ① with respect to 'x'

$$\frac{\partial \psi(x)}{\partial x} = A \cos \frac{2\pi}{\lambda} \times x \times \frac{2\pi}{\lambda}$$

$$\frac{\partial^2 \psi(x)}{\partial x^2} = - A \sin \frac{2\pi}{\lambda} \times x \; \frac{4\pi^2}{\lambda^2}$$

$$\frac{\partial^2 \psi(x)}{\partial x^2} = - \frac{4\pi^2}{\lambda^2} \psi(x)$$

Similarly along y-direction

$$\frac{\partial^2 \psi(x)}{\partial y^2} = - \frac{4\pi^2}{\lambda^2} \psi(y)$$

along z-direction

$$\frac{\partial^2 \psi(x)}{\partial z^2} = - \frac{4\pi^2}{\lambda^2} \psi(z)$$

$$\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{\partial^2 \psi(x)}{\partial y^2} + \frac{\partial^2 \psi(x)}{\partial z^2} = \frac{-4\pi^2}{\lambda^2} (\psi(x) + \psi(y) + \psi(z))$$

$$\nabla^2 \psi = - \frac{4\pi^2}{\lambda^2} \psi \qquad \nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

substituting
× De broglie wavelength $\lambda = \frac{h}{mv}$;

$$\nabla^2\psi + \frac{4\pi^2 m^2 v^2}{h^2}\psi = 0$$

If 'E' and 'V', are the Total and Potential Energies of The particle respectively then its Kinetic Energy is

$$\frac{1}{2}mv^2 = E-V$$

$$m^2v^2 = 2m(E-V)$$

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

$$\boxed{\nabla^2\psi + \frac{2m}{\hbar^2}(E-V)\psi = 0} \quad \left(\hbar = \frac{h}{2\pi}\right)$$

This is the 'Schrodinger Independent wave Equation

b) formula + solutioh ---------1M+3M

The wavelength of electron $\lambda_1 = \frac{h}{m_1 v_1}$

The wavelength of proton $\lambda_2 = \frac{h}{m_2 v_2}$

$$\lambda_1 = \lambda_2$$

$$\frac{h}{m_1 v_1} = \frac{h}{m_2 v_2} \Rightarrow \boxed{\frac{m_2}{m_1} = \frac{v_1}{v_2}}$$

$m \propto \frac{1}{v}$

Mass of electron is lesser than proton, so, electron moves faster than proton.

OR

9)a) Any four postulates of Quantum free electron theory -4M

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. The distribution of electrons among the various Energy levels are obey's Pauli's Exclusion principle

4. The attraction between lattice ions and electrons as well as Repulsions of electrons are neglected.

9).b) Derivation of electrical conductivity based on quantum free electron theory—6M

Quantum free electron theory :-

According to Quantumfree electron theory, the electron move freely in a Solid with a constant Potential 'V'. We assume that the Potential to be zero.

$$-\frac{\hbar^2}{2m}\nabla^2\psi = E\psi \longrightarrow ①$$

where 'E' is total Energy. i.e kinetic Energy.

the Solution of the wave Equation

$$\psi = \psi_0 \exp(iK\cdot r)$$

where the wave-vector $K = 2\pi/\lambda$ and $r^2 = x^2+y^2+z^2$

Hence $\frac{d^2\psi}{dx^2} = -K^2x\psi$

$$\frac{\partial^2\psi}{\partial y^2} = -K^2y\psi$$

$$\frac{d^2\psi}{dz^2} = -K^2z\psi$$

$$\nabla^2\psi = \frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2}$$

$$= -(K_x^2+K_y^2+K_z^2)\psi$$

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

substituting Equation ② in Equ ①

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

$$E = \frac{\hbar^2K^2}{2m} = \left(\frac{h}{2\pi}\right)^2\left(\frac{2\pi}{\lambda}\right)^2\frac{1}{2m}$$

$$= \frac{h^2}{2m\lambda^2} = \frac{h^2p^2}{2mh^2} \quad (\because \lambda = h/p)$$

$$\boxed{E = P^2/2m} \longrightarrow ③$$

This represents the Energy of free particle

If 'L' is length of Solid, applying boundary conditions. $K = \frac{2\pi n}{L}$

$$E = \frac{\hbar^2K^2}{2m} = \frac{n^2h^2}{8mL^2}$$

Energy levels of electrons in the solid differ by 10^{-17} ev i.e., too small they form as Quasi Continuous band.

When an External electricfield 'E' is applie electron produces a force $-eE$.

Force, is also rate of change of momentum.

$$-eE = dP/dt$$

Since momentum $P = h/\lambda = \frac{h}{2\pi} \times \frac{2\pi}{\lambda} = \hbar k$

$$-eE = \frac{d}{dt}(\hbar k) = \hbar \frac{dk}{dt}$$

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

Due to this force electron moves at a distan 'dk' in time 'dt'. If there is imperfections in Solid electron comes to steady state the time taken to the electron to come to steady state is called average collision time 'τ'.

$$dk = -\frac{eE\tau}{\hbar}$$

$\because$ $P = mv = \hbar k$, incremental velocity 'Δv' is given by

$$\Delta v = \frac{\hbar}{m} \Delta k$$

$$= -\left(\frac{\hbar}{m}\right) \frac{eE\tau}{\hbar}$$

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

If 'n' is the number of electrons per unit volume is 'n' Then the current density 'J' is given by

$$J = n(-e)\Delta v$$

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

$\therefore$ $J = \sigma E$ (ohm's law

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

'σ' is electrical conductivity.

UNIT-IV

10 a) Any two Differences between conductors, semiconductors, insulators-------- 4M

Answer:

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.

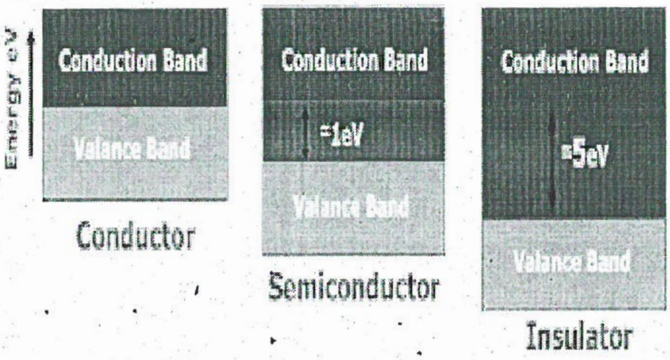


Fig: Classification of Solids on the basis of electricity Conduction

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

A good conductor should possess the following characteristics

i. High electrical and thermal conductivity,
ii. High melting point,
iii. Good oxidation resistance,
iv. Low cost,
v. Good wear and abrasion resistance
vi. Better mechanical properties

Semiconductors:-

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, Arsinic, 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, bakelite etc..

10) **b) Definition of Inrinsic, extrinsic semiconductor + explanation of p-type and n type semiconductor** **2 M +4 M**

Answer:

Intrinsic (or) pure Semiconductor: A pure semiconducting material without any impurity is called intrinsic semiconductors. IV group elements are the intrinsic (or) pure semiconductors.

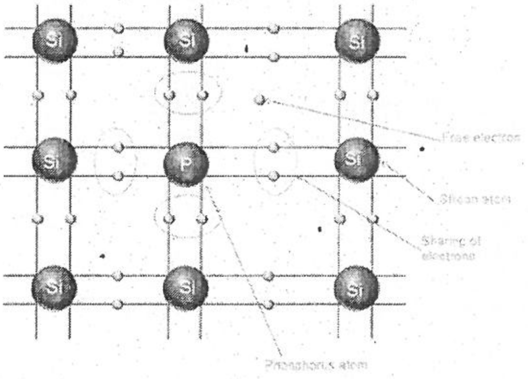
For eg: Si, Ge.

Extrinsic Semiconductors (or) impure semiconductors: The semiconductor in which impurities are added is called extrinsic semiconductor.

N-type semiconductor

When pentavalent impurity is added to an intrinsic or pure semiconductor (silicon or germanium), then it is said to be an n-type semiconductor. Pentavalent impurities such as phosphorus, arsenic, antimony etc are called donor impurity.

Pentavalent impurity phosphorus is added to silicon as shown in below figure. Phosphorus atom has 5 valence electrons and silicon has 4 valence electrons. Phosphorus atom has one excess valence electron than silicon. The four valence electrons of each phosphorus atom form 4 covalent bonds with the 4 neighboring silicon atoms. The fifth valence electron of the phosphorus atom cannot able to form the covalent bond with the silicon atom because silicon atom does not have the fifth valence electron to form the covalent bond.Thus, fifth valence electron of phosphorus atom does not involve in the formation of covalent bonds. Hence, it is free to move and not attached to the parent atom.

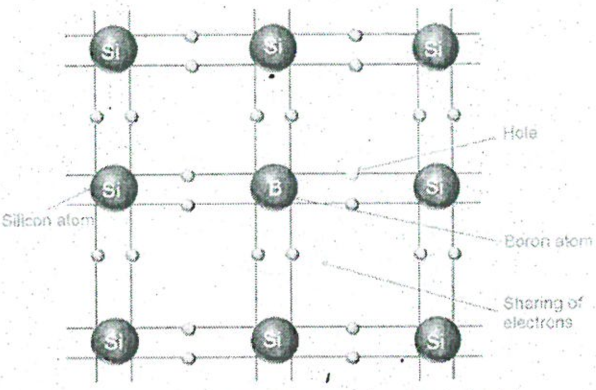


This shows that each phosphorus atom donates one free electron. Therefore, all the pentavalent impurities are called donors. The number of free electrons are depends on the amount of impurity (phosphorus) added to the silicon. A small addition of impurity (phosphorus) generates millions of free electrons.

P-type semiconductor

When the trivalent impurity is added to an intrinsic or pure semiconductor (silicon or germanium), then it is said to be an p-type semiconductor. Trivalent impurities such as Boron(B), Gallium (G), Indium(In), Aluminium(Al) etc are called acceptor impurity.

Trivalent impurity boron is added to silicon as shown in below figure. Boron atom has three valence electrons and silicon has four valence electrons. The three valence electrons of each boron atom form 3 covalent bonds with the 3 neighbouring silicon atoms.



Copyright © 2013-2014, Physics and Radio-Electronics, All rights reserved

In the fourth covalent bond, only silicon atom contributes one valence electron, while the boron atom has no valence electron to contribute. Thus, the fourth covalent bond is incomplete with shortage of one electron. This missing electron is called hole. This shows each boron atom accept one electron to fill the hole. Therefore, all the trivalent impurities are called acceptors. A small addition of impurity (boron) provides millions of holes.

OR

11 a) Derivation of N- Type semiconductors- --8M

Answer:

Carrier Concentration In N-Type:

In n- type donor level is just below the conduction band.

E_d is donor energy level

N_d is donor concentration

$$n = 2\left(\frac{2\pi\, m_e^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_F - E_c}{k_B T}\right)$$

No of vacancies per unit volume of donor level is

$$N_d[1 - F(E_d)] = N_d\left[1 - \frac{1}{1 + exp\left(\frac{E_d - E_F}{k_BT}\right)}\right]$$

$$N_d[1 - F(E_d)] \cong N_d exp\left(\frac{E_d - E_F}{k_BT}\right)$$

The number of vacancies present in the donor level is equal to density of electrons. So

$$2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_F - E_c}{k_BT}\right) = N_d exp\left(\frac{E_d - E_F}{k_BT}\right)$$

$$\left(\frac{E_F - E_c}{k_BT}\right) - \left(\frac{E_d - E_F}{k_BT}\right) = log\ log\ N_d - log\ log\ 2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}}$$

$$2E_F - (E_d + E_c) = k_BT\ log\ log\ \frac{N_d}{\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}}}$$

$$E_F = \frac{E_d + E_c}{2} + \frac{k_BT}{2} log\ log\ \frac{N_d}{\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}}}$$

This is the Fermi energy level in n-type semiconductors.

Then

$$n = 2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{\frac{E_d + E_c}{2} + \frac{k_BT}{2} log\ log\ \frac{N_d}{\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}}} - E_c}{k_BT}\right)$$

$$= 2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_d - E_c}{2k_BT} + \frac{1}{2} log\ log\ \frac{N_d}{2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}}}\right)$$

$$= 2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}} exp\left\{\left(\frac{E_d - E_c}{2k_BT}\right) + log\ log\ \frac{N_d^{\frac{1}{2}}}{2^{\frac{1}{2}}\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{4}}}\right\}$$

$$= 2\left(\frac{2\pi\, m_e^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_d - E_c}{2k_B T}\right) \frac{N_d{}^{\frac{1}{2}}}{2^{\frac{1}{2}}\left(\frac{2\pi\, m_e^* k_B T}{h^2}\right)^{\frac{3}{4}}}$$

$$= (2N_d)^{\frac{1}{2}}\left(\frac{2\pi\, m_e^* k_B T}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_d - E_c}{2k_B T}\right)$$

b) Write the Einstein relation **----2M**

The Relation between diffusion Constant & mobility

$$\frac{D_n}{\mu_n} = \frac{KT}{e}$$

$$\frac{D_p}{\mu_p} = \frac{KT}{e}$$

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{KT}{e}$$

$$\boxed{\frac{D_n}{D_p} = \frac{\mu_n}{\mu_p} = \frac{KT}{e}}$$