PVP 23

Code: 23BS1203

I B.Tech - II Semester – Regular Examinations - JULY 2024

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)	Mention the characteristics of a laser.	L1	CO2
b)	Define Total Internal Reflection.	L1	CO1
c)	Define packing fraction.	L1	CO1
d)	Discuss any two applications of X-ray diffraction.	L2	CO3
e)	Define Di-electric polarization and Di-electric constant.	L1	CO3
f)	Write any two properties of anti-ferro magnetic materials.	L1	CO3
g)	An electron is bound in one-dimensional potential box of size $1x10^{-10}$ m. Find its energy value in the ground state.	L3	CO5
h)	Define Fermi energy.	L1	CO5
i)	Show the variation of Fermi level with temperature in n-type semiconductor.	L2	CO4
j)	What is an intrinsic semiconductor?	L1	CO1

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Demonstrate the construction and working of Ruby laser.	L3	CO2	6 M
	b)	Explain pumping and illustrate various pumping mechanisms.	L4	CO4	4 M
		OR			
3	a)	Explain acceptance angle and numerical aperture. Derive the expression for acceptance angle.	L3	CO2	7 M
	b)	Select and discus any three general applications of optical fiber.	L4	CO4	3 M
		UNIT-II			
4	a)	Sketch the seven types of crystal systems with the Bravais Lattices.	L3	CO3	7 M
	b)	Copper has FCC structure and the atomic radius is 0.1278 nm. Calculate the inter planar spacing for (2 1 2) planes.	L3	CO3	3 M
		OR			
5	a)	Explain Bragg's law of X-ray diffraction.	L3	CO3	3 M
	b)	Explain powder method to determine the crystal structure.	L4	CO5	7 M
		UNIT-III			
6		Explain electronic polarization, Calculate the electronic polarizability in a Di-electric material.	L3	CO3	10 M
		OR			
7	a)	Explain the classification of magnetic materials into Dia, Para and Ferro magnetic materials.	L3	CO3	6 M
	b)	Differentiate soft and hard magnetic materials.	L4	CO5	4 M
		UNIT-IV			
8	a)	Interpret Schrodinger time independent wave equation for a particle.	L3	CO3	7 M
	b)	Explain the significance of wave function.	L4	CO5	3 M
		OR			
9	a)	Explain Fermi-Dirac distribution function and its variation with temperature.	L4	CO5	7 M
	b)	Explain the salient features of classical free electron theory of metals.	L3	CO3	3 M
		UNIT-V			
10		Calculate the density of electrons in the conduction band of an intrinsic semiconductor.	L3	CO2	10 M
		OR			
11	a)	Explain Hall effect and derive the expression for Hall coefficient.	L4	CO4	7 M
	b)	Infer any three applications of Hall effect.	L4	CO4	3 M

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

ENGINEERING PHYSICS (Common to CSE, ECE, EEE)

SCHEME FOR VALUVATION

PART-A

1.

a	Any two characteristics of a laser	2m
b	Definition of Total Internal reflection	2m
c	Definition of packing fraction	2m
d	Any two applications of X-ray diffraction	2m
e	.Definition Di-electric polarization and Di-electric constant	1+1 = 2m
f	Any two properties of Anti –ferro magnetic materials	2m
g	Formula +Substution +Result $E = \frac{n^2h^2}{8ma^2}$; $n=1$, $a = 1\times10^{-10}m$ $E = 37.6\,eV$	2m
h	.Define Fermi energy	
i	Variation of Fermi level in n-type semiconductor	2M
j	Definition of Intrinsic Semiconductor	2M

UNIT-I

2\. a) Diagram+ Construction and working of Ruby laser ---1+2+3--------6M

b) Definition of Pumping + Names of pumping mechanisms + Explanation --- 1+1+2-4M

OR

3\. a) Explanation Acceptance angle and numerical aperture+ Derive the expression for Acceptance angle 2+5----7m

b) Any three general applications of optical fiber -----3m

UNIT-II

2\. a) Names of Seven crystal systems +Diagrams--------------------2+5---7m

4. b) Given data+ formula+ solution and answer -----------1+1-1-----3m

OR

5.a) Explanation of Braggs Law -------------3m

5.b) Diagram + Explanation of powder method to determine crystal structure -----5M

Unit-III

6.a) Explanation of Electronic polarization + calculation of electronic polarizability--- 2+8-10m

OR

7.a) Classification of magnetic materials into Dia, Para, Ferro (any three points for each) —2*3 = 6m

b) Any two Differences between soft and Hard magnetic materials --- 2m+2m ---4m

UNIT-IV

8.a) Derivation of Schrodinger Time independent wave equation -------7m
b) Any three points on significance of wave function ---------3m

OR

9 a) Explanation of Fermi Dirac distribution functions ? Any four postulates of Quantum free electron theory -2m+5m---7m

9 b) Any three points on sailent features of Classical free electron theory of metals -3m

UNIT-V

10 a) Derivation of Density of electrons in the conduction band of an intrinsic semiconductor -----10m

OR

11 a) Explanation of Hall Effect + derivation of Hall coeeficient --2m+5m ----7m

b) Any three application of Hall effect ----3m

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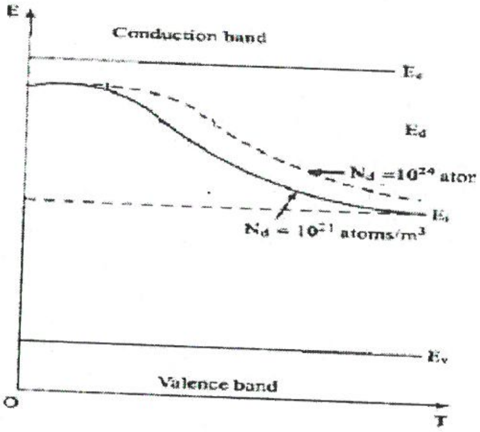
SCHEME FOR VALUVATION

PART-A

1.

a	**Characteristics of a laser are** (i) Coherence (ii) Directionality (iii) Monochromacity (iv) High Intensity.	**2m**
b	**Definition of Total Internal reflection** When the light ray enters from a denser medium to rarer medium at an angle greater than critical angle, the light gets Totally reflected. This phenomenon is called TIR. **Sin** $\theta_c = \frac{n_2}{n_1}$	**2m**
c	**Definition of packing fraction** It is the ratio of volume occupied by the atoms in an unit cell (v) to the total volume of the unit cell (V).It is also known as packing fraction. i.e. P.F = v/V	**2m**
d	**Any two applications of X-ray diffraction :** shape and structure determination of compounds size and orientation of atoms	**2m**
e	**Definition Di-electric polarization and Di-electric constant** It is defined as the dipole moment per unit volume. It is given by $$P = \frac{\mu}{V} = \frac{q \times l}{A \times l} = \frac{q}{A}$$ **Dielectric Constant :-** it is defined as the ratio of the permittivity of the medium to the permittivity of the free space. $$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$$ It is also defined as the ratio between capacitance with dielectrics between the plates to the capacitance with air between the plates. It has no units. $$\varepsilon_r = \frac{C}{C_0}$$	**1+1 = 2m**
f	**Any two properties of Anti –ferro magnetic materials** Antiferromagnetic materials have aligned electron spins in opposite directions, leading to overall zero magnetisation. They exhibit a critical temperature, known as the Néel temperature, above which they become paramagnetic. Or **Any other**	**2m**
g	$E = n^2h^2/8ma^2$; $a = 1 \times 10^{-10}$ m	**2m**

	$n=1$ $E_1 = \frac{h^2}{8ma^2} = \frac{(6.625\times10^{-34})^2}{8\times9.1\times10^{-31}\times(1\times10^{-10})^2} = 0.376\times10^{2}$ ev $= 37.6$ ev	
h	**Define Fermi energy** Fermi Energy is a concept in quantum mechanics. **The value of the Fermi level at absolute zero temperature is known** as the Fermi energy.	2M
i	**Variation of Fermi level with Temperature in n-type semiconductor** At 0K the fermi level E_F lies between the conduction band and the donor level. As temperature increases more and more electrons shift to the conduction band leaving behind equal number of holes in the valence band or 	**2M**
j	**Definition of Intrinsic 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.	**2M**

UNIT-I

2. a) Diagram+ Construction and working of Ruby laser ---1+2+3--------6M

RUBY LASER: The essential components of ruby laser are

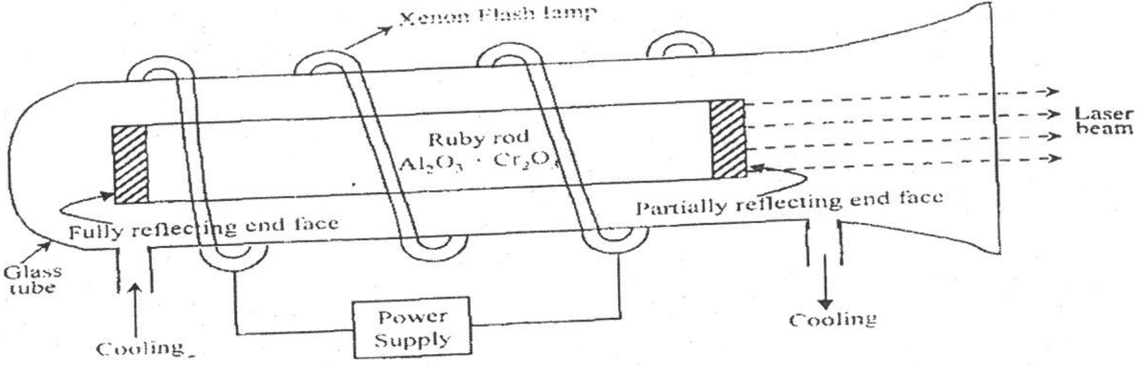
Active medium: Cr3+ ions present in the Ruby rod.

Energy source : A helical shaped Xenon flash lamp.

Cavity resonator: The one end of the ruby rod is completely silvered and other end is Partially silvered.

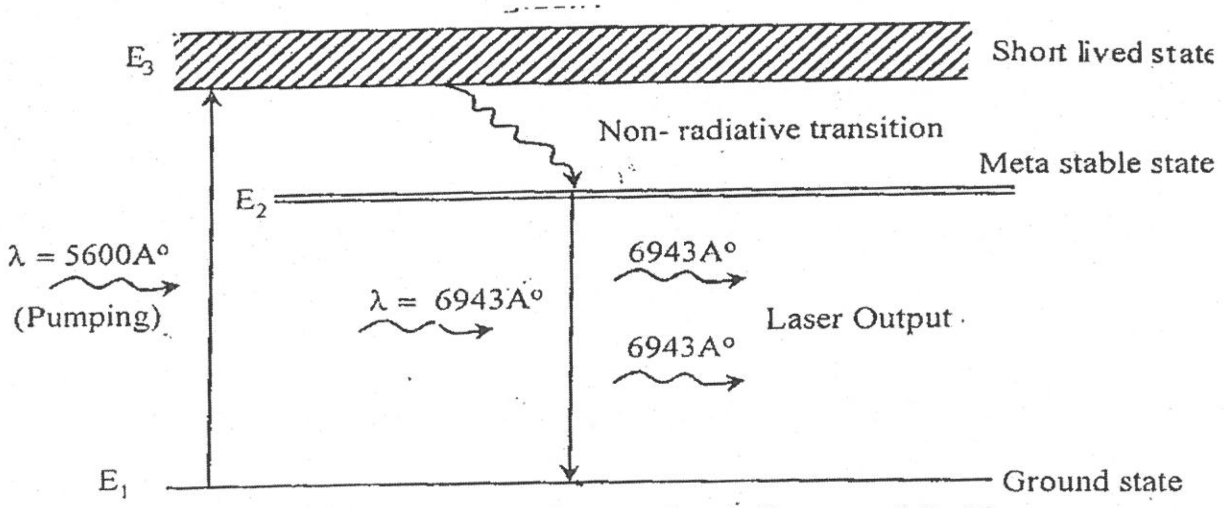
CONSTRUCTION:

Ruby laser is a three level solid state laser. It was constructed by Maiman.In ruby laser, the active element is pure Al2O3 with 0.05% of chromium.It is shaped into a cylinder with parallel reflectors at both ends.The color of ruby rod is pink. Pumping source is flash lamp.Xenon flash lamp tube is spirally wound over the ruby rod and is connected to a power supply. The emitted wavelength of radiation is 6943A0.

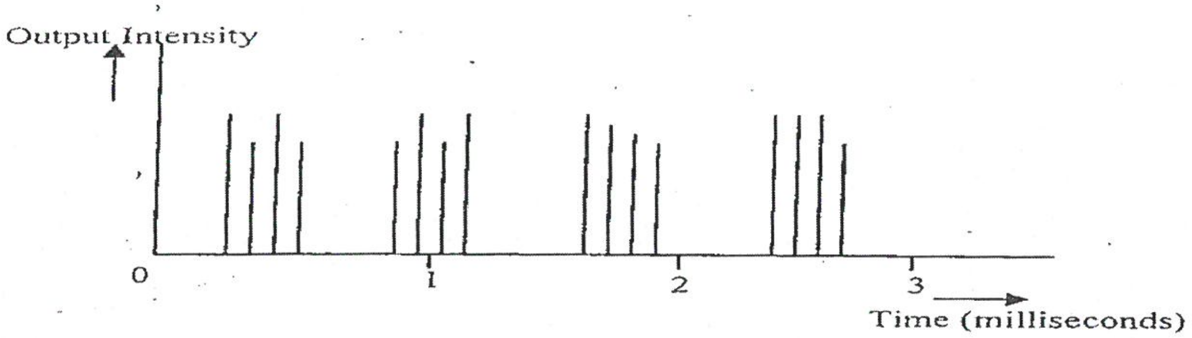


Working:

The chromium ions are responsible for stimulated emission.Chromium ions in the Ruby rod are responding to the flash light having wavelength of 5600A0.The Cr3+ ions are excited to level E3 so the population of E3 increases.The chromium ions can stay in E3 for 10-8 sec and make a non-radiative transition to the Meta stable state. In Meta stable state, the ions remain for 10-3 sec. As a result stimulated emission takes place and the chromium ions translate from Meta stable state to ground state. This transition gives rise to emission of laser light of wavelength 6943A0.The emitted photons traveling along the axis of the rod are reflected at the ends and pass through the amplifying medium. They stimulate the atoms in Meta stable state.The out put of Laser consists of series of pulses with microsecond duration.



Energy level diagram of Cr^{+3} ion



The output pulses with time

2. b) Definition of Pumping + Names of pumping mechanisms and Explanation --- 1+3-4M

Pumping Process: This process is required to achieve population inversion.Pumping process is defined as: "The process which excites the atoms from ground state to excited state to achieve population inversion".

Pumping can be done by number of ways

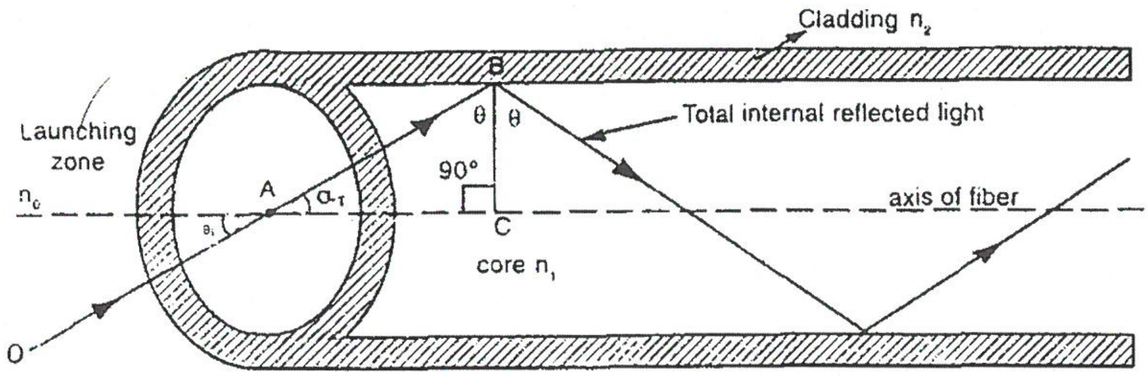
- Optical Pumping: excitation by strong source of light (flashing of a Camera)
- Electrical Pumping : excitation by electron impact
- Chemical Pumping: excitation by chemical reactions
- Direct Conversion : Electrical energy is directly converted into radiant Energy in devices like LED's, population Inversion is achieved in forward bias

OR

3. a) Explanation Acceptance angle and numerical aperture+ Derive the expression for Acceptance angle 2+5----7m

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.

All these rays within the core will suffer total internal reflections and enter in to the core. The other rays refracted to the cladding and are lost. The light ray is entered from a medium of refractive index n0 in to the core. The ray OA enters the fiber at an angle α_i to the axis of the fiber.



Let the refractive indices of core and cladding are n1 and n2. 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.

According to Snell's law, $\Rightarrow$ n0 sin θi = n1 sin α_r

$$\Rightarrow n0 \sin \theta i = n1 \sin (90-\theta) \quad (\because \alpha_r + \theta = 90)$$

$$\Rightarrow \sin \theta i = \frac{n_1}{n_0} \cos \theta.$$

when $\theta = \theta_c$, θi=(θi)max then sin(θi)max = $\frac{n_1}{n_0} \cos \theta_c$ ----------- (1)

we know that $\cos \theta_c = \sqrt{1 - \frac{n_2^2}{n_1^2}} = \frac{\sqrt{n_1^2 - n_2^2}}{n_1}$ (since $\sin \theta_c = \frac{n_2}{n_1}$)

Now equation ------ (1) becomes, sin (θA)= $\frac{n_1}{n_0} \frac{\sqrt{n_1^2 - n_2^2}}{n_1} = \frac{\sqrt{n_1^2 - n_2^2}}{n_0}$.

This maximum angle is called Acceptance angle.

NUMERICAL APERTURE:

Numerical aperture represents the light gathering capacity of an optical fiber.It is defined as the sine of the maximum acceptance angle. i.e., NA= sin θA

Let n1, n2 and n0 be the refractive indices of core, cladding and the medium from which the ray is incident.

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

If the fiber is surrounded by air i.e., n0=1 then NA= $\sqrt{n_1^2 - n_2^2}$

3. b) Any three general applications of optical fiber -----3m

Optical fibers are used in telecommunication. More channels can be sent through the optical fiber cable.

The **loss of energy** during transmission is **less.**

Optical fibers can carry information to several kilometers.

Fiber scopes are used in **Endoscope** applications.

These instruments used to view internal parts of body without performing surgery.

Fiber optic endoscopes are classified on desired applications.

Gastroscope to examine the stomach. It is used to destroy **tumors.**

Bronchoscope to view the upper passages of lungs.

In the engineering field, they are used as **sensors.**

***Any other give marks**

UNIT-II

4a) Names of Seven crystal systems +Diagrams---------------------2+5---7m

SEVEN CRYSTAL SYSTEMS AND BRAVAIS LATTICES

. The seven crystal systems are

1) Cubic(C)
2) Tetragonal(T)
3) Orthorhombic(O)
4) Monoclinic(M)
5) Triclinic (T)
6) Trigonal(T)
7) Hexagonal(H)

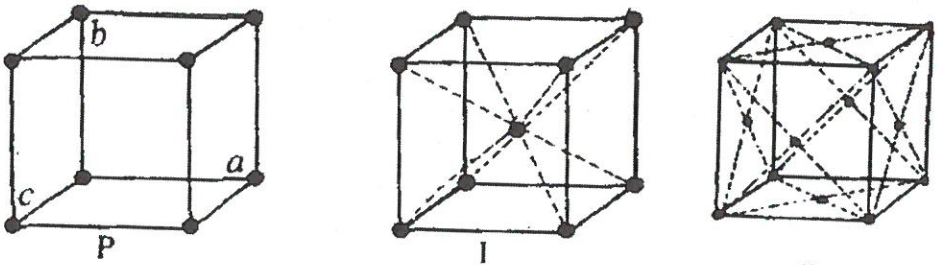
CUBIC SYSTEM

- In the cubic system the crystal is made up of three equal axes at right angles to each other. i.e. $a = b = c$; $\alpha = \beta = \gamma = 90^0$ It exists in three forms.

(A) SIMPLE CUBIC : In this the particles are only at the corners of the unit cell

(B) BODY CENTERD CUBIC : In this the particles are only at the corners as well as at the center of the unit cell

(C) FACE CENTERD CUBIC :In this the particles are only at the corners as well as at the center and each face of the of the unit cell

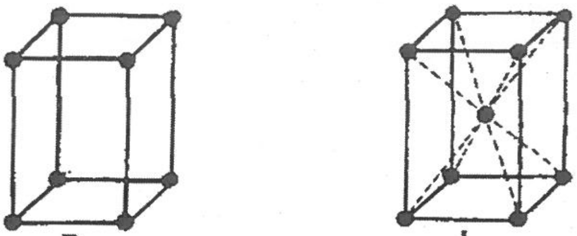


Cubic

TETRAGONAL SYSTEM

- In this the three axes are at right angles to each other and two axes are equal. It exists in two forms a) primitive (p) b) body centered (I)

$a = b \neq c$ and $\alpha = \beta = \gamma = 90^0$

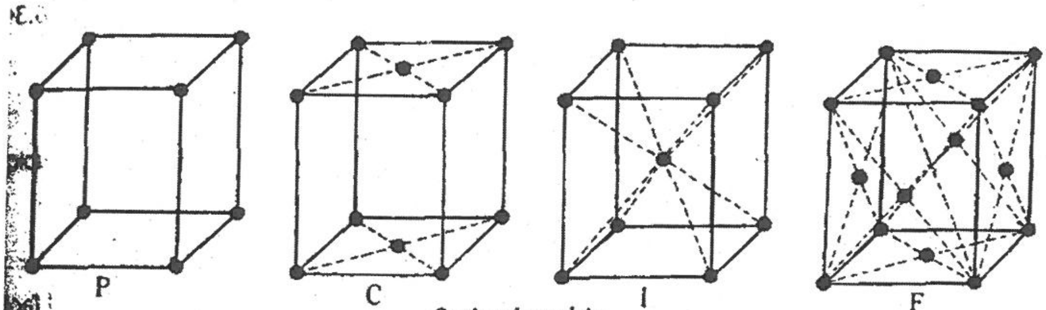


P I

Tetragonal

ORTHORHOMBIC SYSTEM:

- This system includes the crystals in which crystallographic axes are unequal but they are right angles to each other. $a \neq b \neq c$ and $\alpha = \beta = \gamma = 90^0$. It exists in four forms



P C I F

Orthorhombic

MONOCLINIC SYSTEM:

- In this type of crystals the three axes are unequal and one axis perpendicular to other 2 axes. i.e, $a \neq b \neq c$ and $\alpha = \beta = 90^0 \neq \gamma$

  It exists in 2 forms. They are primitive (P) and body center(C)

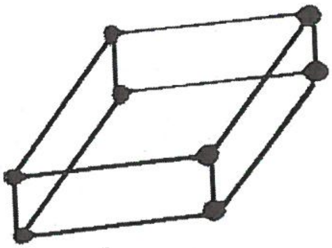
P C

Monoclinic

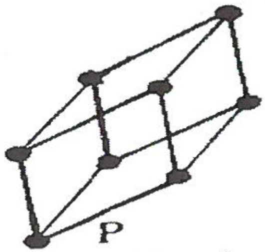
TRICLINIC SYSTEM:

- In this system the three axes and angles are unequal. $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma \neq 90^0$

It exists in only one form. It is primitive



TRIGONAL SYSTEMS :



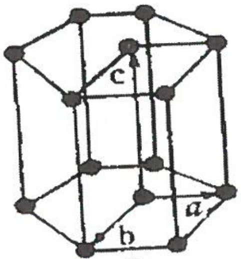
Trigonal

- In this system the crystals are made ep of three equal angles with 2 equal angles.

$a = b = c$ and $\alpha = \beta = \gamma \neq 90^0$. It exists in only one form. It is primitive

HEXAGONAL SYATEMS :

- The system has 8 faces .In this system 2 axes are equal in length in one plane lying at 120^0 and third one is perpendicular to this plane. $a = b \neq c$ & $\alpha = \beta = 90^0$, γ 120^0. It exists in only one form.



Hexagonal

4. b) Given data+ formula+ solution and answer ----------1+1-1-----3m

$(hkl) = (212)$

atomic radius $r = 0.1278\,nm$

Interplanar distance $d = \dfrac{a}{\sqrt{h^2+k^2+l^2}} = \dfrac{0.3614}{\sqrt{2^2+1^2+}}$

Fcc structure $a = 2\sqrt{2}r = 0.361$

$\boxed{d = 0.128nm}$

$d = 0.12nm$

OR

5.a) Explanation of Braggs Law ------------3m

__**Bragg's law : 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.

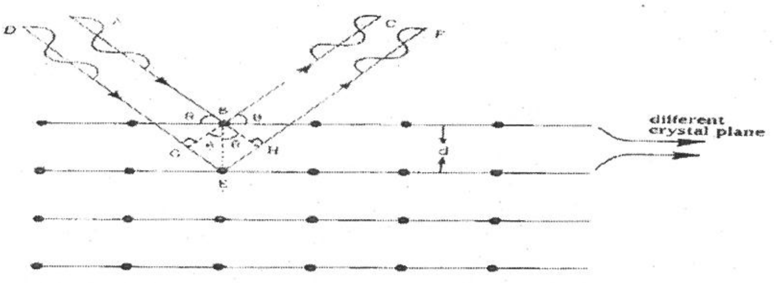


Fig. 3.8. Different planes and diffraction rays in a single crystal

Proof:

Let us consider a crystal of equidistant parallel planes with interplanar spacing d.Consider a monochromatic beam of X- ay 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, sinθ=GE/BE = GE/d => GE =d sinθ. From ΔBHE, sinθ=EH/BE = EH/d => EH =d sinθ.

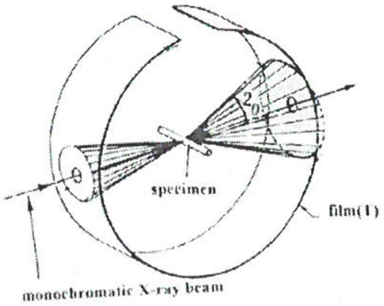
Path difference = GE+EH = 2d sinθ.

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) Diagram + Explanation of powder method to determine crystal structure -----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.

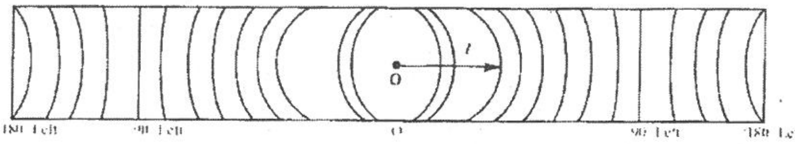
X-rays from a suitable source are passed through a filter which absorbs all the wavelengths except one wavelength thus monochromatic beam is produced by passing through the fine slits S1and S2.

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 $4\theta = S/R \Rightarrow \theta = S/4$

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

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



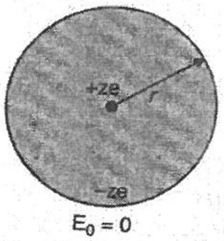
Lines on the powder photograph film

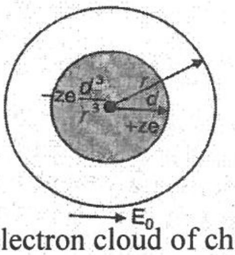
Unit-III

6. Explanation of Electronic polarization + calculation of electronic polarizability--- 2+8-10m

Electronic polarisation:

An electric strain produced in an atom due to the application of electric field is called electronic polarisation It is a result of 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 i a sphere of radius R. The charge density is given by

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

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 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 $F_L = -F_C$

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

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

We can write dipole moment $\mu_e = Zex$

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

Hence α_e E = Zex

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

Equating 5 and 6 we get

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

So it is proportional to volume of the atom $\alpha_e = 4\pi\varepsilon_O R^3$

We know that $\overline{P} = \varepsilon_o(\varepsilon_r - 1)E$

The relation between $\overline{P}$ and $\overline{\mu}$ is given by $\overline{P} = N\overline{\mu} = N\alpha_e E$

$\alpha_e = \varepsilon_o(\varepsilon_r - 1)E / N$

OR

7.a) Classification of magnetic materials into Dia, Para, Ferro (any three points for each) —2*3 = 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.

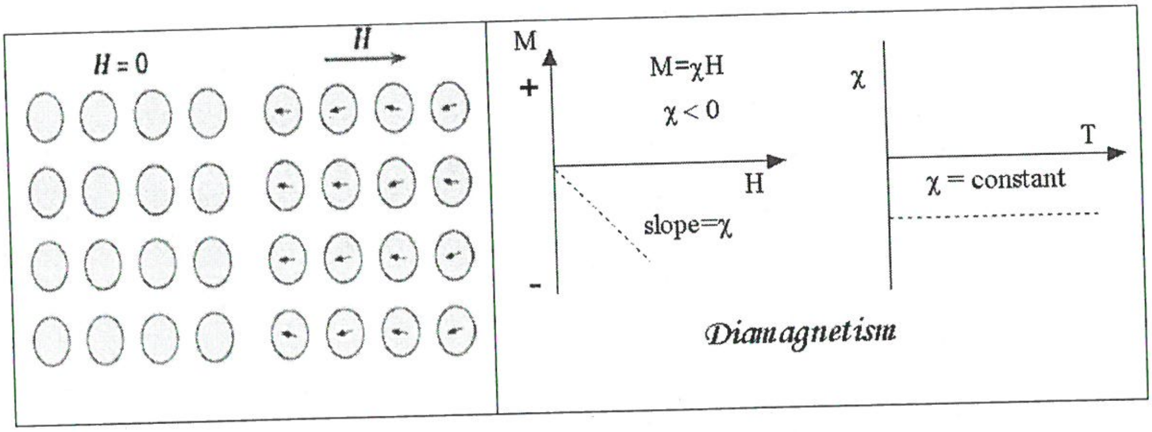
Ex :- Antimony, Bismuth, Copper, etc.,

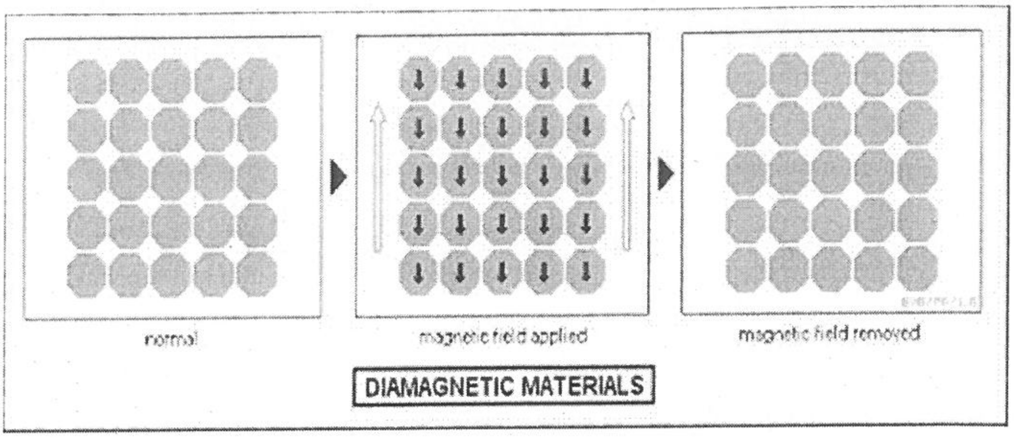
♠ The atoms in the diamagnetic material contains as many electrons orbiting in clockwise as in anticlockwise direction.

♠ 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.



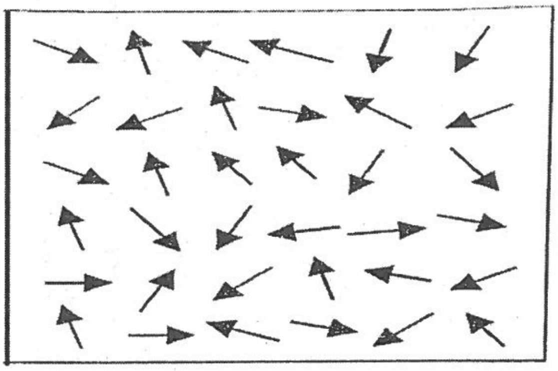


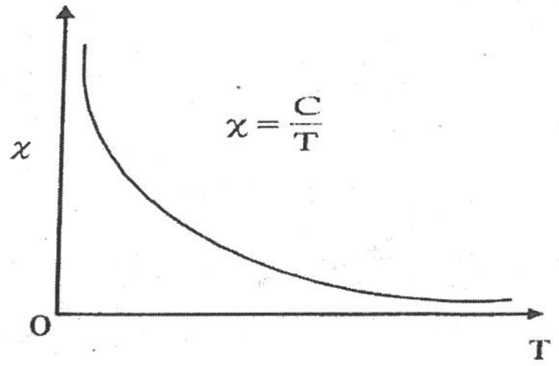
PARA MAGNETIC MATERIALS:

♠ 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

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

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

FERROMAGNETIC MATERIALS:

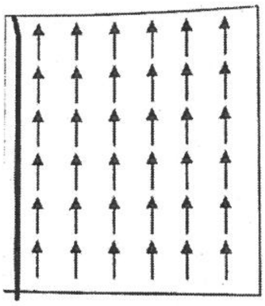
- The substances which are strongly attracted by magnets are called **ferromagnetic** Materials.

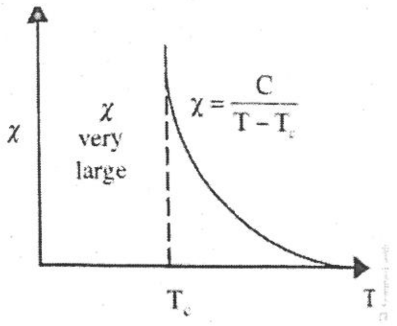
  Ex :- Iron, Nickel, Cobalt
- Ferromagnetism is a phenomenon by which **spontaneous magnetization** occurs when $\boxed{\mathbf{T} \le \theta}$ and so even in the absence of applied field.

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.

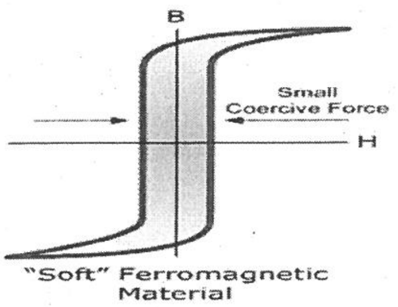
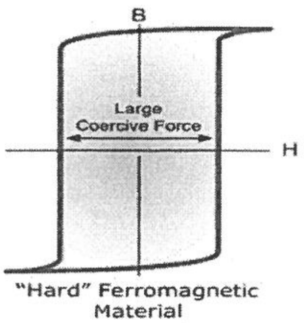
- When it is suspended freely after some time it comes to rest in the field direction.
- The magnetic lines of force shows more performance to pass through the substance than through air, so permeability is large. i.e., $\boxed{\mu_r >> 1}$.
- Susceptibility χ_B is large and positive.
- When heated these 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

7 b) **Any two Differences between soft and Hard magnetic materials --- 2m+2m ---4m**

SOFT MAGNETIC MATERIALS	H HARD MAGNETIC MATERIALS
 1.The figure shows nature of hysteresis loop of soft materials.	 The figure shows nature of hysteresis Loop of hard materials.

2. 2. These materials can be easily Magnetized and demagnetized.	2. 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.
8. Ex:-Iron-Silicon alloys, Fe-Ni, Ferrites and Fe-Co alloys.	8. Ex:- Al-Ni-Co alloys, Cu-Ni-Co alloys and Cu-Ni-Fe alloys.
They can be produced by heating and slow cooling.	They can be produced by heating and sudden cooling.
Low eddy current loss.	High eddy currents loss.

UNIT-IV

8.a) Derivation of Schrodinger Time independent wave equation -------7m

- Schrödinger's equation is a D.E for debroglie's waves associated with a particle and thus describes the motion of the particle.

- Now we introduce a wave function ψ associated with the moving particle.
- It is the basic equation in Quantum mechanics. It is derived from the de Broglie's concept of matter waves.
- According to deBroglie's a moving particle of mass 'm' is associated with a wave whose wavelength is λ.
- In classical mechanics the equation for a plane wave moving along X- direction is given by $y = a \sin \frac{2\pi}{\lambda}(x-vt)$ ------- (1)

Where y = displacement

a = amplitude

x = position coordinate in x direction

Differentiating the above equation w.r.t 'x' we get

$$\frac{dy}{dx} = a\,\frac{2\pi}{\lambda}\cos\frac{2\pi}{\lambda}(x-vt)$$

$$\Rightarrow \frac{d^2y}{dx^2} = -\frac{4\pi^2}{\lambda^2}a \sin\frac{2\pi}{\lambda}(x-vt)$$

$$\Rightarrow \frac{d^2y}{dx^2} = -\frac{4\pi^2}{\lambda^2}y \text{ (since eqa--- (1))}$$

$$\Rightarrow \frac{d^2y}{dx^2} + \frac{4\pi^2}{\lambda^2}y = 0 \text{ ------- (2)}$$

Schrodinger derived the time independent wave equation in Quantum mechanics by replacing y with ψ and $\lambda = \frac{h}{mv}$

$$\frac{d^2\psi}{dx^2} + \frac{4\pi^2m^2v^2}{h^2}\psi = 0 \text{ ------- (3)}$$

We know that the total energy is sum of Kinetic energy and Potential energy.

Total energy E = K.E (U)+P.E(V)

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

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

Substituting this value in equation (3), we get $\frac{d^2\psi}{dx^2} + \frac{4\pi^2}{h^2} 2m(E-V)\psi = 0$

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

This is Schrodinger's time independent wave equation in one direction.

Put $\hbar = \frac{h}{2\pi}$, the above equation becomes $\frac{d^2\psi}{dx^2} + \frac{8\pi^2}{4\pi^2\hbar^2} m(E-V)\psi = 0$

$$\boxed{\Rightarrow \frac{d^2\psi}{dx^2} + \frac{2m}{\hbar^2}(E-V)\psi = 0}$$

For the same particle moving in 3 dimensional space, the equation becomes

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

where ∇ is known as Laplacian operator. And $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$

For a free particle, V = 0, then Schrdinger's equation for a particle is

$$\boxed{\nabla^2\psi + \frac{2m}{\hbar^2}E\psi = 0}$$

8. **b) Any three points on significance of wave function** **---------3m**

Physical Significance of wave function (Ψ):

- The wave function ψ is a complex quantity. It represents the variations of the matter wave.
- ψ represents the probability of finding a particle in an atomic structure.
- we can say that wave function as probability amplitude since it is used to find the

location of the particle.

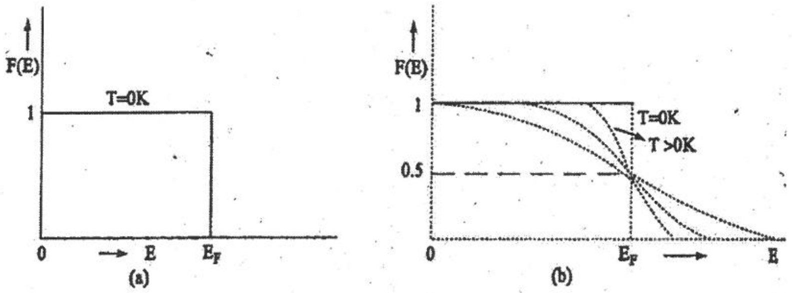
- $|\psi|^2$ is called probability density.
- The probability of finding a particle in a volume $d\tau$ is $|\psi|^2 d\tau = \psi\,\psi^* d\tau$
- $\iiint |\psi|^2 \, \mathbf{d\Gamma = 1}$ when the particle's presence is certain in the space.
- The wave function ψ must have a finite or zero value at any point.
- It must be single valued.
- It must be continuous and have a continuous first derivative every where.
- ψ has no physical meaning but when we multiply this with its complex conjugate

  the product $|\psi|^2$ has physical meaning.

OR

9 a) Explanation of Fermi Dirac distribution functions? Any four postulates of Quantum free electron theory -2m+5m---7m

FERMI DIRAC DISTRIBUTION:



(a) (b)

Fermi - Distribution Function :-

According to Quantum theory, If we assume the electron gas behaving like a system of fermi Particles obeying Fermi- Dirac statistics.

The probability F(E) of an electron occupying an Energy level E is given by

$$F(E) = \frac{1}{1+\exp\left(\frac{E-E_F}{KT}\right)}$$

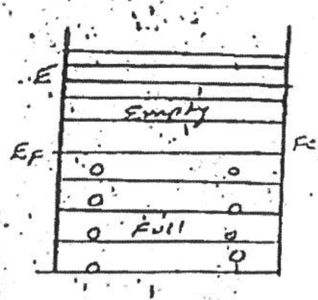
where 'E_F' is called Fermi Energy

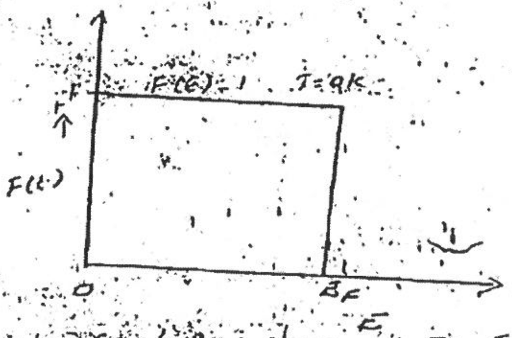
F(E) is called Fermi Function.

If T= 0K. all the Energy levels with Energy below 'E_F' are completly occupied above 'E_F' are unoccupied. The highest filled state at 0K is called the Fermi Energy 'E_F' and the Energy level is known as Fermi level.

At T=0K ; $E < E_F$ $F(E) = 1$ → this indicates all the states are filled with below fermi level electrons

$T = 0K$, $E > E_F$ $F(E) = 0$ → This indicates above fermi level all the states are empty.

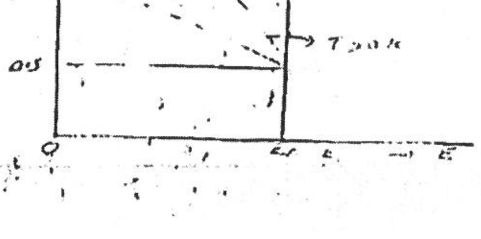




If we raise temp at certain temp $E = E_F$ then

∴ $F(E) = 1/2$

∴ Fermi Energy is the Energy of the state at which the probability of electron occupation is 1/2 at any temp above 0K



9 b) Any three points on sailent features of Classical free electron theory of metals --3m

1. A solid metal is composed of atoms and the atoms have nucleus, around which there are revolving electrons.
2. In a metal the valance electrons of atoms are free to move throughout the volume of the metal like gas molecules of a perfect gas in a container
3. The free electrons move in a random directions and collide with either positive ions fixed to the lattice or other free electrons and collisions are elastic in nature i.e. there is no loss of energy.
4. The movement of free electrons obeys the classical kinetic theory of gasses. The mean K.E. of a free electron is equal to that of gas molecule KT
   2
5. The electron velocities in a metal obey Maxwell-Boltzman distribution of velocities.
6. The free electrons move in a uniform potential field due to ions fixed in the lattice
7. When an electric field is applied to the metal the free electrons are accelerated. The accelerated electrons move in opposite direction of the applied.
8. The electric conduction is due to the free electrons only.

UNIT-V

10 a) Derivation of Density of electrons in the conduction band of an intrinsic semiconductor -----10m

Density of electrons in the conduction band:

Let us assume the number of states in the energy range E and E+dE is Z(E) dE, where Z(E) is the density of states. Since each of these states has an occupation probability F(E), the number of electrons in the energy range E and E+dE is given by

$$dn = Z(E)F(E\,)dE\,.........(1)$$

If E_c is the energy corresponding to the bottom of the conduction band, the number of electrons in the conduction band can be calculated by integrating the above equation from E_c to the energy corresponding to the top of the conduction band ∞. Then,

$$n = \int_{E_c}^{\infty} \quad Z(E)F(E\,)dE\,............(2)$$

We know that the density of states i.e., the number of energy states per unit volume within the energy interval E and E +dE is given by,

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

Since the electron is moving in a periodic potential, its mass has to be replaced by its effective mass m_e^*. Hence,

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

For semiconductors, E starts at the bottom of the conduction band E_c. Hence,

$$Z(E)dE = \frac{4\pi}{h^3}\,(2m_e^*)^{\frac{3}{2}}(E - E_c)^{\frac{1}{2}}\,dE \quad \text{.........(3)}$$

The probability occupation of an electron in an energy state E under thermal equilibrium is

$$F(E) = \frac{1}{1 + exp\left(\frac{E - E_F}{k_B T}\right)}$$

Where k_B is Boltzmann constant and T is temperature in Kelvin. E_F is the energy of the Fermi level.

$$F(E) = \left[1 + exp\left(\frac{E - E_F}{k_B T}\right)\right]^{-1}$$

For all possible temperatures, $E - E_F >> k_B T$

Hence,

$$F(E) \cong exp\left(-\frac{E - E_F}{k_B T}\right) \cong exp\left(\frac{E_F - E}{k_B T}\right) \text{................(4)}$$

Substituting equations (3) & (4) in equation(2) , we get

$$n = \int_{E_c}^{\infty} \frac{4\pi}{h^3}\,(2m_e^*)^{\frac{3}{2}}(E - E_c)^{\frac{1}{2}}\,exp\left(\frac{E_F - E}{k_B T}\right) dE$$

$$n = \frac{4\pi}{h^3}\,(2m_e^*)^{\frac{3}{2}} \int_{E_c}^{\infty} (E - E_c)^{\frac{1}{2}}\,exp\left(\frac{E_F - E}{k_B T}\right) dE$$

To solve this integral, let us put, $E - E_c = x$. If $E = E_c$, then $x = 0$

Therefore $E = E_c + x$ and $dE = dx$

$$n = \frac{4\pi}{h^3}\,(2m_e^*)^{\frac{3}{2}}exp\left(\frac{E_F}{k_B T}\right) \int_{0}^{\infty} (x)^{\frac{1}{2}}\,exp\frac{-(E_c + x)}{k_B T}\,dx$$

It can be shown that using gamma function

$$\int_0^{\infty} (x)^{\frac{1}{2}} exp\frac{-(x)}{k_BT}dx = (k_BT)^{\frac{3}{2}}\frac{\pi^{\frac{1}{2}}}{2}$$

Hence

$$n = \frac{4\pi}{h^3}(2m_e^*)^{\frac{3}{2}} exp\left(\frac{E_F - E_c}{k_BT}\right)(k_BT)^{\frac{3}{2}}\frac{\pi^{\frac{1}{2}}}{2}$$

i.e The number of electrons per unit volume of the material is given by

$n = 2\left(\frac{2\pi\, m_e^* k_BT}{h^2}\right)^{\frac{3}{2}} exp\left(\frac{E_F - E_c}{k_BT}\right)$............(5)

This is the expression for Density of electrons in the conduction band of an intrinsic semiconductor.

OR

11 a) Explanation of Hall Effect + derivation of Hall coeeficient --2m+5m ----7m

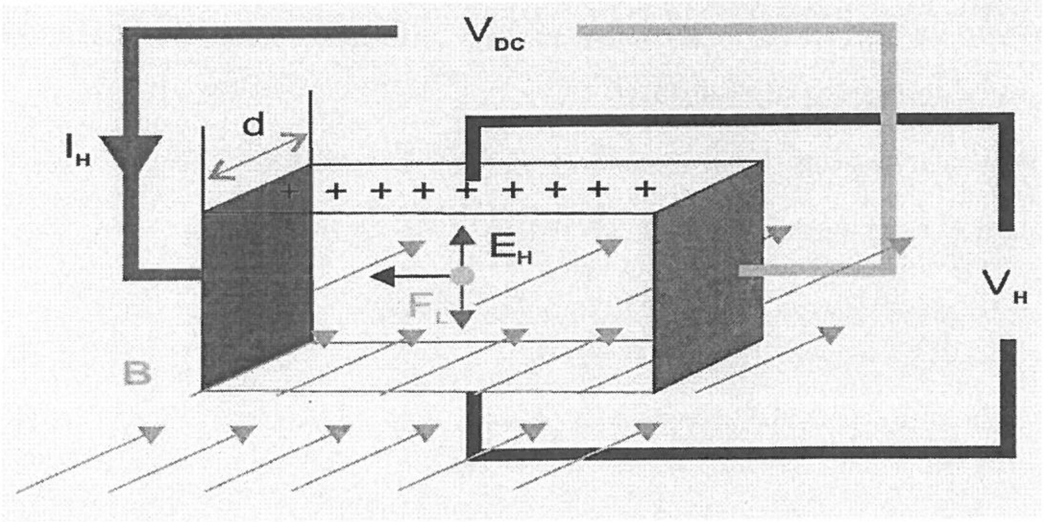
HALL EFFECT:

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

$$\mathbf{F_L = - B.e.V_d}$$

V_d - 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 $J = -n e V_d$

$V_d = -J/ne$ or $E_H = -JB/ne$

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

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

$$\Rightarrow E_H = R_H. JB$$

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

NRI.

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~~Dr. N. Abhiram, Asst. Prof.~~

~~Ms. TV Narmada, Asst. Prof.~~

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

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

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

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

11. b) Any three application of Hall effect ----3m

The Hall Effect measurements provide the following information about the solid:

1. Determination of type of semiconductor whether it is p-type or n-type.
2. The carrier concentration can be calculated.
3. The mobility of charge carriers can be measured directly.
4. The magnetic flux density can be measured.

The power in an electromagnetic wave can be measured