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(U19CS012) PMN ASSIGNMENT

1.) Define :

Magnetic Fields : The portion of space near a magnetic body or a current carrying body in which the magnetic forces due to the body or current can be detected.

Magnetic Induction (B) : ① Induction of magnetism in a body when when it is in a magnetic field or in the magnetic flux set up by a magnetomotive force - symbol 'B'.

$[B = \phi/A]$

② The product of magnetic permeability of a medium by the intensity of magnetic field in it is called magnetic flux density.

Magnetic moment (μ_m) : A vector quantity that is a measure of the torque exerted on a magnetic system (such as a bar magnet or dipole) when placed in magnetic field and that for a magnet is the product of the distance between its poles and strength of either pole.

Magnetic Intensity (H) : A vector quantity pertaining to the condition at any point under magnetic influence (as a magnet or electric current or an electromagnetic wave) measured by the force exerted in a vacuum upon a free unit north pole placed at the point in question.

$[B = \mu H]$

Magnetization: An instance of magnetizing or the state of being magnetized.

Permeability : The property of magnetizable substance that determines the degree in which it modifies the magnetic flux in the region occupied by it in a magnetic field.

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Magnetic susceptibility : The ratio of magnetization in a substance to the corresponding magnetizing force.

2.> Discuss the properties and effect of External fields on the Dia, Para and Ferro magnetic material.

2.>

DIAMAGNETIC : (•) Materials have weak, negative susceptibility to magnetic fields

(•) Slightly repelled by magnetic field

$(\mu_r < 1)$ (•) Does not retain magnetic properties when external field is removed

(•) All electrons are paired, so there is no permanent net magnetic moment per atom Eg: Silver and Gold.

PARAMAGNETIC : (•) Materials have small, positive susceptibility to magnetic field

(•) Slightly attracted by magnetic field.

$(\mu_r > 1)$ (•) Does not retain magnetic properties when external field is removed

(•) Paramagnetic properties are due to presence of some unpaired electrons

Eg: Lithium, Magnesium

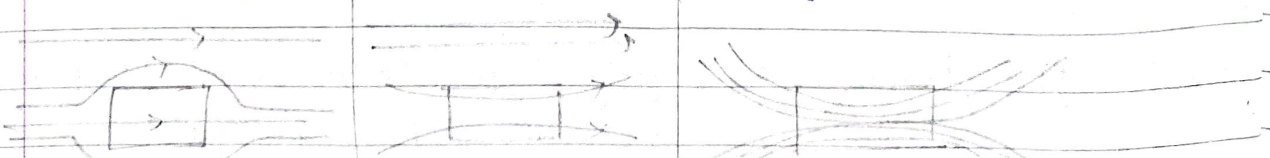
FERROMAGNETIC : (•) Material have large, positive susceptibility to magnetic field

(•) Exhibit Strong attraction to magnetic field

(•) Retain magnetic properties when external ~~for~~ field is removed

$(\mu_r >> 1)$ (•) They have some unpaired electrons so have net magnetic moment

(•) Strong magnetic properties due to magnetic domains



DIAMAGNETIC PARA MAGNETIC FERRO MAGNETIC

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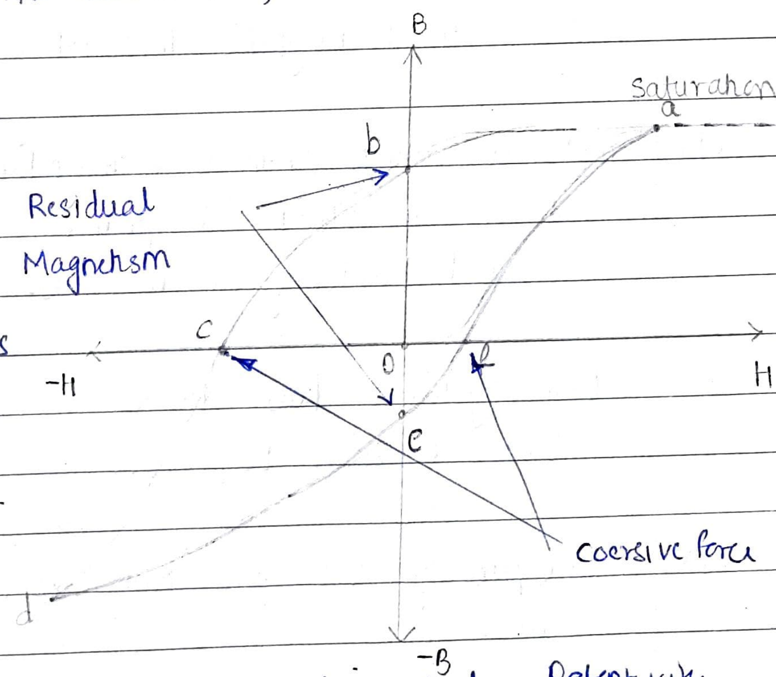
3.> What are ferromagnetic domains? Draw B-H curve for ferromagnetic material and identify retentivity and coercive field on the curve. What is energy loss per cycle.

3.> Ferromagnetic Domain :(.) Region within a magnetic material in which the magnetization is in a uniform direction. This means that the individual magnetic moments of the atoms are aligned with one another and they point in same direction.

(.) The magnetization within each domain points in a uniform direction, but magnetization of different domains may point in different direction.

(.) This structure is responsible for the magnetic behaviour of ferromagnetic material like iron, nickel etc.

(A) Retentivity : The magnetic flux does not completely dis-appear as the electromagnetic core material still retains some of its magnetism even when the current has stopped flowing in coil. The ability of coil to retain some magnetism within the core after process has stopped is called Retentivity.



(B) COERCIVE FORCE: To reduce the residual flux density to zero is by reversing the direction of the current flowing through the coil, thereby making the value of 'H', magnetic field strength negative. Thus effect is called coercive force (H_c).

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Energy loss per cycle = Area under Hysteris curve.

(1) Hysterisis Loss is due to reversal of ~~magnetisation~~ magnetization of transformer core whenever it is subject to Alternating nature of magnetizing force.

(2) Whenever the core is subjected to an Alternating magnetic field, the domain present in the material will change their orientation after every half cycle.

(3) The power consumed by the magnetic domains for changing the oreintation after every half cycle is called Hysterisis Loss.

4.) Distinguish between Soft and Hard magnetic Material.

	Hard Magnetic Material	Soft Magnetic Material
(1)	Materials which retain their magnetism and are difficult to demagnetize are called hard magnetic materials.	(1) Soft magnetic materials are Easy to magnetize and demagnetize
(2)	Large hysterisis Loss due to Large hysterisis Loop area.	(2) Low hysterisis Loss due to small hysterisis area
(3)	Susceptibility and permeability are low.	(3) Susceptibility and permeability are high.
(4)	Coercivity & rententivity values are high.	(4) Coercivity and retentivity are less.
(5)	Magnetic Energy stored - HIGH	(5) They are not used to make permanent magnets. (Low)
(6)	Eddy current Loss is high	(6) Eddy current Loss is Less. (↑ resistivity)

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5.) Distinguish between Anti-ferro and ferri-magnetic materials.

5.)

Anti Ferro Magnetic	Ferri magnetic Materials
(1) Successive magnetic dipoles are aligned in opposite direction.	(1) The successive magnetic moments are of different magnitude and aligned in opposite direction.
(2) At room temperature, manganess and chromium in the solid state exhibit anti-ferromagnetism. the ratio of a/d for Mn & Cr is less than 1.4 and here a negative exchange energy.	(2) A Large magnetization is produced on applying a small magnetic field.
(3) Susceptibility is very small and positive. It increase with increasing temperature and reaches a maximum value at one particular temperature called as Neel temperature, ~~the~~ ↑ Above Neel temperature, the anti ferromagnetic becomes a paramagnetic material.	(3) They are used in high frequency application
Eg: Ferrous oxide, Zinc ferrite	Eg: Ferrous Ferrite, Nickel ferrite.

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6.) A magnetic material has a magnetisation (M) of 3400 Am^{-1} and magnetic flux density (B) of 0.0048 $Wb m^{-2}$. Calculate the magnetic field strength (H) and relative permeability of the material.

6.) Given: $M = 3400 \ Am^{-1}$ $B = 0.0048 \ Wb m^{-2}$ $\mu_0 = 4\pi \times 10^{-7}$

To find: $H = (?)$ $\mu_r = (?)$

$B = \mu_0 (M + H)$

$0.0048 = 4\pi \times 10^{-7} (3400 + H)$

$3819.71 = 3400 + H$

$[H = 419.71 \ Am^{-1}]$

$\mu_r = \dfrac{\mu}{\mu_0} = \dfrac{B}{\mu_0 H} = \dfrac{(0.0048)}{(4\pi \times 10^{-7})(419.71)}$

$= [9.1]$

7.) A magnetic field strength of $2 \times 10^5 \ Am^{-1}$ is applied to paramagnetic material with relative permeability of 1.01. Calculate the value of B and M.

7.) $H = 2 \times 10^5 \ Am^{-1}$; $\mu_r = 1.01$; $\mu_0 = 4\pi \times 10^{-7}$

$\mu_r = \dfrac{\mu}{\mu_0}$

$\mu_r \mu_0 = \mu \Rightarrow \dfrac{B}{H} = \mu_r \mu_0$ —(1)

$B = H \mu_r \mu_0 = (2 \times 10^5) \times (1.01) \times 4\pi \times 10^{-7}$

$[B = 0.2538 \ Wb m^{-2}]$ (Magnetic flux Density)

$B = \mu_0 (H + M)$

$\left(\dfrac{B}{\mu_0}\right) = (H + M)$ (From eqn (1))

$\mu_r H = H + M$

$M = (\mu_r - 1) H = (2 \times 10^5)(1.01 - 1)$

$[M = 2 \times 10^3 \ Am^{-1}]$ (M ⇒ Magnetization)

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(Q.8) What are the assumptions introduced by Drude-Lorentz to explain classical free electron theory of metals? Discuss the acheivements and failures of this method.

(A.8) → Drude and Lorentz proposed this theory in 1900. Acc. to this theory, the metals containing the free electrons obey the laws of classical mechanics.

(*) ASSUMPTIONS

1.) The valence e^-(s) are free to move about the whole volume of the metal.

2.) The free electrons move in random direction and collide with either the ions fixed to the lattice or the other free electrons. All the collisions are elastic in nature.

3) The momentum of free electrons obeys the laws of the classical kinetic theory of gases.

4.) The e^- velocities in a metal obey classical Maxwell-Boltzmann distribution of velocities.

5.) When the electric field is applied to the metal, the free electrons are accelerated in the direction opposite to the direction of applied electric field.

6.) The mutual repulsion among the electrons is ignored, so that they move in all the directions with all possible velocities.

7.) In absense of field, the energy associated with an

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electron at temperature T is given by $\frac{3}{2}kt = \frac{1}{2}m v_{th}^2$,

v_{th} = thermal velocity

* Achievements

1.> It verifies Ohm's Law

2.> It explains electrical conductivity of metals. and also explains thermal conductivity of metals.

3.> Widemann- Franz Law is also derived.

* Drawbacks

1.> It could not explain photoelectric effect, Compton effect and black body radiation.

2.> Electrical conductivity of semi-conductors and insulators could not be explained

3.> Widemann - Franz Law is not applicable at lower temperature.

4.> Ferromagnetism could not be explained by this theory.

5.> According to this theory, the specific heat of metals is given by 4.5R where as the experimental value is given by 3R.

6.> According to classical free e- theory, the electronic specific heat is equal to $\left(\frac{3R}{2}\right)$ while the actual value is 0.01R.

Q9.> State Wiedmann-Franz Law. Deduce the law using the results of Classical free electron theory.

A9.>

→ Wiedmann- Franz Law is the law which which relates thermal conductivity (K) and electrical conductivity (σ or $1/\rho$) of a material which consist of somewhat freely moving e^- in it.

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We know that in metals,

free e^-

if $T\uparrow \Rightarrow v\uparrow \Rightarrow$ Heat Transfer $\uparrow$ $\Rightarrow$ collision between lattice ions &

$\therefore$ Electrical conductivity $\downarrow$

$\therefore$ According to Law; $\quad \frac{K}{\sigma} = LT$, $\quad L$ = Lorentz number $= 2.44\times10^{-8}\ W\Omega K^{-2}$

(T = Temperature)

* Derivation

(1) Lets Assume a homogeneous isotropic material with temperature gradient $\frac{dT}{dx}$ and direction of heat flow opposite to it.

(2) Heat flowing through the material per unit time per unit area is ~~the~~ Heat flux

$$\left[\ q = -k\frac{dT}{dx} \quad W/m^2 \ \right] \quad -(i)$$

k = Coefficient of thermal conductivity (W/mK)

(3) Assume the flow of heat is from higher to lower temperature in a metal slab which has temperature gradient $\left(\frac{dT}{dx}\right)$

$$\therefore\ q = \frac{mnv}{3\lambda C_v}\cdot\frac{dT}{dx} \quad -(ii)$$

C_v = Specific Heat

n = no. of particles per unit volume

λ = mean free path

v = velocity of e^-(s)

From (i) & (ii)

$$k = \frac{mnv\lambda C_v}{(3)} \quad -(iii)$$

(4) Energy of free electrons is $mC_vT = \frac{3}{2}k_BT$

$$\therefore \left[\ C_v = \frac{3}{2m}k_B\ \right] \quad -(iv)$$

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Put (iv) in (iii)

$$\boxed{K = \frac{n v \lambda k_B}{2}}$$

(5) Specific heat of an ideal gas at constant volume

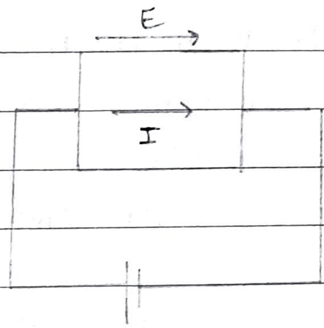
$$C_v = \frac{3 n k_B}{2} \qquad \left[k_B = \frac{2C_v}{3n}\right] \quad -(vi)$$

Put (vi) in (v)

$$\therefore \quad K = \frac{1}{3} C_v \lambda v \quad -(vii)$$

(6) Now consider electrical current density of metal

Ohm's Law $\quad J = \sigma E$



$$\sigma = \frac{ne^2\tau}{m} \quad -(viii)$$

$$\therefore \quad \boxed{J = \frac{ne^2\tau}{m} E}$$

(7) Also $\quad \tau = \frac{\lambda}{v_d} \quad -(ix)$

e = charge of e^-

τ = Collision time $\qquad v_d$ = drift velocity

$$\boxed{\sigma = \frac{ne^2\lambda}{m v_d}} \quad -(x)$$

(8) The equipartition theorem gives

$$\frac{1}{2} m v_d^2 = \frac{3}{2} k_B T \quad (xi)$$

$$m = \frac{3 k_B T}{v_d^2} \quad -(xii)$$

Put (xii) in (x) $\qquad \sigma = \frac{n\lambda e^2 v_d}{3 k_B T} \quad -(xiii)$

$\therefore$ from (v) & (xiii)

$$\frac{K}{\sigma} = \frac{3 v k_B^2}{2 v_d e^2} \quad -(xiv)$$

[Assume $v = v_d$]

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$$\frac{K}{\sigma} = \frac{3k_B^2 T}{2e^2} \quad -(xv)$$

$$\frac{K}{\sigma T} = 5.838 \times 10^{-9} \ \Omega \text{ cal } k\text{-sec}$$

$$\frac{K}{\sigma T} = 2.44 \times 10^{-8} \ \Omega \, W/k^2 = \text{Lorentz number } (L)$$

$$\therefore \boxed{\frac{K}{\sigma} = LT} \quad : \text{Wiedemann - Franz Lorenz Law}$$

Q10.> If Wiedmann-Franz Law is valid under quantum mechanical treatment, compute the electrical resistivity of copper at 20°C if the thermal conductivity at this temperature is 380 $W m^{-1} K^{-1}$.

A10.>

From Wiedmann Franz Law $\frac{K}{\sigma} = LT$, $L = 2.44 \times 10^{-8} \ \Omega W/k^2$

Given: $K = 380 \ W m^{-1} K^{-1}$

$T = 20°C = 293 K$

To find: $\rho = (?)$

$$\therefore \frac{K}{\sigma T} = (2.44 \times 10^{-8}) \ \Omega \, W \, K^{-2}$$

$$\frac{1}{\sigma} = \frac{(2.44 \times 10^{-8})(293)}{380} \ \Omega m$$

$$\boxed{\rho = \frac{1}{\sigma} = 1.88 \times 10^{-8} \ \Omega m}$$

$\therefore$ Resistivity $= \boxed{\rho = 1.88 \times 10^{-8} \ \Omega m}$

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Q11.> A copper wire of length 0.5 metre and diameter 0.3 mm has a resistance 0.12 Ω at 20°C. If the thermal conductivity of copper at 20°C is 390 $W m^{-1} K^{-1}$, calculate Lorentz number. Compare this value with the value predicted by Classical free electron theory.

A11.> Given: $l = 0.5\ m$; $R = 0.12\ \Omega$; $T = 20°C = 293\ K$

$d = 0.3\ mm = 0.3 \times 10^{-3}\ m$; $K = 390\ W m^{-1} K^{-1}$

$$\Rightarrow A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = 0.7065 \times 10^{-7}\ m^2$$

$[R = 0.12\ \Omega]$

We know that, $R = \frac{\rho l}{A}$

$$\sigma = \frac{1}{\rho} = \frac{l}{RA}$$

$$\sigma = \frac{0.5}{(0.7065) \times 10^{-7} \times 0.12} = [5.89 \times 10^{7}\ \Omega^{-1} m^{-1}]$$

From wiedmann-Franz law,

$$\frac{K}{\sigma} = LT$$

$$L = \frac{K}{\sigma T} = \frac{390}{((5.89) \times 10^{7})(293)}$$

$$= 0.22598 \times 10^{-7}\ \Omega W/K^2$$

$$[L = 2.26 \times 10^{-8}\ \Omega W/K^2]$$

ANS: The obtained value of L is less than that predicted by classical free electron theory $[L = 2.44 \times 10^{-8}\ \Omega W/K^2]$

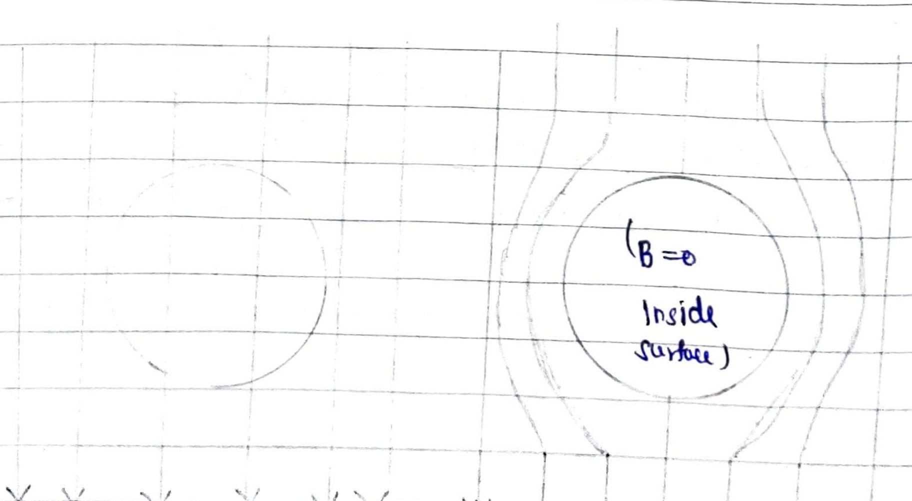
Q12.> What is Superconductivity? Give an elementary account of superconductivity?

A12.>

⇒ Certain metals and alloys exhibit almost zero resistivity when they are cooled sufficiently to low temperature is known as super conductivity.

⇒ Certain substances completely lose their electrical resistance below a certain critical temperature. The characteristic transition temperature T_c varies from 0.15K to 20K for pure metals. However ceramic materials have transition temperature T_c around 90K. The transition temperature of an element differs for different isotopes.

⇒ Below the transition temperature, when a substance is a superconductor, the superconducting property may be destroyed by the application of a sufficiently strong magnetic field. At any temperature below T_c, there is a critical magnetic field H_c such that the superconducting property is destroyed by the application of a magnetic field intensity $H > H_c$. The value of H_c decreases as the temperature (which is less than T_c) increases.



a) Normal $T > T_c$ or $H > H_c$ b) Superconductivity $(T < T_c)$ $(H < H_c)$

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⇒ The thermal properties such as specific heat and thermal conductivity of a substance change abruptly. Superconductivity can be explained satisfactorily by wave mechanics. The electrons tend to scatter in pairs rather than individually. This give rise to an exchange force between electrons. The force is attractive and is very strong if e^-'s have opp. signs and momenta.

→ In superconducting state, the forces of attraction between the conduction electrons exceed the forces of electrostatics repulsion. The system of conduction electrons the becomes a bound system. No transfer of Energy takes place from this system to lattice ions. Substance does not possess any electrical resistivity.

Q13.> Write a short note on meissner effect.

A13.>

(1) When a weak magnetic field is applied to a super conducting specimen at a temperature below T_c, the magnetic flux lines are expelled from the specimen.

(2) The specimen acts as an ideal dia-magnetic this is known as "meissner effect". It is reversible, that when a temperature of speciment is raised below T_c at $T = T_c$, the flow suddenly starts penetrating the specimen.

(3) The specimen comes back to normal stage, under the condition magnetic induction of a specimen $B = \mu_0(H+I)$, where $H \rightarrow$ applied magnetic field and $I \rightarrow$ magnetisation

As → $B = 0$ $\quad \mu_0(H+I) = 0 \quad \therefore H = -I$

$$\left[\because \chi = \frac{I}{H} = -1 \right]$$

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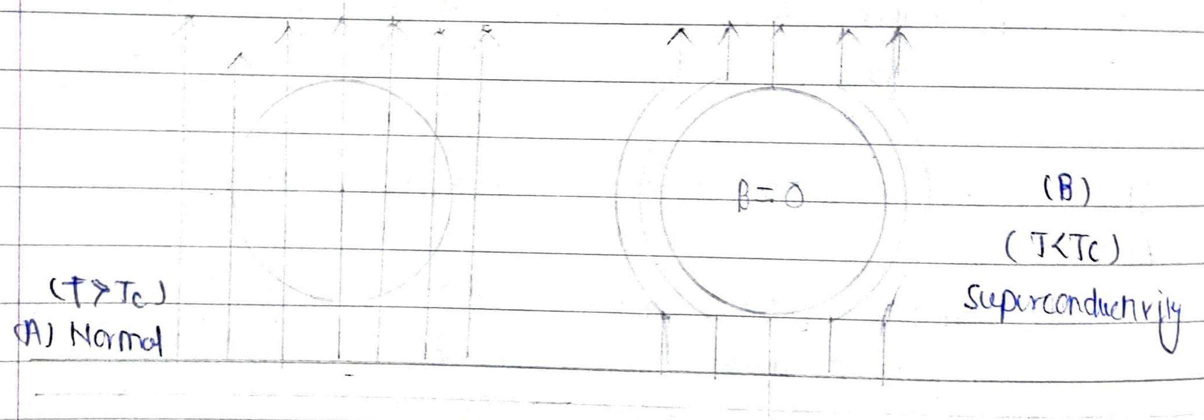
Hence susceptibility is -1, the substance are diamagnetic
In case of Super conductors, $\rho = 0$
But electric field $\mathcal{E} = J\rho \Rightarrow [\mathcal{E} = 0]$

Also, Del $\mathcal{E} = \frac{dB}{dt} \Rightarrow \frac{dB}{dt} = 0$; so B should be constant.

This contradicts meissner effect itself.

Hence, we can say that, super conducting substance behave differently from that of normal specimen. Ultimately in super conducting stage $E = 0$ & $B = 0$



Q14.> Explain Type I and Type II superconductors. Also briefly discuss the important property changes during the transition

A14>

Type I Super conductor : They also known as soft super conductors, when the magnetic field is applied & increased gradually from its initial value H<Hc, the diamagnetism disappears abruptly.

Super conducting specimen changes to normal state sharply.

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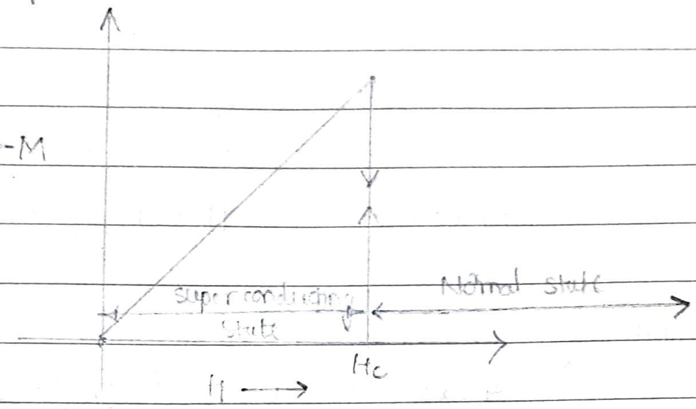
- The transition from a superconducting state to a normal state due to external magnetic field is sharp and abrupt for this superconductor.

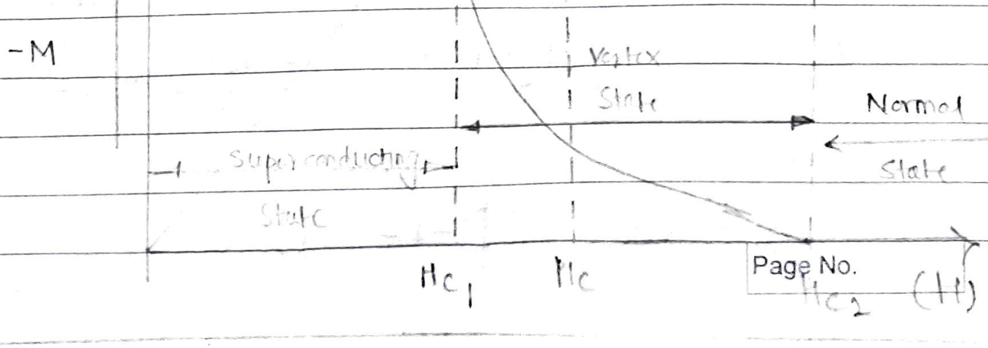
Eg. Pb, Sn, Hg

- Exhibits meissner effect & have no mixed state.



Type II Superconductor : They have two critical fields namely H_{c_1} and H_{c_2}. Up to the field H_{c_1} the specimen is in pure superconducting state rejecting all the magnetic lines. Beyond H_{c_1} lower critical field, magnetic lines start penetrating the specimen, upto second critical field (H_{c_2}). the specimen is in mixed state.

- In mixed state, the meissner effect is incomplete. This region is "Vortex-region". Beyond H_{c_2} the specimen completely becomes Normal from Super conducting State.
- Also called "Hard superconductors"



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Q15.) For a specimen of V_3Ga, the critical fields are respectively 1.4×10^5 and 4.2×10^5 A/m. For 14K and 13 K. Calculate the transition temperature and critical fields at 0K and 4.2k.

ANS.) We know that, $H_c(T) = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]$

$$\therefore (1.4\times10^5) = H_c(0)\left[\frac{(T_c)^2 - (T)^2}{(T_c)^2}\right]$$

$$(1.4\times10^5) = H_c(0)\left[\frac{(T_c)^2 - (14)^2}{(T_c)^2}\right] \quad -(i)$$

Similarily,

$$4.2\times10^5 = H_c(0)\left[\frac{(T_c)^2 - (13)^2}{T_c^2}\right] \quad -(ii)$$

From (i) & (ii), we get

$$\frac{4.2\times10^5}{1.4\times10^5} = \frac{(T_c)^2 - (13)^2}{(T_c)^2 - 14^2}$$

$$\frac{1}{3} = \frac{T_c^2 - 14^2}{(T_c)^2 - 13^2}$$

$$(T_c)^2 = \left(\frac{419}{2}\right)$$

ANS: $\therefore \boxed{T_c = 14.47\ K}$

$$\therefore H_c(0) = \frac{(1.4\times10^5)\times(14.47)^2}{(14.47)^2 - (14)^2}$$

ANS: $\boxed{H_c(0) = 2.19\times10^6\ A/m}$

$\therefore$ For $T = 4.2k$

$$H_c(4.2) = H_c(0)\left[1 - \left(\frac{4.2}{14.47}\right)^2\right]$$

ANS: $\boxed{H_c(4.2) = 2\times10^6\ A/m}$

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