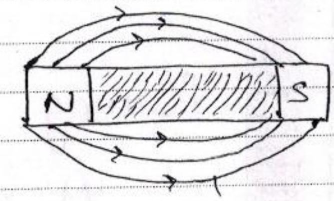
Magnetic Properties of Materials

Magnetic Movement:

An atom consists of positively charge nucleus and negetively charged electron revolving around the nucleus in a circular orbit. Each revolving electron produces electric Current and circulating electron is equivalent to (dipole) current loop which produces magnetic feild. Thus, an atom is equivalent to magnetic dipole.

We calculate the magnetic movement due to orbital motion of electron.



magnetic lines of forces

Current due to orbital motion of electron:

$$i = \frac{e}{T} \quad -①$$

Notes

Now, if v is the velocity of electron in circular orbit of radius R then $T = \frac{dis}{v} = \frac{2\pi r}{v}$

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In (1) equation, $i = \frac{e \cdot v}{2\pi r}$ — (2)

Magnetic movt. $= i \times$ Area

$= \frac{ev}{2\pi r} \times \pi r^2$

$= \frac{evr}{2}$ — (A)

According to bohr condition of quantised orbit, angular momentum,

$L = \frac{nh}{2\pi}$ $[n = 0, 1, ---]$

And, angular movnemtum = Linear momentum x dist.

$= mvr$

Now, $mvr = \frac{nh}{2\pi}$

$vr = \frac{nh}{2\pi m}$ — (3)

Putting the (3) in eq (A)

$M = \frac{e}{2} \cdot \frac{nh}{2\pi m} = \frac{n\,eh}{4\pi m}$

$M = n\left[\frac{eh}{4\pi m}\right]$

Magnetic momement is the integral multiple of $\frac{eh}{4\pi m}$ called bohr magnetron.

S	M	T	W	T	F	S
30	31					1
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Magnetic induction:

An atom consists of positively charged nucleus and negatively charged electron revolving around the nucleus. Each circulating electron is equivalent to current loop that produces magnetic feild.

When the magnetic material is placed in external uniform magnetic feild, then the elementary current present in the material tends to align parallel to the magnetic feild. The material gets magnetised and acquire magnetic dipole movement.

The no of magnetic lines of forces passing per unit area in free space is called magnetising feild H. and no of magnetic lines of forces (net) passing per unit area through medium is called as magnetic dipole movement.

Notes

The magnetising feild and magnetic feild is denoted by H and flux density as well as magnetic dipole movement is denoted by I.

Birthday / Anniversary

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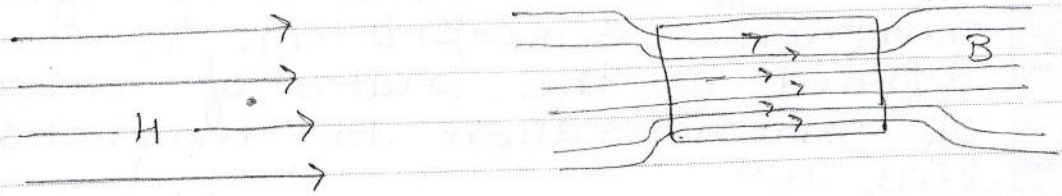
Be observant. Notice what is going on both in your world and in the world of great events. Use all your five senses; sight, hearing,touch, smell, & taste, to acquire more knowledge of your surroundings.



Intensity of Magnetisation:

Acquired magnetising feild H per unit volume is called intensity of magnetisation. It is denoted by I.

$$I = \frac{M}{V}$$

Relative Perimiability

Relative permiability is defined as the ratio of permiability of medium to the permiability of free space.

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

Magnetic Suscipibility

In isotropic materials, intensity of the magnetisation is directly proportional to magnetising feild H

$$I \propto H$$

$$I = \chi_m H$$

Notes

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where χ_m is constant and often called magnetic susceptibility. It can be defined as the ratio of intensity of magnetisation to magnetising feild H.

Relation between μ_r, χ_m and I

In actual total feild is the sum of magnetising feild H and intensity of magnetisation (I).

$$B = \mu_0 (H + I) \quad -(1) \quad \text{in C.G.S unit}$$

In S.I unit, both H and I are in same units.

$$B = \mu H \quad -(2)$$

From (1) and (2)

$$\mu H = \mu_0 (H + I)$$

$$\frac{\mu}{\mu_0} = \left(\frac{H+I}{H}\right)$$

$$\mu_r = \left(1 + \frac{I}{H}\right)$$

$$\therefore \mu_r = 1 + \chi_m$$

Sakshi

Piyush

Notes

Orbital Theory of Diamagnetism:

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8.00 Diamagnetic Substances are those which are weakly magnetised by feild
9.00 and in opposite direction.
when the bar of diamagnetic
10.00 Substance is placed in a uniform external magnetic feild then the
11.00 magnetic lines of forces in free space is more than the magne-
12.00 tic lines of forces in a material.
Therefore, magnetic susceptibility,
1.00 relative permiability is negetive and intensity of magnetisation
2.00 is also negetive.

3.00 According to faraday's, line integral of electric feild over any closed
4.00 surface is equal to rate of change of magnetic feild over any closed
5.00 surface.

$$\oint E \cdot dl = -\frac{d}{dt}\left(\oint \vec{B} \cdot ds\right)$$

$$E \times 2\pi r = -\frac{dB}{dt} \cdot \pi r^2$$

$$E = -\frac{r}{2}\frac{dB}{dt}$$

Notes
when electric feild is applied on the electron then torque is produced.

τ = Force x dis

= $-eE \cdot r$

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$$\tau = \frac{er}{2}\frac{dB}{dt}\cdot r$$

Rate of change of angular momentum is torque

$$\frac{dJ}{dt} = \frac{er^2}{2}\frac{dB}{dt}$$

$$\Delta J = \frac{er^2 B}{2} \quad -(1)$$

Now, magnetic movement is related with angular momentum as,

$$M = -\frac{e}{2m}\cdot mvr$$

$$M = -\frac{e}{2m}\cdot \text{angular momentum.}$$

(−) Sign shows that magnetic movement is point in direction opposite to the direction of vector representing angular momentum.

$$M = \frac{-e}{2m}\cdot\frac{er^2 B}{2}$$

$$= \frac{-e^2 r^2 B}{4m}$$

If x, y, z are the coordinate of any point then : (circular radius R).

Notes

$$R^2 = x^2 + y^2 + z^2$$

In spherically symmetric forms

$$\frac{R^2}{3} = x^2 = y^2 = z^2$$

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If the feild $\vec{B}$ is acting along z-axis then:

$$x^2 + y^2 = \frac{2R^2}{3}$$

Total magnetic movement:

$$M = -\frac{e^2 B}{4m} \sum r^2$$

$$= \frac{-e^2 B z \cdot 2R^2}{4m \cdot 3} = \frac{-e^2 z B 2R^2}{12m}$$

If Substance Contains 'n' no. of electrons per unit volume then intensity of magnetisation (I):

$$I = \frac{-ne^2 z B 2 R^2}{12m}$$

Dividing by 'H' on both Sides

$$\chi_m \left(\frac{I}{H}\right) = \frac{-ne^2 z B R^2}{6m H}$$

$$\mu_r = 1 + \chi_m$$

$$\Rightarrow \mu_r = 1 + \left(-\frac{ne^2 z B R^2}{6m H}\right)$$

Notes: $\therefore$ which is less than 1.

$\boxed{\mu_r < 1}$

$\boxed{\chi_m < 1}$

Diamagnetic

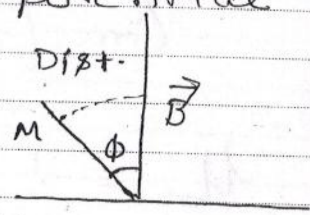
Classical Theory of Paramagnetism:

Paramagnetic are those fairly Substances which is weakly magnetised in Same ~~direction~~ of applied feild.

When the bar of paramagnetic Substances is placed in a uniform external magnetic feild then number of magnetic lines of forces in free space is less than magnetic lines of forces in medium.

According to Longevin, all paramagnetic Substances have permanent magnetic moment and the only force acting on the Substances is external magnetic feild.

If a atomic dipole makes an angle θ with $\vec{B}$ feild then potential energy is given as:



$$w = -mB\cos\theta$$

$$dw = mB\sin\theta \, d\theta \quad -(1)$$

According to boltzmann, Classical Statistics, no of atoms/molecules having energy in the range of w and $w + dw$ is given as:

$$dn = ce^{-w/KT} \, dw$$

Putting value of $d\omega$ and ω

$$dn = C e^{\omega/kT} mB \sin\theta\, d\theta$$

$$dn = C e^{mB\cos\theta/kT} \cdot mB \sin\theta\, d\theta$$

$$\theta \rightarrow 0 \text{ to } \pi$$

$$n = \int dn = \int C e^{mB\cos\theta/kT} \cdot mB \sin\theta\, d\theta \quad -(2)$$

$$C = n \Big/ \int e^{\frac{mB\cos\theta}{kT}} \times mB \sin\theta\, d\theta.$$

Now, intensity of magnetisation is

$$dI = m\cos\theta\, dn$$ (?) ये कहाँ से आया

on integration

$$I = \int m\cos\theta \cdot C e^{\frac{mB\cos\theta}{kT}} \cdot mB \sin\theta\, d\theta$$

$$I = C \int m^2 B\, e^{\frac{mB\cos\theta}{kT}} \cdot \sin\theta\cos\theta\, d\theta$$

Value is C is;

$$I = \frac{nm^2 \int B\, e^{\frac{mB\cos\theta}{kT}} \cdot \sin\theta\cos\theta\, d\theta}{\int mB\, e^{\frac{mB\cos\theta}{kT}} \cdot \sin\theta\, d\theta}$$

$dI = m\cos\theta\, dn$

$$I = nm \int e^{\frac{mB\cos\theta}{kT}} \cdot \sin\theta\cos\theta\, d\theta$$

$$\int e^{\frac{mB\cos\theta}{kT}} \cdot \sin\theta\, d\theta$$

Put $\left(\frac{mB}{kT} = x\right)$ and $\cos\theta = t$

$-\sin\theta\, d\theta = dt$

$$I = nm \int e^{xt} \cdot t\, dt \rightarrow \text{I}$$

$\boxed{-1 < t < 1}$ (ILATE)

$$\int e^{xt}\, dt \rightarrow \text{II}$$

Solving (I): $\left| \frac{e^{xt} \cdot t}{x} \right|_{-1}^{1} - \int_{-1}^{1} \frac{e^{xt}}{x}$

$$= \left[\frac{2}{x}\cosh x - \frac{2}{x^2}\sinh x \right]$$

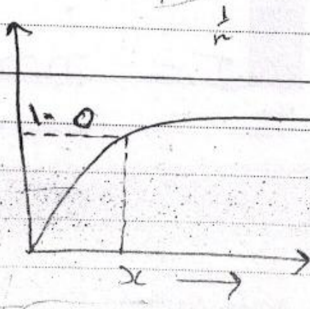
Solving (II): $\left(\frac{e^{xt}}{x} \right)_{-1}^{1}$

$$= \frac{2}{x}\sinh x$$

$$I = nm \left[\frac{\frac{2}{x}\cosh x - \frac{2}{x^2}\sinh x}{\frac{2}{x}\sinh x} \right]$$

$$I = I_s \left[\coth x - \frac{1}{x} \right]$$

Notes Graph shows that for large value of x, function tends to unity, means saturation is being reached.



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For large value of x, magnetic dipoles are aligned parallel to the magnetic feild. But for small value of x we can write the expansion of $\coth x$ as $\coth x = \left[\frac{1}{x} + \frac{x}{3} - - -\right]$

$$I = \frac{mnx}{3}$$ $$\left[x = \frac{mB}{kT}\right]$$

$$I = \frac{mn \cdot mB}{3kT}$$

$$I = \frac{nm^2 B}{3kT} = \frac{nm^2 \mu_0 H}{3kT}$$ $(B = \mu_0 H)$

$$\chi_m = \frac{nm^2 \mu_0}{3kT}$$

$\mu_r = 1 + \chi_m$ which is positive and greater than 1.

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RIM

Molecular Feilds:

Mid term I

In 1907, Weiss modified the theory of paramagnetism by introducing a new concept of molecular feild. Acc. to Weiss, in case of paramagnetic substances molecular feild is produced by neighbouring dipoles which is directly proportional to magnetising feild H.

Molecular feild = αH.

Thus, total feild on the Substance is given by molecular feild (by neighbouring dipoles) and actual feild acting on the Substance.

$$\boxed{H_i = H + \alpha I}$$

$\chi_m = \frac{C}{T - \theta_c}$

Now, intensity of magnetisation is:

$$I = \frac{nm^2 \mu_0 (H + \alpha I)}{3kT}$$

$= \frac{C}{T - \theta_c}$ $\frac{\chi_m}{}$ $\frac{n m^2 \mu_0}{3kT}(H + \alpha I)$

$$\frac{I}{H} = \frac{m^2 n \mu_0}{3kT}\left(\frac{H + \alpha I}{H}\right)$$

$$\chi_m = \frac{nm^2\mu_0}{3kT}\left(1 + \frac{\alpha I}{H}\right)$$

$$\chi_m = \frac{nm^2\mu_0}{3kT} + \frac{nm^2\mu_0}{3kT} \cdot \alpha \chi_m$$

$$\chi_m\left[1 - \frac{\mu_0 nm^2\alpha}{3kT}\right] = \frac{nm^2\mu_0}{3kT}$$

$$\frac{\chi_m}{T}\left[T - \frac{\mu_0 nm^2\alpha}{3k}\right] = \frac{nm^2\mu_0}{3kT}$$

$m_f \propto H$

Notes

$$\chi_m = \frac{\lambda}{T - \theta_c}$$

$\boxed{H_i = H + \alpha I}$

where $\frac{\mu_0 nm^2\alpha}{3k} = \theta_c$ (Curie temperature).

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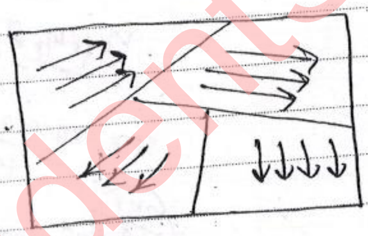
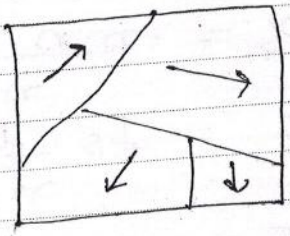
λ is Curie Constant. This is known as Curie weiss law. This relation holds good only when $T > \theta_c$

Weiss Theory of Ferromagnetism

In order to explain the relation between para and ferromagnetic substances, weiss introduces a concept of Domain theory.

Ferromagnetic Substances also Contain permanent magnetic moment as in a case of paramagnetic Substances. But due to Special form of interaction called exchange coupling exists between adjacent groups of atom dipole which tends to aligned in direction of applied feild.





Weiss made the assumption, Same as in case of paramagnetic Substances.

$H_i = H + \lambda I$ feild Cofficient

If the molecular

Notes

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is positive then Spontaneous magnetisation will arises even in the absence in magnetic feild.

Hence, (condition) possibility of spontaneous magnetisation can be find out by taking $H = 0$

$$\therefore \quad I = I_s \left(\frac{x}{3}\right)$$

$$\frac{I}{I_s} = \frac{x}{3}$$

The Slope is curve is $\frac{1}{3}$.

Now, $\boxed{x = \frac{mB}{kT}}$

$$x = \frac{m\mu_0(H + \alpha I)}{kT} \qquad [\because H = 0]$$

$$x = \frac{m\mu_0 \alpha I}{kT}$$

$$x = \frac{mn\mu_0 \alpha I}{nkT}$$

$$x = \frac{I_s \mu_0 \alpha I}{nkT}$$

$$I = \frac{nkTx}{I_s \mu_0 \alpha}$$

$$\frac{I}{I_s} = \frac{nkTx}{(I_s)^2 \mu_0 \alpha} \quad -(2)$$

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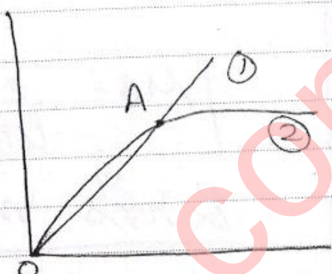
The equation is of straight line with slope $\frac{nkT}{(I_s)^2 \mu_0 \alpha}$

After ploting a graph we see that slopes of curve meet at o and A.



If the slope of curve 2 is greater than slope of longevin's curve than non zero point of intersection of two curves will not exist and spontaneous magnetisation will occur.

$$\frac{nkT}{(I_s)^2 \mu_0 \alpha} > \frac{1}{3}$$

$$T > \frac{(I_s)^2 \mu_0 \alpha}{3nk}$$

$$T > \frac{m^2 n^2 \mu_0 \alpha}{3nk}$$

$$T > \frac{m^2 n \mu_0 \alpha}{3k}$$

Notes

$T > \mu$

This is the condition of the spontaneous magnetisation.

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① The substances whose atomic dipoles are aligned in anti parallel manner and there will no spontaneous megnitisation are called as antiferromagnetic substances,

$\left[\mu_B = \frac{eh}{4\pi m}\right]$

Bohr's magneton

[MnO, MnF_2]

antiferromagnetic substances

Define $\left[I = \frac{M}{V} \text{ or } \frac{m}{H}\right]$

M = magnetic dipole moment
V = volume
m = pole strength
H = magnetising feild

LG
FATHOM
Htc G1
Motorola MT 710
Blackberry 8330 curve

$\left[\chi_m = \frac{I}{H}\right]$ define

Types of Magnetic Substances $[\mu_r = 1 + \chi_m]$

Notes

Diamagnetic, Paramagnetic, Ferromagnetic, Anti ferro magnetic, ferri magnetic

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