**Experimental Physics - III**
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**Lecture - 19**
**Measurement of Magnetization of Ferromagnetic Material**

I will discuss about the experiment to measure the Magnetization of magnetic material ferromagnetic material. you know that different kinds of magnetic materials this ferromagnetic materials, anti-ferromagnetic materials, ferromagnetic materials, paramagnetic materials, diamagnetic materials

, what about now I want to discuss that is ferromagnetic type material and how to measure the magnetization of ferromagnetic material as a function of magnetic field that experiment I will demonstrate. before that let me discuss about the theory of this experiment or working principle of this experiment.

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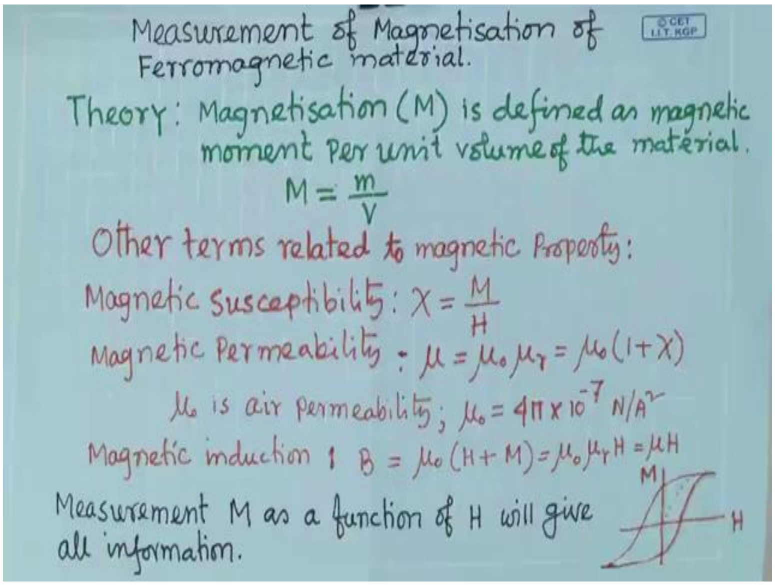


here Measurement of Magnetization of Ferromagnetic Material, what is magnetization? ferromagnetic material any material is made of atoms., atoms have seen in magnetic material., atoms each atom have basically magnetic moment magnetic moment or magnetic dipole moment.

now, this dipole moment in ferromagnetic material dipole moment it formed the domain, basically form the domain means group of group of atoms in an in a certain region. They interact with each other they have exchanged interaction and they form a region within that region, they have exchange interaction I., that region is called the domain.

this ferromagnetic material has many domains and these domains., each domain have total magnetization total magnetic moment in a certain direction. now, we can think there are many domains and each domain have magnetic moment dipole moment, giant dipole moment and these dipole momenta randomly oriented.

, net moment of the sample is 0., we express I this phenomena, we experience this moment of the material in terms of magnetization., it is basically independent of the volume of the material., magnetic moment per unit volume that we tell the magnetization.

magnetization is basically defined as magnetic moment per unit volume of the material., moment total moment of the material it depends on the dimension of the material or volume of the material, but magnetization is independent of the volume of the material it is per unit volume.

now, this there are different parameter we use for magnetic material to define the magnetic material., what are those parameters? We say susceptibility, permeability, it depends on susceptibility of the materials magnetic material is defined as M by H., chi chi equal to M by h that is susceptibility and permeability is a mu; mu equal to mu 0 mu r., mu 0 is the for vacuum permeability for vacuum and mu r is the relative permeability of the material.

relative permeability means with respect to permeability mu by mu 0 . , that is mu r relative permeability and this permeability is related with the susceptibility. , mu 0 1 plus chi that means, that chi is related to M by H . , mu 0 is here permeability or permeability in vacuum it is the constant it is the these value. , here you can see another term we use that is the magnetic induction B , B is related with this applied magnetic field H and the magnetization of the of the medium . , this is mu 0 H plus M there is the B.

, the B is basically mu H B is basically mu H., from here you can see that if we measure magnetization as a function of magnetic field then all information we will get., you can find out what is the chi susceptibility of the material, what is the permeability of the if find out chi, then what is the permeability of the material we can calculate and then we can find out. If we measure M as a function of H what is the b we can find out or yes, we can find out.

M magnetization as a function of magnetic field, if we can measure then basically we will know about the about the magnetic property of the material. , that is why it is very important to measure magnetization of a material ferromagnetic, specially ferromagnetic material we will use in our laboratory. , purpose why you should measure? , purpose is this to know about the magnetic property of this of this ferromagnetic material and this is a very famous hysteresis loop if it is ferromagnetic material. , we should get the hysteresis loop.

this dotted line it is telling basically if you start from the 0 magnetic field and then goes that maximum magnetic field start experience from there., you are decreasing field it will go and negative field then maximum negative field then decrease and coming back to the 0 and then to the highest magnetic field., then you gave get the hysteresis loop MH loop or BH loop.

, one can hear plot MH or BH al because if B can find out if you know M, H plus M that is B., BH loop or MH loop., this is a very famous for magnetic material if you measure this one., you will know what is the; what is the coercively of that ferromagnetic material, what is the; what is the remanent magnetization of the material, what is the saturation magnetization of this material for that what feel you need.

basically this what is the saturation value of magnetization, this you can find out what is the remanent at 0 magnetic field, what is the magnetization that is remanent magnetization at which field I this M become 0., that is the coercivity or we tell switching field.

, you see that you can see this at this magnetic field at coercivity., if slightly fill increase or decrease then direction of magnetization from positive to negative to positive it goes. that means, that it is switch this magnetization switch from this one direction to the to the another direction. that is why these coercive I field we tell the switching field; switching field for the magnetization.

this experiment we want to do in our laboratory teaching laboratory. Now, how to measure the; how to measure the magnetization as a function of magnetic field? there are different experimental techniques for measuring magnetization as a function of magnetic field.

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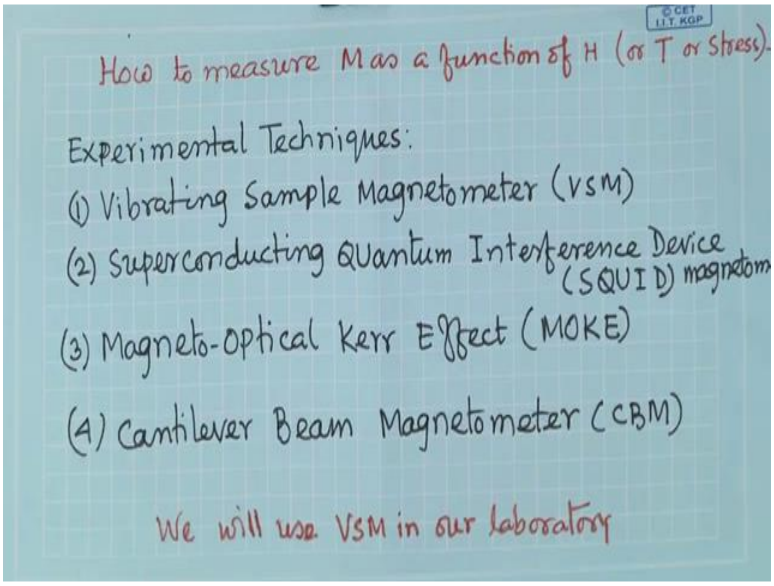


, very famous techniques and frequently you use in our laboratory specially research laboratory, one is Vibrating Sample Magnetometer VSM. Vibrating sample magnetometer, then superconducting quantum interference device SQUID magnetometer, then magneto optical Kerr effect ME then cantilever beam magnetometer CBM. There are other technical al, but these four techniques are very popular although last one is not very popular it is the specialized technique I used in my research laboratory.

But other thing specially this over than 2 these are in research laboratory, these 2 are frequently used this third one al in many laboratories it is used. But last one is used in few laboratories but all these called magnetometer, because it is this technique this magnetometer is used for measuring the magnetic property of the magnetic material.

magnetic property you as I told that you want to know susceptibility, you want to know permeability, you want to know magnetic induction, you want to know Curie temperature., using this magnetometer one can get all this information., there are four techniques but one of them you can use., in our laboratory teaching laboratory we use these VSM; VSM vibrating sample magnetometer., what is VSM? What are the working principle of VSM let me tell you?

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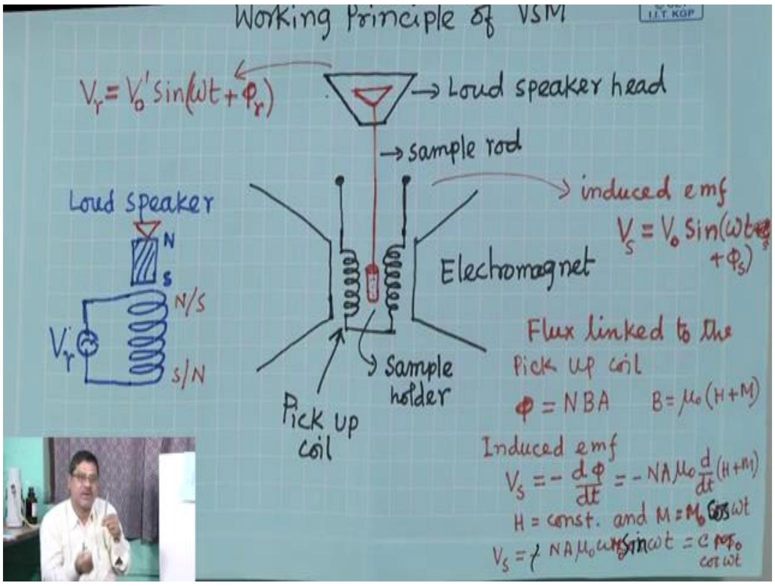


, working principle of VSM is not very difficult it is a simple., I have a magnetic material ferromagnetic material, you can take cobalt nickel or iron or any other materials ferromagnetic material.

these ferromagnetic material if it is in powder form or it can be in lot form or it can be in thin film whatever. , here there is a rod; here there is a rod, with this rod below if it is powder from these in straw . , you put this material or if it is film or if it is bulk material, we there is a there will be sample holder we attach this sample with this sample holder. , this we can take a sample holder with sample. , what about the form of the sample it can be powder, it can be thin film, it can be bulk material .

, this is the sample it is this sample holder is attached to with the rod with the rod and this rod is connected here you can see and this rod is connected here with a head of a loud speaker you know loud speaker.

, to speak loudly, we will speak normally but people can hear loudly., to which this magnification is done amplification is done that is the loud speaker., loud speaker the I will tell the principle of loud speaker., here this red one it is attached to this loud speaker head., this is in a box., this is a box loud speaker box, this is the loudspeaker head., as a whole this is the arrangement for loud speaker, see this rod is attached with this loud speaker.

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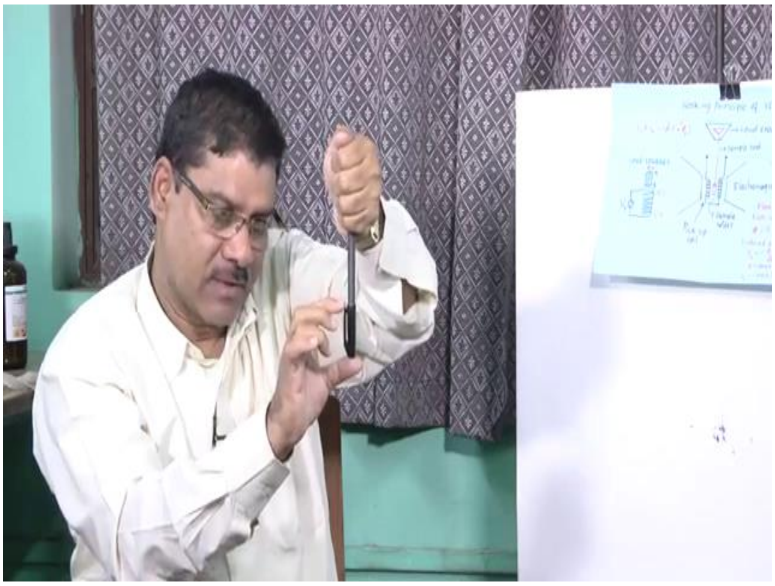

Now, here; now I have I have held my sample; I have held my sample this is the sample holder and it is attached with this rod. Now this rod is with the me loud speaker head. Now, what I want to study?> I want to study the I want to measure the magnetization of this sample as a function of magnetic field., I have to apply magnetic field, I have to put this sample in magnetic field, that is what done., this is the pole pieces of an electromagnet., I have put my sample between the pole piece.

, from electromagnet I will apply magnetic field and I will be able to vary magnetic field and at different magnetic field what is the magnetization induced in this sample that I want to measure. Now, now, this I have to; I have to; I have to measure magnetization I know the magnetic field, from the electromagnet I know the magnetic field for this magnetic field what is the magnetization., for a particular magnetic field the sample is magnetized means there will be magnetization along the magnetic field and that magnetization I want to quantify.

Now, this for measurement of this magnetization we will use, there are 2 ways to measure the magnetization; one is course method another is induction method., here we will use induction method in another experiment we will use course method, that I will discuss later on. Now induction method means that this magnetization; this magnetization it basically it magnetization is equivalent to magnetic field because B equal to H plus M, H and M basically both are same., if you have magnetization it will judge magnetic field means it will generate lines of force magnetic lines of force right.

, magnetic lines of magnetic force or magnetic flux it will depend it is it will depend on the strength of the magnetization, higher the magnetization higher the flux. now, if I put an if I put a coil here induction coil here that is what I have put induction coil, 2 coils they are connected in both side we have put 2 coils there is no physical connection.

Now, lens this paradise induction law. What is that? If magnetic field or flux varies then there will be induced EMF in the coil. If may if a coil in a magnetic field now if this magnetic field varies with time, then there will be induction there will be induced EMF in the coil.

, change of the flux with time will give induced EMF in the coil., due to this induced EMF there will be current corresponding voltage., this induced EMF is related to the flux is related to the magnetization, here whatever the magnetization that magnetization will give lines of force I flux and that flux will link with this coil, but then it will there will not be any induced EMF as long as you are not this flux is not varying I with time

I need to vary the flux link with this coil, that is why we have put this one on the loud speaker head; loud speaker head actually what it does? It is basically vibrating loudspeaker., drum you have seen when we drum., und makes because of the vibration of the drum, here this same thing me drums me spin kind of things is there., inside me arrangement is there it is the vibrating., this drum that spin al vibrating it is the making louder und., in loudspeaker there are arrangement for vibration, vibration with me frequency.

how it vibrates that I will tell you, but this is the arrangement to vibrate this vibrate this sample, vibrate this sample., I have coil; I have coil here sample; here sample now I have make arrangement for vibration of this pen., what is happening? this magnetization due to magnetization lines of force due to magnetization lines of force, now it is going out from the coil.

now, there is no; there is no flux linked with the coil. now, flux with time flux link with the coil coming from this magnetization., it is the it is going it is going from maximum value to 0 maximum value to 0, this flux changing with time d phi by dot., how fast it is vibrating, that is an important., I'd phi by dot and then from faraday law you know induction law induced EMF equal to minus d phi by dot induce EMF equal to minus d phi by dot.

what happened? I will get the induced EMF I will gets the induced EMF in terms of say as a signal as a signal Vs I equal to V0 sin omega t plus phi s . , why I have written psi I that if this it is vibrating whatever the way it is vibrating if it is sinusoidal it is vibrating with me frequency. whatever the frequency here that it will be same frequency, as the frequency of this vibration the loudspeaker., if I give the frequency to the loudspeakers with this with this signal that V 0 dash sin omega t plus phi r me initial phase phi r.

, if this sinusoidal signal is given to the loudspeakers for vibrating the vibrating this loud speaker head sample is attached to this head. , sample al will vibrate with the same frequency. , this flux link with this coil will vary with the same frequency and corresponding induced EMF I will get I as a signal. , that is why here I have written these say here AC signal AC voltage we are using that is Very equal to V0 dash sin omega t plus phi r corresponding induced EMF I will get Vs equal to V0 sin omega t plus phi s. , you see this experimental arrangement one has to make for fulfilling the; for fulfilling the physics law.

, actually here I am converting I am converting the magnetization into the electrical signal., the way magnetization or sample is vibrating, I am getting electrical signal with the same frequency., this is purely based on the faradays induction law. Now, here when we give AC signal to the loudspeaker head then how it vibrates inside what is there you know loud speaker., here inside there is a coil like this there is a coil and inside and on top of this coil there is a permanent magnet a bar magnet. now, AC signal in this coil is given that is V r, I sinusoidal it is varying from positive to negative positive to negative.

that means, current in the coil is changing the direction you know with time., this coil is equivalent to a magnet, it will have this North and south and then with time it becoming south and North., with this signal this the polarity of this to end of this coil is changing now we have permanent it is on the time it is n and s., when this end is end, there will be a repulsion., it will go up then next cycle it is south then it will attract this one North pole.

And south Pole it will come for next cycle it is going up coming down going up coming down, this way it is vibrating. Now here this that it is attached with this loudspeaker that spin as I told. that head we tell loudspeaker that head is connected with this permanent this bar magnet., this one is going up as a I have shown here inside this inside this box., this is vibrating here in the box is vibrating we are getting the louder und.

, this exactly this we are using for our vibration of the of the of the sample., based on that we are getting basically this AC signal which is related with this magnetization., measuring this signal induced EMF that signal we can find out the magnetization., one has to it is a they are related magnetization and this and this the voltage.

, here you can see this we tell the pickup coil; we tell pick up coil, but yes., flux link to the pickup coil if it is phi phi equal to n BA, n is the number of trans in the number of trans in the coil B is the magnetic induction, B is basically h plus M mu 0 h plus M., applied field from this electromagnet as well as the field due to the magnetic magnetization, that is B that is the B, B equal to mu 0 h plus M.

And A is the area A is the area, area to which this lines of force are passing., this it depends on the number of trans of the coil it depends on the cos area of the coil area of the coil and it depends on the flux will depend on the of course the magnetic field H as well as this M magnetization of the M. Now, this induced EMF as I told this minus d phi by dt, Vs induced EMF equal to minus d phi by dt.

Now, phi is this phi is this, n A mu 0 d by dt H plus M, H plus M other these are constant number of terms in the coil area of the coil and mu 0 these are constant these are constant and H al flux link with the coil., since these are permanent these the electromagnet and all the time these flux are leave and this electromagnet and these coils are fixed.

, flux due to this magnetic field H that is that that is not varying with time that will not vary with time ah. , it remain constant it will be independent of time and then this only flux coming from the magnetization that will change with time, because this magnetization that sample we are taking out and putting in taking out putting in . , this only magnetization flux coming from the magnetization that will change with the time. , that is why here we will get Vs equal to minus sin is there n A mu 0. If you say if now M; M it is a varying basically here how this., M that is seeing or this M that is seeing by the coil in which way it is seeing which time.

when it is here then this it is seeing this M 0, now sinusoidal it is vibrating now, sinusoidal when it is here it cannot see. this it is varying with this is sinusoidal., this coil will see this like M 0 sin omega t; M 0 sin omega t., maximum that is M 0 t equal to 0-time sine omega t 0 this or cos I think it should be cos., at t equal to 0, then you are getting this cos omega t cos t equal to 0 at time t 0 it is the cos omega t 1 M 0.

Now, it is going up at t to the power 4, this compete t to the power t by 2 at time t by 2 here, then again at their t by 2 at the time omega t by 2 that will be that will be 0, omega t that will be again 1., this way it is vibrating sinusoidal and this coil we will see like n it will see like M 0 cos omega t but or sin omega t it depends starting from while you are starting.

if your starting point from here, then it will be sin omega t, if starting point from here it will be cos omega t., it does not matter., here I have written sin omega t, but on the right cos omega t. Then if your l does differentiation d by dt it will be I think I should write this cos omega t. I will write I cos omega t, then it will be sin omega t, it will be sin omega t and this one that omega 0 and this minus sign will be plus.

, now this Vs equal to hear you are getting this constant term this we are writing V0 M 0 here., all this is the constant term, we are writing this V0 sin omega t me initial phase maybe their phi s., that is why signal I have written here V s equal to V0 sin omega t plus phi s.

, in V 0 basically you see these M 0 is there M 0 is there., magnetization is there., V 0 equal to V 0 equal to one can write n A mu 0 omega M 0., I want to measure M 0 M 0 is related with the V0, if I can measure V 0 or V s, I will get M., does a different magnetic field magnetization will be different V s will be different.

, I will give the magnetization as a function of magnetic field. Using this instrument, it is called VSM why is called VSM. Now, it is cleared because the principle of this magnetometer is that vibrating up the sample is the main part, if sample will not vibrate you will not get any induction you will not get any voltage although you have magnetization. VSM vibrating sample magnetometer, that is that is why it is the name.

, experiment we will do here a just this is the you can take this is the schematic of the experimental setup., this is the schematic diagram of the setup., basically electromagnet, first we have to calibrate the electromagnet using the Gauss meter that is the first work and then secondly, we have to; we have to we have to vibrate this sample using the loudspeakers and corresponding induced AC signal will get and that AC signal we have to measure.

While we will measure this AC signal we will get this voltage and voltage is proportional to the magnetization M, because V as I told V that is related with this part you know V 0 let us say M 0 is there M 0 is there., it is basically other term are constant, V 0 is V or V s is proportional to the to the magnetization.

, generally we use known sample nickel sample to calibrate this voltage and the magnetization, for known sample nickel sample. If I know the magnification of that one for a particular saturation magnetization say of this sample, I will I put that sample first and I will note down the corresponding signal voltage.

now, that proportionality constant magnetization is proportional to V., that proportionality constant I will find out this come known magnetization and corresponding major voltage., then for unknown sample one can do the experiment., I will I will demonstrate this experiment using VSM in our laboratory.

Thank you I will in next class I will demonstrate.