Solid State Physics
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Lecture - 58
Magnetic Property of Solid

So we will study Magnetic Properties of Solids.

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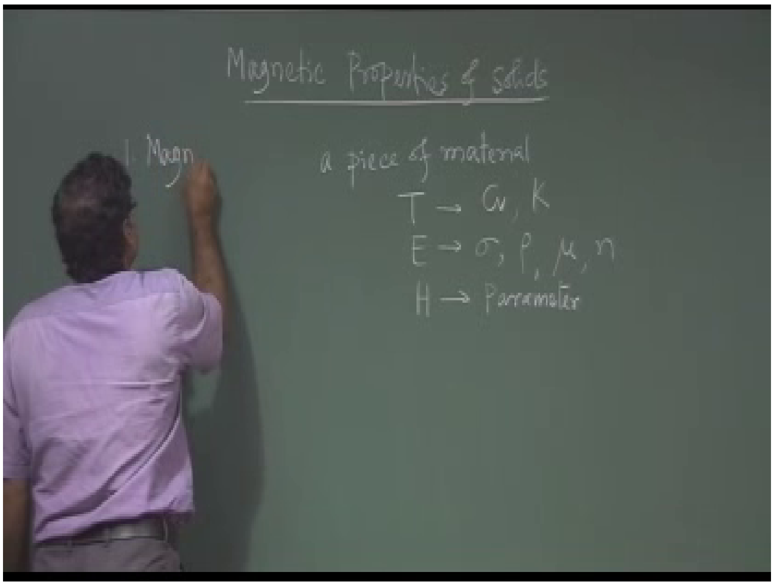

So, to study the property of a solid we need to apply external parameter, and see the response of the material to that parameter. So, you have seen that let say if I take a piece of material. So, I want to study the thermal properties of this material. So, I have to applied the thermal energy.

And it is temperature means temperature the system will change and response of this material to temperature. So, that gives us the thermal properties of the material in terms of some parameter. So, that is basically specific heat or for thermal heat capacity, or this conduction of this thermal conduction right. In case of electric properties of material of this piece of material, see if I want to study so I have to apply electric field and see the parameter like conductivity, resistivity right. Mobility, density of states or density of carriers etcetera.

Similarly if I want to study the magnetic property; so I have to apply magnetic field, and see the response of this magnetic field, response of this material to the magnetic field in terms of some parameter, which basically tells us the about the magnetic property of the material which are those parameter in case of magnetic property so this parameter so one is magnetization.

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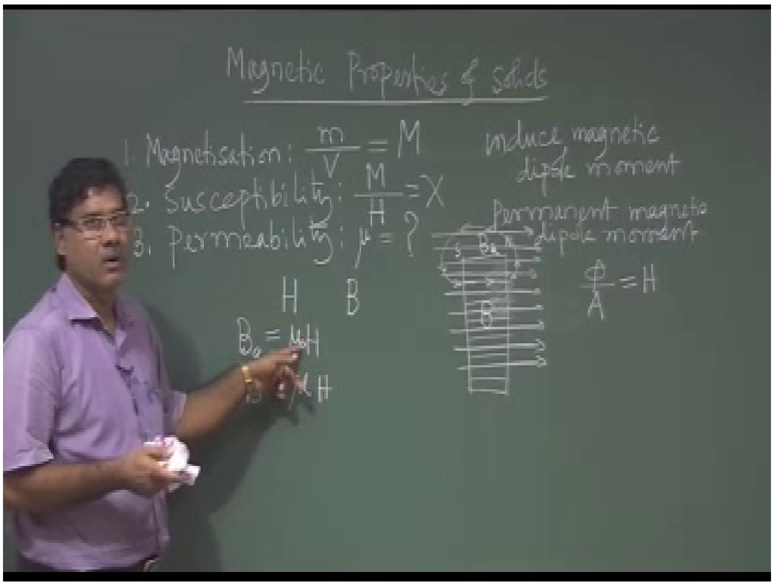

So magnetization of this material is defined by the magnetic moment per unit volume. So, this material is having the magnetic moment if it has. So, all material have magnetic moment. So, 2 types of magnetic moments are there, one is induced magnetic moment or dipole moment, induced magnetic dipole moment and another is permanent magnetic dipole moment.

So, we tell magnetic dipole moment because another kind of dipole moment are there. So, that is electrical dipole moment. So, that will see in case of a dielectric material. So, in magnetic material; so this there is a there are dipole moments, it can be induced dipole moment or permanent dipole moment right.

So, whatever the dipole moment magnetic dipole moment; so total dipole moment of this of a piece of material if it is m, and then divided by the volume of this material. So, that will give you the magnetization. So, you write in using the capital M right. So, varying the value of this magnetic moment magnetization, or the value of this magnetization as a function of magnetic field as a function of temperature so that tells about the properties of this metal magnetic material right.

So, another parameter we use that is susceptibility as I told this magnetization is varies as a function of magnetic field. So, the susceptibility is basically define as the magnetization per unit magnetic field. So, for a particular magnetic field you will get magnetization, value of magnetization now for unit field, what will be the magnetization that is the definition of susceptibility? We write even chi.

Third parameter says is basically permeability. So, that is really we write my mu. So, mu in used for the symbol used for many cases the refractive index, this permeability to for dipole moment. So, just you should not be confused just wherever we are reading. So, you have to know the context and you have to think that what is that either permeability or deductive index or dipole moment. So, the symbol mu; so now what is mu; so to explain that I need to tell about the difference between the magnetic field H and the magnetic induction B. So, both are field. So, what is magnetic field? Basically this magnetic field is we express in terms of lines of force per unit area.

So, per unit area, through per unit area what is the number of lines of force? So, that is the magnetic field. So, these basically we tell these lines of force we tell in terms of flux, magnetic flux. So, magnetic flux means magnetic lines of force, and this flux per unit area so that is the magnetic field, lines of force per unit area that is the magnetic field.

Now, in your we in your if there is no material. Specially there is no magnetic material; air or vacuum or of this nonmagnetic material. Their whatever we applied external magnetic field that is that is H, but in presence of magnetic field, sorry in presence of magnetic material in a magnetic field. So, in this magnetic field if you place a material, if it is nonmagnetic material. So, there is the problem lines of force is like this. So, density will not change. Density of magnetic this flux per unit area it will not change. It will be like this, but if it is magnetic material then this lines of force change, because this magnetic material, it will be magnetized by this magnetic field. And so, this magnetic material, it will behave like a magnet; that means, this this magnetic metal itself will generate magnetic field will generate magnetic field.

So now, you will have this 2 field, one is your external field H and another is field due to the this magnet. It is a it will behave like a magnet which will generate magnetic field.

So now, inside of this material, whatever total field, field this lines of force were this external field and some lines of force for this this magnet. So, this will so if it is say it is magnet means, it will be a surface is says south pole and then this north pole, then lines of force general it comes out from this north pole, and enter into the south pole. And then from south pole to north pole. So, here direction is this, here direction is this.

So, you have external magnetic field, now here you can see this outside the direction of this external magnetic field and this magnetic field due to this magnetic material. So, they are in opposite direction in outside, opposite direction, but inside it is in same direction. So, as if they will outside they will cancel this external magnetic field of or it will reduce the strength of this external magnetic field. So, what would happen? Inside the material this now lines of force will be more. And outside of this material lines of force will be less.

So now, this inside whatever this field, you will total field you will get that is expressed by B magnetic induction, magnetic flux density inside the material is V magnetic flux density outside the material, that will be expressed by Ba, a I mean this err. Magnetic flux in here, so because this is known it is H, it will change because this this magnet will affect the it will affect the magnetic field, it will affect the field outside of this material of course, inside the material it is it will change.

So, in presence of magnetic field, presence of magnetic material in your we use term, this term Ba. And that Ba equal to we write it is it has relation with H. So, that is H is we write mu 0 H, and B inside of this material we write B equal to mu H. So, this mu is basically called the permeability, this mu is called the permeability right. So, mu 0 the permeability of air or vacuum or nonmagnetic material, and mu is the mu is the permeability of this magnetic material.

So, basically this field will be enhanced due to this factor or it will be reduced due to this factor depending on whether mu is less than 1 or mu is equal to 1 or mu is greater than 1.

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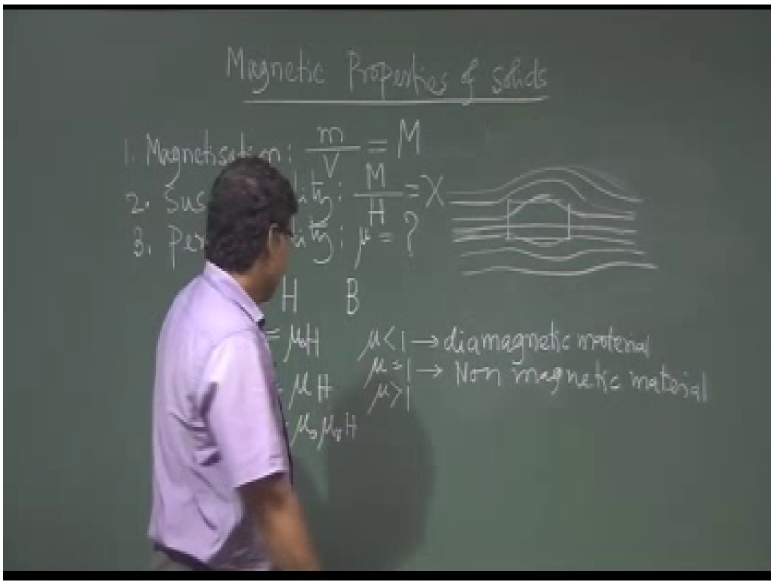

So, this mu is the permeability and that is written with respect to your permeability since written mu 0 into mu r H. So, mu r is called the relative permeability. So, with respect to the your what is the value of the permeability, permeability of this material. So, mu r the relative volume, and mu 0 is the absolute permeability of the year.

So, there are some material while it is seen that this V is reduced mu is less than 1. So, that type of material is called diamagnetic material. Means inside the material these lines of force, number of lines of force are reduced. So, we can think that there is a magnetic material, there is a material. So, lines of force basically, lines of force it is whatever your it is external magnetic field. So, assume this there is a repulsion, as if there is a repulsion. So, here lines of force what about the initial external magnetic field whatever the lines of force, density of lines of force were there now it is reduced. So, this type of material is called the diamagnetic material. So, and superconductor is a perfectly diamagnetic, it shows the perfectly diamagnetic property superconductor, that we will see.

So, this is the case and this, and in case of this mu equal to 1. So, there is a change of the field inside the material. So, this basically nonmagnetic material and when mu is greater than 1, then density of these lines of force inside the material will be higher right. So, it will be just opposite as if this magnetic material attracted this lines of force inside the material.

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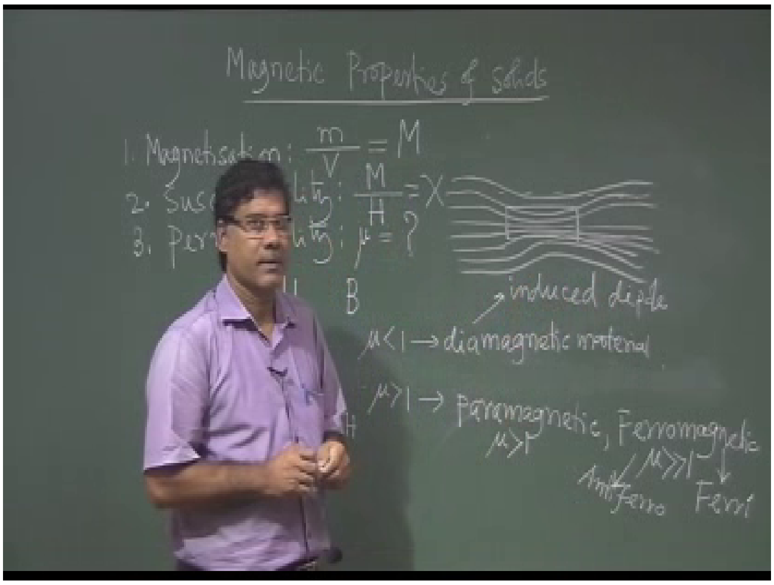

So whatever it will be; so what is supposed to go by this. So, it will enter into the material like this.

So, inside of this material this delaine density of lines of a force will be increased. So, mu is greater than 1. So, this magnetic flux density will be higher, B will be higher than H. So, then this is call the this call the paramagnetic material, paramagnetic materials or ferromagnetic material right. Now this if mu is just slightly greater than 1, then this paramagnetic if mu is very, very greater than 1 very, very greater than 1. So, then it is ferromagnetic right. And now in ferromagnetic there are other, other type of material magnetic material. So, there is it is the when mu is very, very greater than 1. So, this it can be ferromagnetic, or it can be anti ferromagnetic or it can be ferri magnetic ok.

So, that will explain. So, you forget this mu equal to 1 nonmagnetic material forget that part. So, when mu is less than 1. So, that is diamagnetic, when mu is greater than 1; so this paramagnetic ferromagnetic, ferri magnetic, anti ferromagnetic. So, as I told that these magnetic materials have 2 types of dipole moment, one is induced dipole moment another is permanent dipole moment. And that is the origin of this magnetization that is the origin of the magnetism

So, this diamagnetic material this which metal shows the diametric met property. So, that is basically, that is that is the materials which are not having which are which are having which will show the induced dipole moment. And this material may have permanent dipole moment or may not have permanent dipole moment. So, it does not matter. It material have permanent dipole moment, it may have induced dipole moment. So, it will show the paramagnetic property, diamagnetic property; if it does not have the permanent dipole moment, but it has the induced dipole moment.

So, then also it will show the diamagnetic property, but in this case this property of the metal is shown by those materials which are having permanent dipole moment, which are having permanent dipole moment. So, permanent dipole moment is compulsory to get this type of property, ferromagnetic property or paramagnetic property, anti ferromagnetic property of ferrimagnetic property. So, this is for this permanent. So, permanent dipole moment is responsible. And this diamagnetic property there is the induced dipole moment is responsible.

So now these materials are classified into two category. One is based on the induced dipole moment. So, there is the diamagnetic property, and another is based on the permanent dipole moment. So, then that is in that category again there is a division; so paramagnetic, ferromagnetic, antiferromagnetic ferri magnetic right. So, these the broad classification of the magnetic material and now will we study the individual one. So but before that let me let me find out the relation among this this parameter there is a relation among this.

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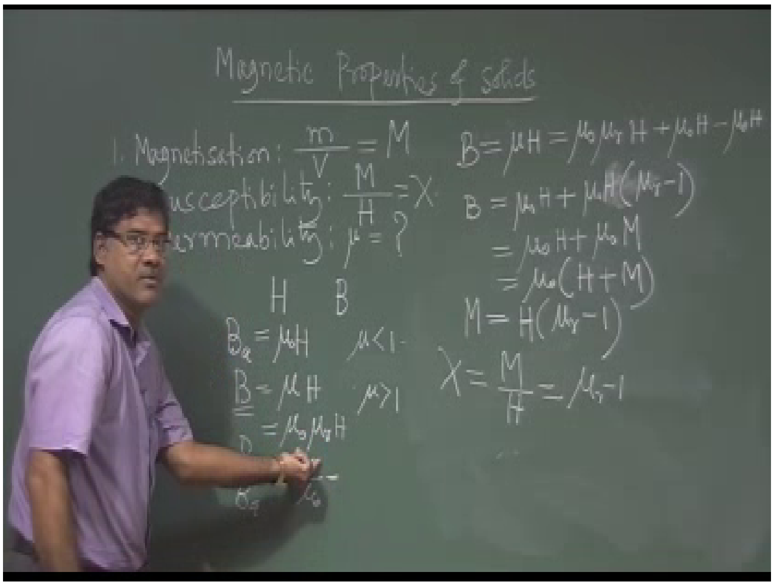

So, B what we got? B equal to mu H, mu can be written mu 0 mu r H. Just if I add mu 0 H and subtract mu 0 H, then I can write B equal to, I can write mu 0 H plus mu 0, then H plus sorry, mu 0 H and then this I can write mu 0 H, and then mu r minus 1 right. This I can write.

So, this mu 0 H plus mu 0 if I write mu 0 m; so mu 0 H- so B has 2 part, as I mentioned one is coming from this external magnetic field, another is coming from the internal this magnetic material right. So, this mu 0 H that is coming from the there is the contribution from the external magnetic field in your, plus this additional for magnetic material. So, magnetic material is having the magnetic moment and magnetic moment gives the magnetic field right. So, that is magnetization gives the magnetic field magnetic moment gives the magnetic field. So, from magnetic material whatever the contribution in field is coming. So, that is we can write mu 0 m, ok.

So, then so this equal to then mu 0 H plus m, then we are getting m equal to, we are getting m equal to H external magnetic field whatever we have applied, mu r minus 1 right. So, chi equal to then m by H is nothing but mu 1 minus 1 right. So, chi is related with this how it is related with the permeability that is that is the relation and this magnetization how it is related with the magnetic field and the permeability. So, these relation between this mu m and chi right: Mu m and chi the relation. So, from here you can also see that if I in presence of magnetic field. So, I can write B by Ba right, B by B a equal to mu by mu 0 equal to mu 0 mu r. So, equal to mu r.

So, these are the relations of this magnetic parameter. So, these are very useful for our studying the magnetic property of the solid. So, then we will discuss we will discuss about this origin of this magnetism. So, that is coming from induced dipole moment as well as the permanent dipole moment.

So, we will discuss the next class. So, I will stop here.

Thank you for your kind attention.