Introduction to Solid State Physics

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Lecture – 24

Introduction to magnetism in metals Part-I

In our earlier lectures, we have studied models which explain different properties of solids like electrical conductivity and thermal conductivity and specific heat. In the next few lectures, we will look at another property of solids namely magnetism and we will see how Sommerfeld model is quite successful in studying one aspect of these complex phenomena of magnetism.

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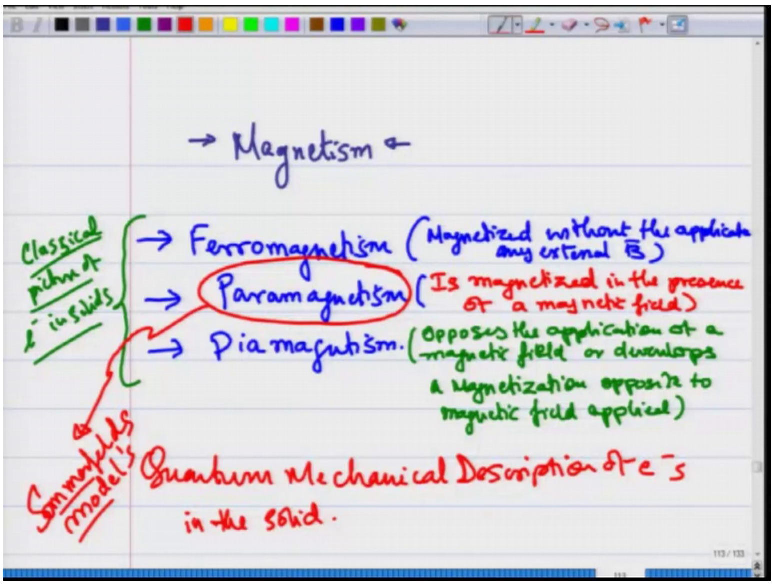

So, we will try and understand the phenomena of magnetism and a certain aspect of this phenomenon of magnetism using Sommerfeld's model. Now, magnetism is a phenomenon which is very old. It is very ancient and one knows the presence of magnets since ancient times and a lot of metals and solids exhibit the phenomena of magnetism and magnetism can be basically derived into three main categories. One is the phenomena of ferromagnetism, paramagnetism, diamagnetism. We know our ferromagnets like pieces of a magnet which have we generate a magnetic field or are magnetized these are magnetized without the application of any external field. So, you do not have to apply any external field.

These magnets that you have are already generating a magnetic field of their own these are typically ferromagnets. Paramagnetism is when the material is magnetized in the presence of a magnetic field. So, only when you apply a magnetic field the material gets magnetized. It develops some sort of magnetism and diamagnetism is where the material opposes the application of a magnetic field or develops a magnetization opposite to magnetic field applied. So, you apply a magnetic field and the material repels it or expels that magnetic field which you have applied. So, that is diamagnetism.

Of course, these are some very broad categories which are the popular categories of magnetism. There are a number of other types of magnetic phenomena which exists like antiferromagnetism, ferrimagnetism and so on which I am not getting into, but these are some broad categories that you are familiar with you have heard about. And, those are ferromagnetism which is a bar magnet. It generates a magnetic field of its own, does not require any external magnetic field to magnetize it. Paramagnetic materials are those materials which get magnetized when you apply a magnetic field to it and diamagnetism are those materials which expelled any magnetic flux that you applied to it.

It opposes, it generates a magnetization opposite to the magnetic field that you have applied to the system. Now, it turns out that none of these phenomena's can really be explained by considering classical picture of electrons in solids. There is no way you can explain any of the features of either diamagnetism, paramagnetism and ferromagnetism by considering electrons in the solids as behaving classically. You have to invoke quantum mechanical description electrons in the solid to describe any of the magnetic phenomena.

So, by default Drude's theory cannot explain any of these features. Some of it can be explained within the Sommerfeld's picture and especially I will just look at the phenomena of paramagnetism and we will try to explain it within the purview of Sommerfeld's model. The ideas which have been developed within the Sommerfeld's model we will try and understand the paramagnetic phenomena or the phenomenon of paramagnetism by using the quantum mechanical description of electrons inside the solid. Now, what is paramagnetism?

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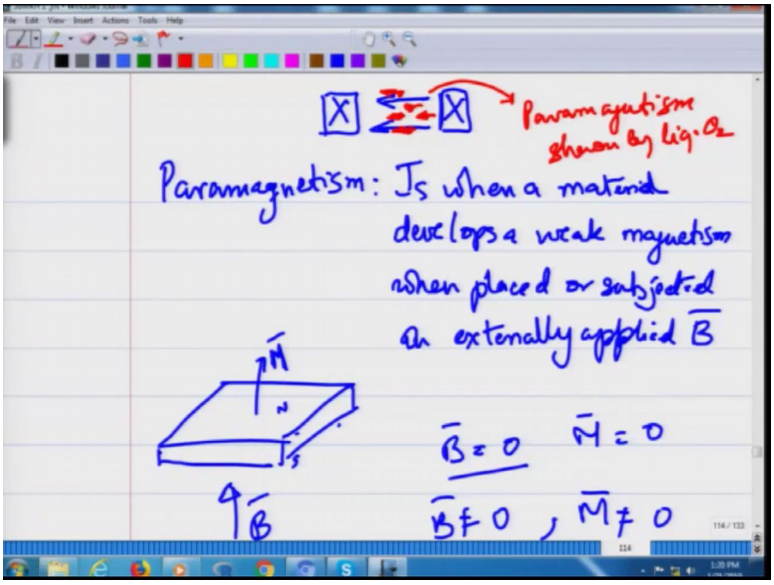

Paramagnetism is when a material develops a weak magnetism when placed or subjected to an externally applied. So, you take a material; you have a sample of a some metal and you place it in a magnetic field. You apply a magnetic field to this metal and, what you will find is that the metal will develop some magnetization. It will get magnetized and that is the phenomena of paramagnetism.

If you make the B equal to 0, external field if you make it 0, the magnetization of the material becomes 0, but the moment you make be non-zero the material is magnetized. It will develop something like north poles and south poles. It will start behaving like a bar magnet only if you apply an external field to it. And, a very striking demonstration of these phenomena is that liquid oxygen also shows paramagnetism and you can see these phenomena in this demonstration.

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You have a bar magnet which is shown here and these are the two poles of the bar magnet. And, between the two poles of the bar magnet the scientist is now pouring some liquid oxygen and what you see is that the liquid oxygen is stuck in between the poles of the magnet. They are not leaving the poles. It looks like the liquid oxygen is boiling, but it is not falling off. Only when you put a finger through it you can remove the liquid oxygen. So, nothing, there is no solidification, nothing is happening the liquid oxygen is between the poles of the magnet.

So, what is happening here is that the oxygen is getting magnetized and it is getting stuck in the bar magnet. The oxygen atoms which are present inside the liquid oxygen when you pour it through the; so, you have poles of the bar magnet which are applying some field and when the oxygen atoms are coming inside these poles they are getting magnetized and they are getting attracted and stuck in between the magnet, they cannot flow. And, so, this is a phenomena of paramagnetism shown by liquid oxygen that the oxygen atoms are getting magnetized in the presence of an external field, ok.

And, just like this phenomena where the oxygen atoms get magnetized and get stuck in a magnetic field. Similarly, metals also develop a weak magnetism when placed in a magnetic field and that is what we will explore in the next lecture.