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Theory and Practice of Non Destructive Testing

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Eddy Current Testing - 1

Hi everyone today we are going to start a new topic and that will be on eddy-current testing. So like what you do always we will first learn about the basic principle of this particular technique and then go on to see how it is done okay. So let us start and see what is the basic underlying principle behind this particular technique and then we will see how it is done as a set okay.

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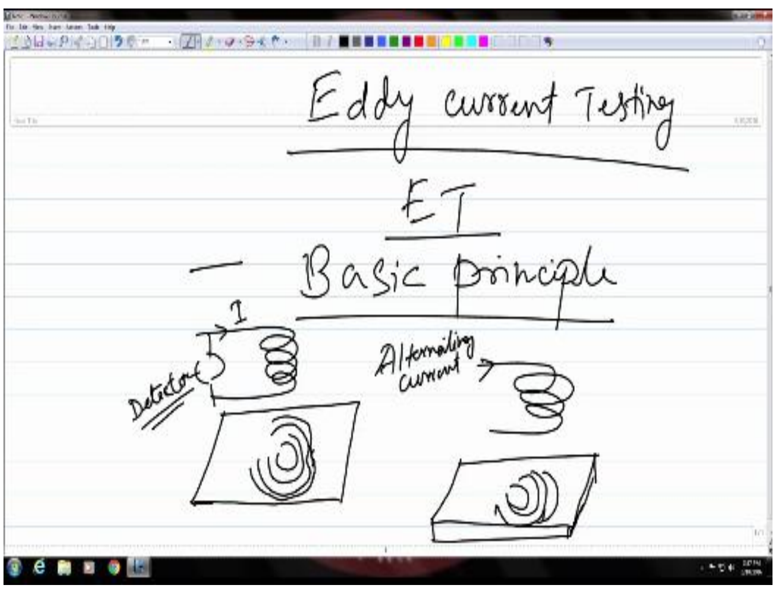

So this is the topic that we have today in short sometime this is known as ET which stands for eddy current testing. Now coming back to this basic principle behind this so first let us understand what is meant by eddy current and why it is called eddy current okay. Now this name eddy it comes from a flow pattern which you can see in a flowing stream of liquid or gas when it encounters an obstacle.

So this flow path around the obstacle in a flowing stream of liquid are called eddies, you might have seen that in a flowing stream of water if the water the flowing water encounters any obstacle for example, like a stone like a rock it tries to go around it in a circular path okay. So this swirling of the water around this obstacle is these are known as eddies okay.

Now this eddy current is nothing but an induced current which we are going to talk about in more detail. So the path of this eddy current or this induced current is similar to the path of the eddies which form in a flowing stream of liquid okay. So because of this as similarity this induced current is named as eddy current okay.

Okay, let us say you have a conductor like this which is carrying an alternating current or changing current and if you bring a second conductor near to it, so on the surface of the second conductor you will have induced current which will be having a flow pattern like this as I said which resembles the eddies which form on a flowing stream of liquid around obstacles when the conditions are right okay.

Now if there is a defect on the surface this flow pattern will be disturbed okay, so on a completely defect free surface like this you will have this kind of flow in this particular pattern and there will be no disturbance in this flow path, but now let us say there is a small discontinuity on the surface let us say there is a discontinuity over here.

So when the current encounters this discontinuity the flow pattern around this will be this stuff like this okay. So there will be a change in this induced current and as a result of that you would also see a change in this coil because the current in the coil is responsible for inducing this current okay.

Now if you can connect a detector to this coil which can detect this change then this will tell you that there is some discontinuity on the surface of the second conductor and that is how you will come to know about defects and flaws on the surface of a conductor which is being brought close to this coil which is carrying an alternating current okay. So these eddy currents that you have they are limited to the surface only and that is why this technique also is a surface entity method okay.

But the question here is how do you detect that change because this change because of a small discontinuity will be very small okay. So if you want to detect that by a sensor connecting to this coil how do you do that and what parameter actually you would look for to detect that change okay. So this is the question that we need to answer in order to understand the basic principle behind this technique okay.

So let me explain that to you, as to how do you detect this change and what parameter is needed for that purpose.

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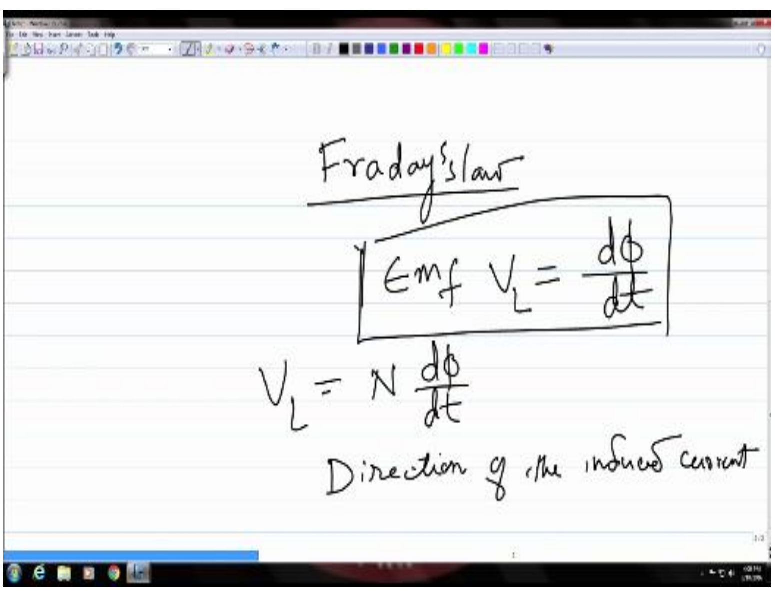

So when you talk about induction or electromagnetic induction you need to go back to Faraday's law which says that if a conductor carries, varying or a changing current it will have a changing magnetic field around it and that changing magnetic field can induce a current or induce an EMF okay, either in the same conductor or to a second conductor which is close to the first conductor okay.

So this is known as Faraday's law which says that this EMF which is the induced EMF it is a if we call that induced EMF as VL this is due to the change in the magnetic flux which is created by the changing current okay. So you need a changing magnetic field to create this induced current or this induced EMF okay. So this is known as Faraday's law of induction okay, and this is the basis of the eddy current technique as I am going to explain now.

So if you have n number of turns in a coil then this will be n$d\phi/dt$ where n is the number of turns okay. But still where we are yet to answer the question that we asked in the beginning as to what is that parameter which is needed for this to connect to eddy current testing okay. So for that apart from Faraday's law we have to consider another law which is about the direction of the induced current okay.

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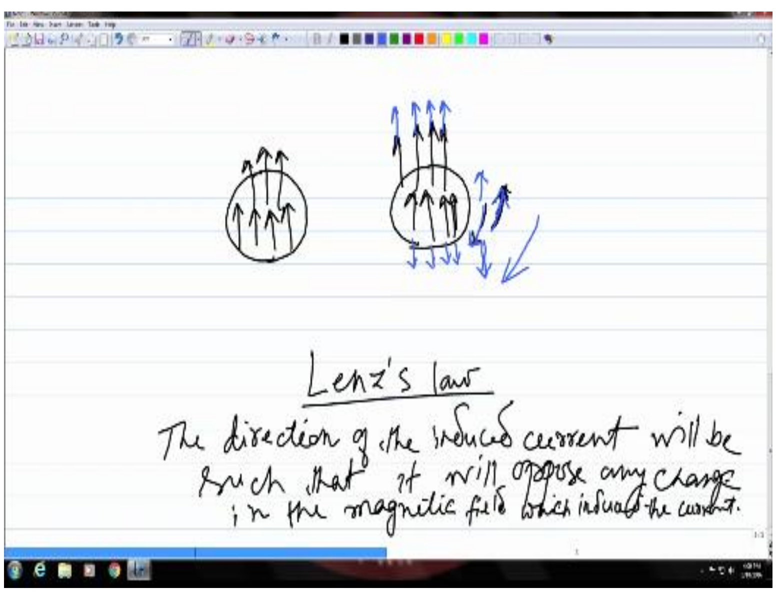

So let us say in this circuit or in this conductor you have a changing current flowing and because of that this changing magnetic field which is represented by these arrows is created okay, so in order to create that induced EMF this magnetic flux has to change it has to either increase or decrease and as a result of that change you will have an induced current, but the question is how do you know what will be the direction of that induced current okay.

So in order to know that direction of the induced current you need to take the help of another law which is known as Lenz's law okay, and it states that the direction of the induced current will be such that it will oppose any change in the magnetic field which induce the current okay. So the induced current will oppose any change in the magnetic flux which induces the current okay.

So that means when these changes let us say the magnetic flux increases, so due to this change there will be an induced current okay. So that induced current could be like this or it can be like this okay, so you do not know in which direction it can go whether it will go clockwise or it will go counterclockwise.

So Lenz's law will help you understand the direction of the induced current based upon the conservation of energy okay. So if you consider this direction if this be the direction of the induced current so this current will have its own magnetic field and the direction of that field can be found by right-hand thumb rule.

So if this is the thumb direction of the thumb of your right hand then the fingers will point towards the magnetic field being generated by this current. So if you put your thumb around this you will see the magnetic field direction will be like this okay, let me give a different color to this, so this will be the direction of the field if the direction of the induced current is like this okay.

So that means this field will be additive to this, so this will be again add to this and the magnetic flux will further increase which is against the conservation of energy law okay. On the other hand if you consider this direction okay, then again by using right hand thumb rule you will see the direction of the field in this case the direction of the induced magnetic field will be like this, and this will then try to decrease this magnetic flux or this will try to oppose the increase in the magnetic flux.

And that is what the Lenz's law say that the direction would be such that it will oppose the change in the magnetic flux which induced the current. So in this case when it increases then the direction will be the direction of the current will be in this direction okay. So now come back to the eddy current testing.

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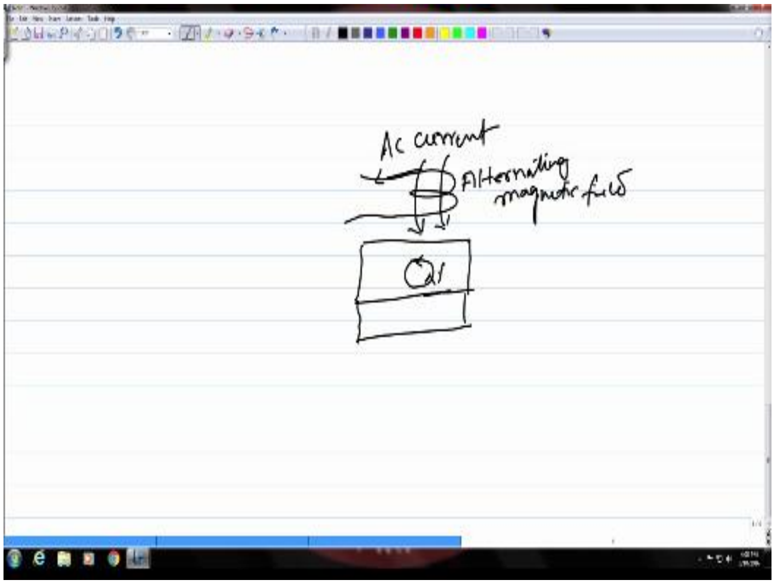

So if this carries an AC current there will be an alternating magnetic field also like this due to that alternating current which will induce this current in this conductor okay. And if there are any discontinuities around this induced current there will be change in the induced current and as a result there will be some change in this coil which needs to be detected in order to detect the defect okay.

So let us see what is that parameter which is needed to detect that and in order to do that we need to go to the basics of flow of electric current that means we have to go back to Ohm's law we need to start from there and then finally with the help of that we could see what is that parameter which is useful for detecting this change.

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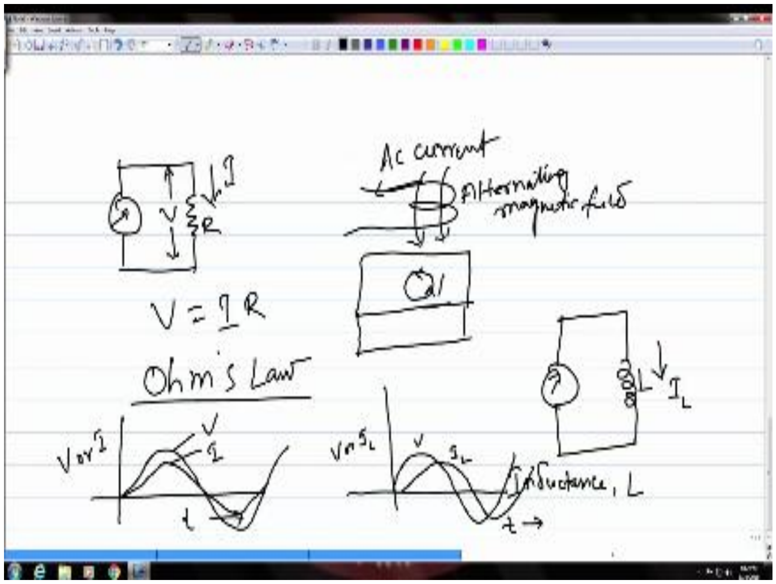

So Ohm's law we all know if you are sending a current I through a register R then the voltage across it will be V=IR okay, so this is well known the basic law of flow of electric current so the total opposition or the total resistance offered to the flow of current in this case is the resistance R, okay. But you could also have a similar scenario, but in this case the resistive element is replaced by an inductive element so in that case the resistance to flow of current will be the inductance which is denoted by L, okay.

And let us call this current as IL to indicate that it is flowing through an inductor, okay. In this case in case of Ohm's law if you plot the voltage or current then the voltage and the current are in phase, okay so let us say this is the voltage and this is the current there is no phase lag between the current and the voltage they are completely in phase. But in case of an inductor if you plot the same then you will see that there is a lag between the voltage and the current which is flowing through the inductor, okay.

So this is the main difference between a completely resistive circuit and a completely inductive circuit, okay.

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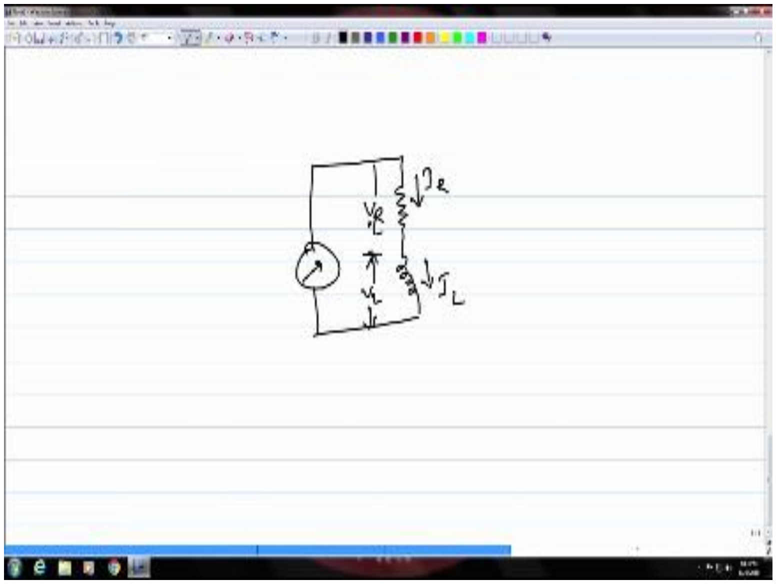

In eddy-current testing what we use to induce the current is a coil okay, so the eddy current probe will have this coil inside and it is a coil of a conductive wire, so that means that coil will have both inductance and the resistance components, okay so that means we need to consider a situation where in this current is going to flow go through a register and an inductor, so that means you need to consider both inductive and the resistive components, okay. But before that let me tell you here what we learn from the Lenz's law.

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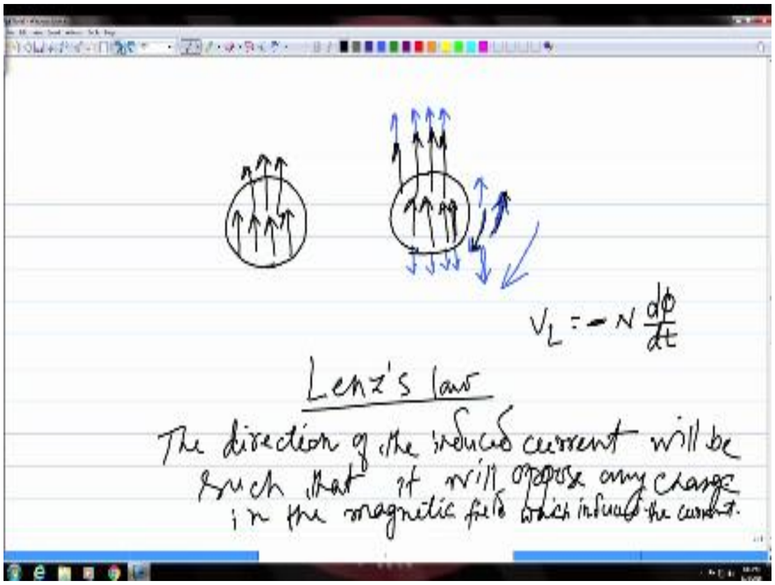

Is that this induced current is opposite to the change in the magnetic flux which induced it and that introduces this negative sign in the Faraday's law so this negative sign indicates that the induced current is opposed to the change of the magnetic flux which is this, okay. So please remember that we will come back to it while deriving that parameter what we are looking for.

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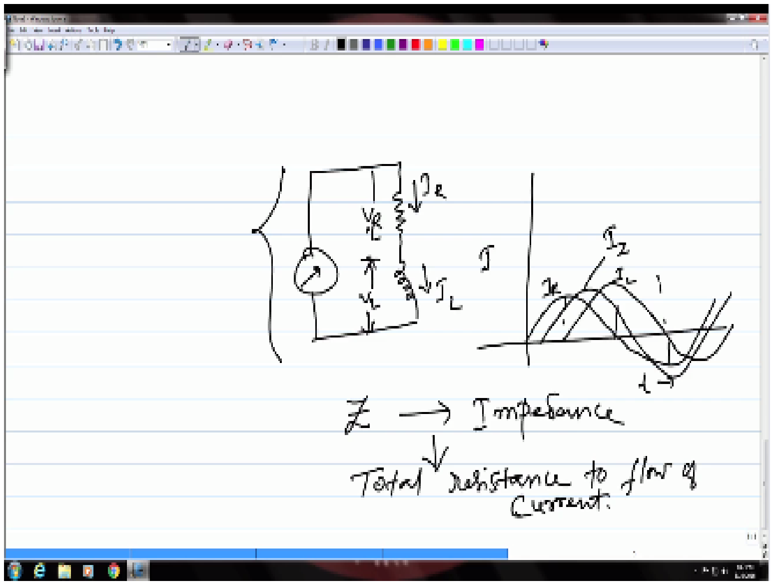

So now coming back to this if you consider a scenario like this where both resistance and inductive components are there together in the same conductor then if you consider the total current, okay then it would look something like this. So let us say this is the current through the register, so let us say this is I_R then I_L will be this one so there is a phase lag between them and in this case the phase lag is 90˚ as you could see, okay so that means the total current flowing through this particular circuit which contains both resistance as well as inductance component will be a sum of these two.

So that that means it will be somewhere in between this like this, okay so this total current will call that as I_Z okay, so here we are getting introduced to a parameter Z which is known as impedance and this now represents the total resistance to the flow of current in a circuit like this where you have both resistance and inductance components, okay.

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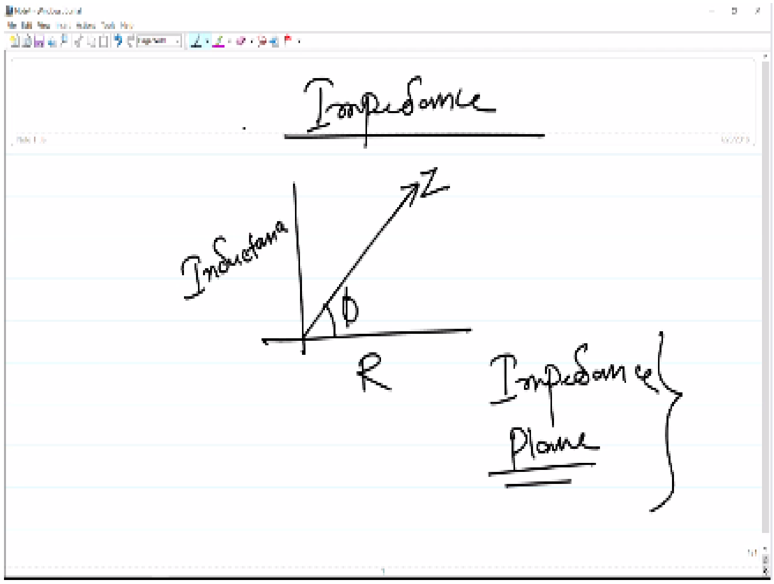

Yeah, so this impedance is the sum of both the resistance component and the inductance component as we saw just now so that means it will be a vector like this and this will be the phase angle between the resistance and the impedance, okay. So in the next class I will show you that based upon this particular parameter impedance we can construct what is called as an impedance plane and this is what is going to form the basis for eddy current testing, okay.

So this will take some time so we will take it up in the next class, so today before we close let us take a moment to summarize.

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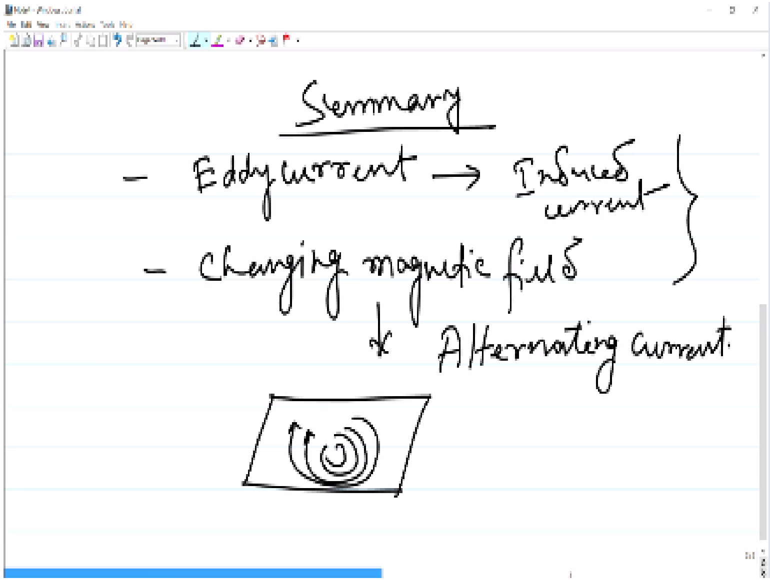

So today first we learn about the eddy current and this is nothing but the induced current on a conductive surface when you bring a current carrying conductor close to a second conductive surface okay, and the source for this eddy current as we discussed today is a changing magnetic field which comes from a changing current or an alternating current, okay.

So that means if you have a conductor which is carrying an alternating or changing current it will have a changing magnetic field also around it and when you bring this changing magnetic field of this conductor to the close proximity of another conductive surface then on the second conductor this eddy currents will be induced.

And we also saw that these currents flow in a particular pattern like this which resembles the eddies which form in a flowing stream of liquid when it encounters an obstacle and that is how this name eddy current is given to this induced currents, okay.

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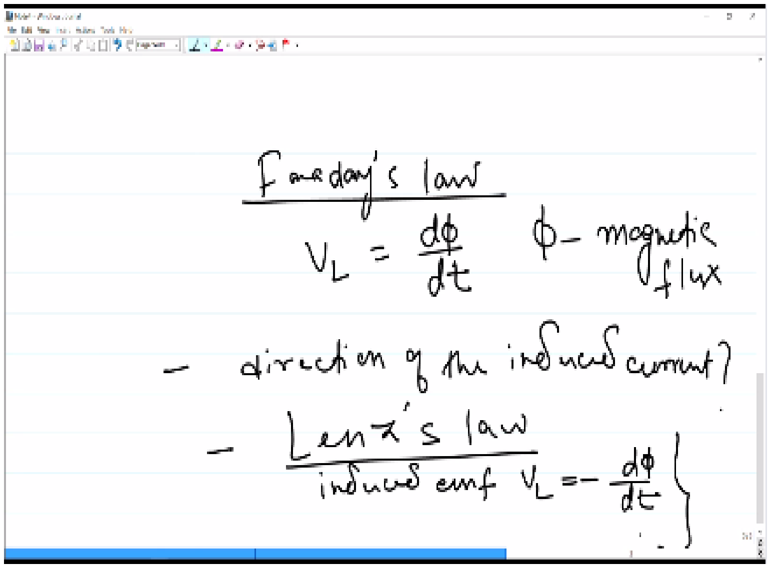

And we also learnt that this comes from Faraday's law which talks about electromagnetic induction or induction and the induced emf if you call that as V_L is the direct result of this changing magnetic field dϕ dt where in ϕ is the magnetic flux, okay. Then there is a question as to what will be the direction of the induced current and then we saw that the answer to this question can be found by using another law which is Lenz's law which states that the direction of the induced current will be such that it will oppose any change in the primary magnetic field which induced the current, okay.

So that means if the induced emf it is V_L then we saw from Faraday's law that it is dϕ dt and this is opposed to the change in the primary magnetic field, so this will introduce a negative sign in this scale which will indicate that the induced current is opposite to the primary magnetic field, okay.

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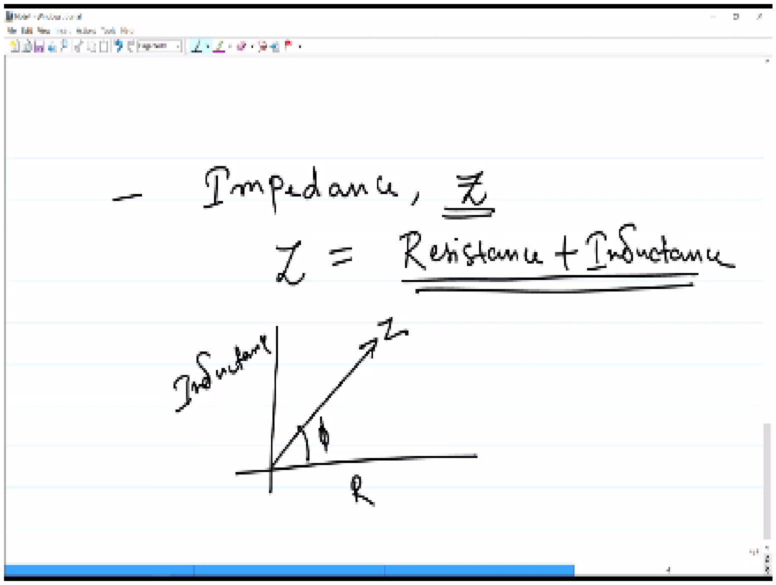

And then finally we derived this parameter impedance which we will call as Z from now onwards and this is the sum of the resistance and the inductance of the conductor in which the current is flowing, okay. If you resolved it in terms of inductance and the resistance components then as we saw it will be a vector like this and this is the parameter that we are going to take up specifically in the next class, first we will derive an expression for this.

And then we will see how this particular parameter is used to do a degree in testing this what we are going to take up in the next class. So this is all I will have for today I will see you next time and then we will discuss about the other aspects and we will continue from here, thank you.

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