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Theory and Practice of Non Destructive Testing

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Eddy Current Testing - 2

So in the last class we started a new topic which is on eddy current testing and then we saw few laws which govern this particular technique and then finally we derived a parameter called impedance and then I told you this is the parameter that we were looking for and this parameter can be used for doing a different testing okay so let us continue on that and then we will see how these impedance that we derived from the last lecture.

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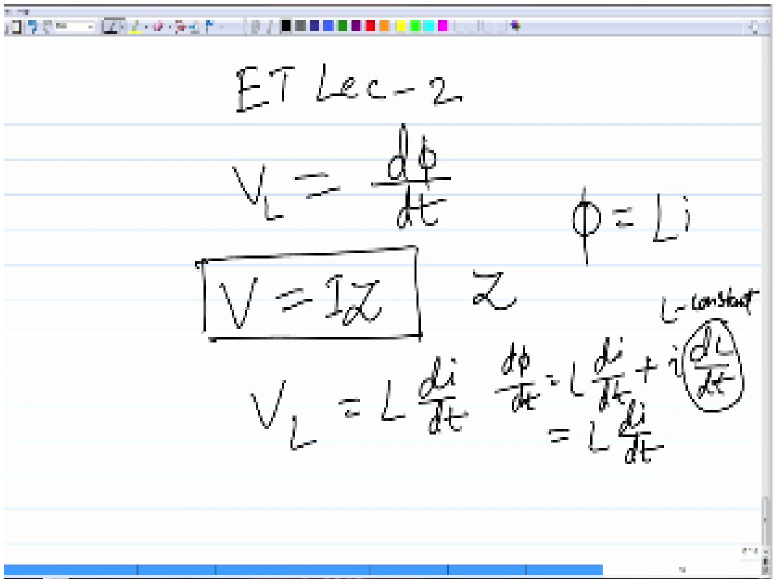

How this can be used to eddy current testing okay so this is what just to give you a quick recap this is what we did finally we arrived this particular parameter Z or impedance which is the total resistance to flow of current in a conductor which contains both a resistive element as well as an inductor okay so if you have a combination of both the inductance and resistance in a circuit the total resistance to the flow of current will be given by impedance okay. So this is the parameter that we derived.

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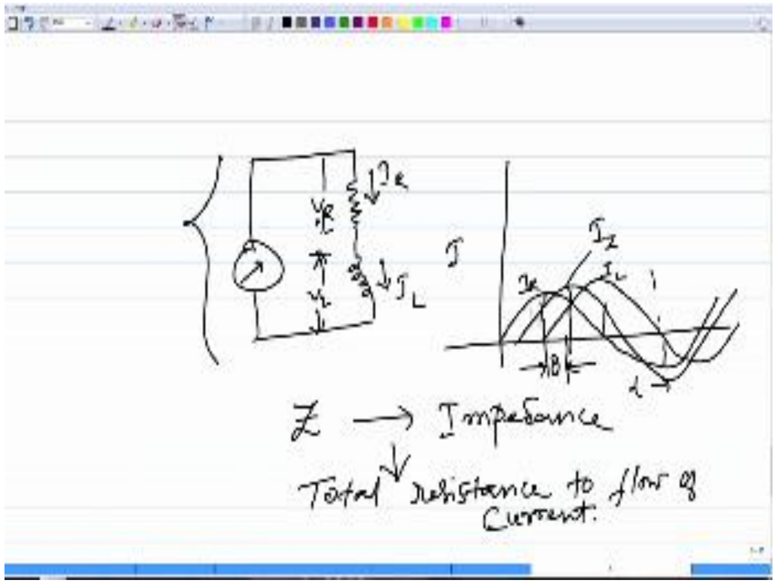

And you could also see from this impedance will have some phase lag θ with respect to the current through the register okay so let us first get an expression for Z and then we will see how it can be used for eddy current testing okay so this will be our topic today so for this you need to again go back to paradise law which we already discussed and there we saw that the induced EMF if you call it VL is this were in D φ DT is the change in the magnetic flux φ is the magnetic flux okay.

Now when I say the total impedance or the total resistance to the flow of current is Z then through Ohm's law you can write this okay because this is what Ohm's law tells you if I be the current and if there is a resistance to current then voltage will be I into that resistance and in this case as I said the total resistance is the impedance okay now if you take a VL in terms of current okay.

Because current is a parameter which can be easily measured on the other hand magnetic flux cannot be easily measured that easily measured like what you can do for the current so it will be convenient to convert the magnetic flux in terms of the current if you want to do that then you have to use this relationship φ is given by L times I where l is the inductance and I is the current okay.

So we can derive for a given conductor or for a given inductor this L is constant so this will be zero and as a result our D φ DT will be equal to DL DT so L is constant dl dt is zero that gives us a defy dt equals to L di DT so we can write P L in terms of the current or the change in the current di DT in this fashion okay.

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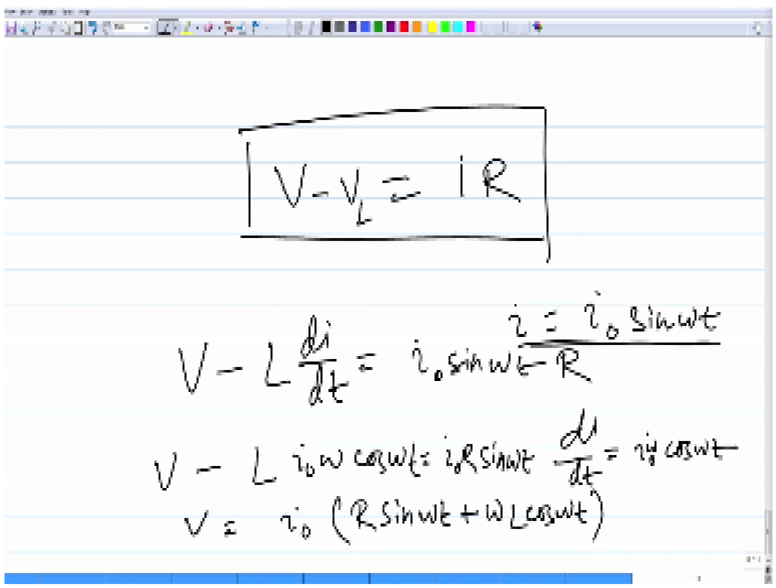

Now coming back to the Ohm's law we know it is V equals to IR this is the case where you have only a purely resistive element carrying the current but when you introduce the inductance also then this induced EMF will also come which is VL and we have seen why this negative sign because this induced EMF is opposed to the primary magnetic field which induced the current and that is why the negative sign okay.

So now we can write this I am from this we can derive an expression for the impedance z okay so let us say this current i is a sinusoidal function okay so that means now we can write and VL the expression of VL we have already got that is L di DT I is i_0 sin ω T and from here you can also derive di DT which is this so now if you write it here.

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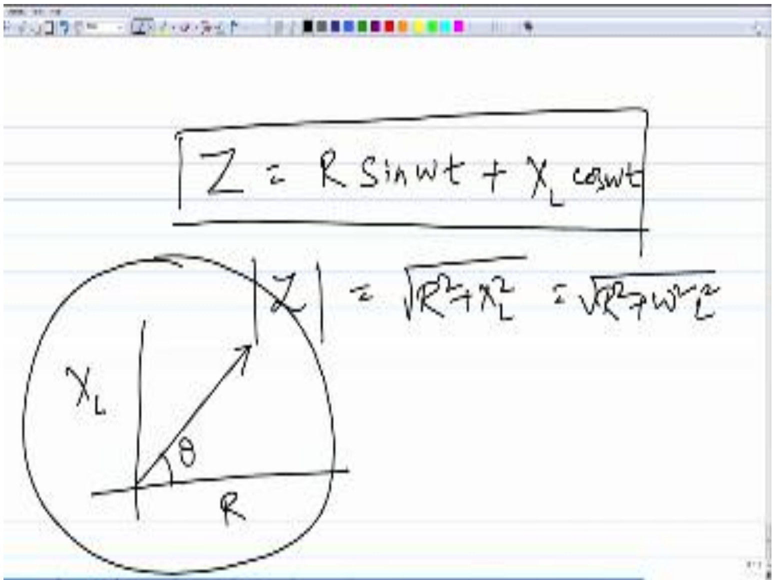

So we have an expression like this yeah which looks very similar to the Ohm's law that is started with in this case okay.

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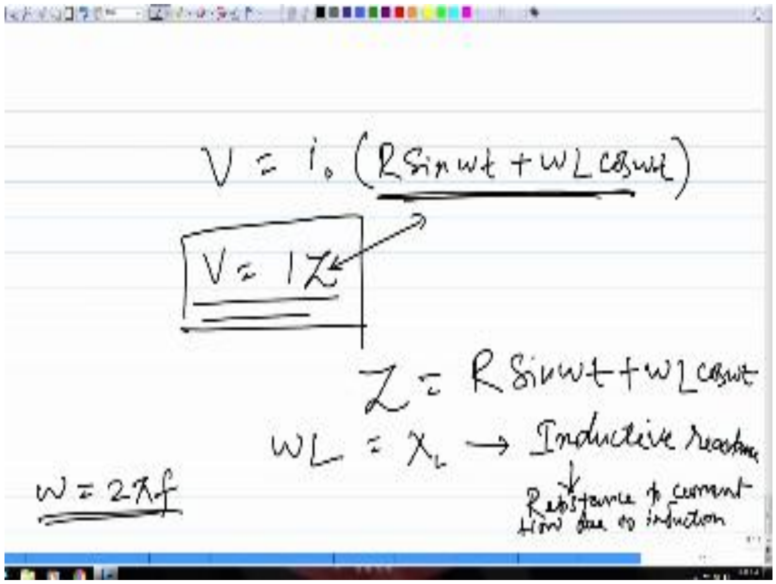

So that means if you replace this parameter with this Z it gives you the same relationship okay so that means z is equal to okay so this is the expression for Z we can simplify a bit by taking a parameter ω l = 2 XL there in XL is known as inductive reactance l is the inductance and ω is the circular frequency which is 2 pi AF FB the frequency so this inductive reactance is nothing but the reduction in current flow or the resistance to current flow due to inductance okay. So finally we have an expression for Z like this.

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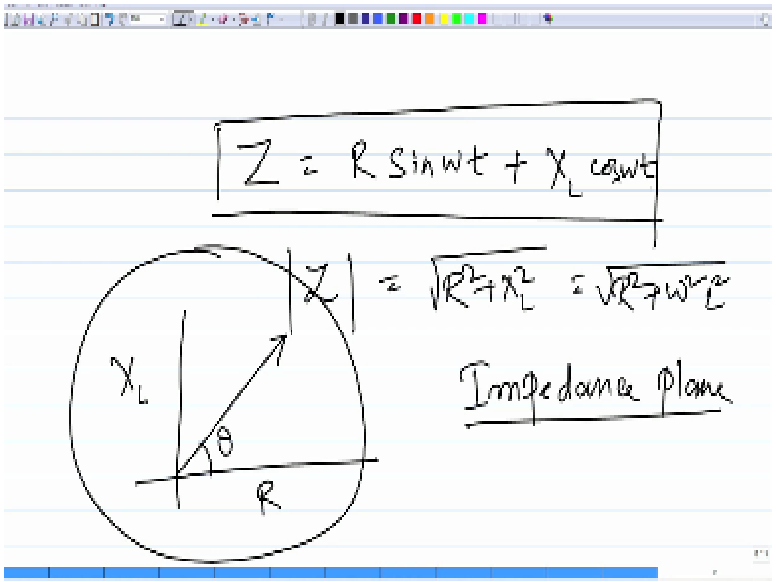

Okay that means the magnitude of Z is this or if you break up Excel then it will be this you can it also it can also be plotted in this fashion with in terms of Excel and are so as you could see a Z is the sum of our and XL so it will be a vector like this okay and this is the phase lag or the phase angle that we talked about before if you remember it is here okay this phase lag between the impedance and resistance that you can see here also okay so this is how Z can be broken in terms of the inductance and the resistance.

Or in other words the total opposition of total resistance to the flow of current which is impedance is a combination of inductance and resistance okay, so based upon this relationship and based upon this particular plot something called an impedance plane is constructed and that is what is used for doing eddy current testing as we are going to discuss right now okay.

So let us see how this impedance plane can be used to do eddy current testing so in eddy current testing what you have as I have told before also.

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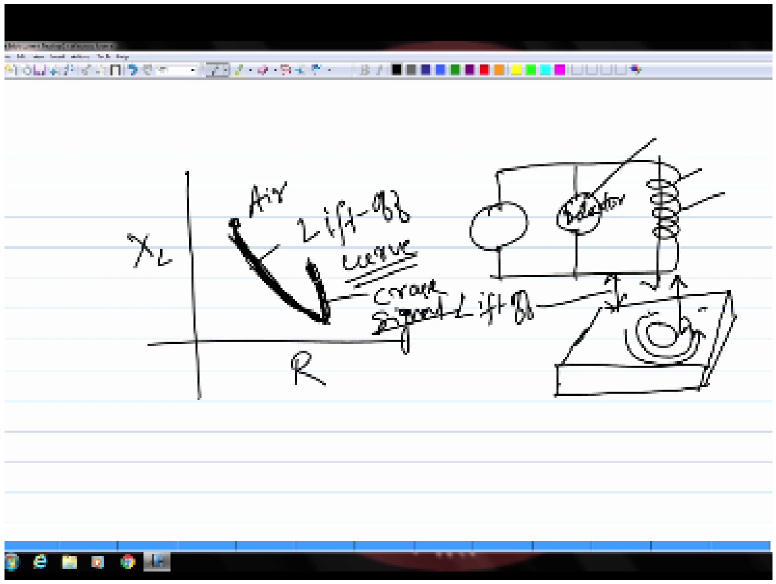

You have this coil which is carrying the current it is carrying an alternating current or a changing current to induce the eddy current onto the sample here nearby if you have a conductive surface you will have this eddy currents forming okay and this will have its own magnetic field the induced current and that is opposed to the primary magnetic field that we have already discussed okay.

And then you have a detector over here to detect any change which may come in this coil so that change will come due to the presence of a discontinuity that means if there is a defect on this surface and due to that defect if there is a change in eddy current due to that change there will be a change in this coil also which will be detected by this detector okay and in order to sense this change this parameter that we derived just now impedance will come into picture.

So what is going to happen when you bring this coil close to the sample surface when it is close enough then this eddy currents will start okay, so the distance between this probe and the sample surface is known as lift off and the moment the induced current or the eddy currents starts flowing in the surface but the eddy currents or the induced current are coming out from the current or from the energy which is flowing in the primary coil right so since the energy is taken away from this coil okay that will be reflected it had increase in the resistance okay.

So let us say first you have this lifted away from the sample that means your coil is in the air and as you decrease this distance or as you reduce the lift of distance then the resistance will increase because as I said now the eddy currents will be induced so some energy will be drawn from the primary coil and that will manifest in terms of an increase in the resistance okay and the inductance or the inductive reactance will decrease because now you have eddy currents and this eddy currents have their own magnetic field which is opposed to the primary field.

And due to that fact the inductive reactance will decrease and the resistance will increase as I said because you are drawing energy from the primary coil so you will get a curve like this as you bring the coil close to the conductive surface or close to the sample okay that is why this curve is called as a lift of curve this is what is going to be shown on that impedance plane because this XL and R as I said this construct the impedance flame and as you bring the coil close to the sample surface this lift up car is going to be shown on the impedance plane okay.

Now depending on whether there is a defect or not you will see a signal here in this impedance flame in this manner okay let us say there is no defect on the surface the surface is defect free so there will be no change in the eddy current and as a result there will be no change in the impedance of the coil okay so you will not see anything apart from this gift of gab so as you move along the surface the signal will move back and forth along this only along the lift of carbon Lee okay now if you have a defect at some point on the surface and the moment you move the coil or move the probe over that defect.

The eddy currents will be affected will be changed and due to that there will be change in the impedance of the coil okay so let us say there is a crack so there is a small opening and because of that opening when you move the probe over the crack the eddy currents will reduce as a result the resistance in the coil will reduce because your extent of eddy current is reducing on the sample surface okay so that means this will tend to go back towards lower value of R and now that you have less eddy currents flowing because of the presence of the crack so the magnetic field of the eddy currents will also reduce.

And as a result the XL or the inductive reactance would also tend to go up okay that means the crack signal will be like this we will immediately see a spike like this the moment the coil or the probe encounters a defect okay so this is the crack signal and that is how this will indicate the presence of a defect on the sample surface okay so this is the basic principle of this particular technique which is based upon this impedance plane which we derived with the help of two Laws primarily one is Faraday's law and the other one is ranges law.

And then we also took the help of Ohm's law and got an expression for this and then once you construct this impedance plane then in this fashion as we discussed you would be able to get a signal out of a defect in this fashion like a spike over the lift of car which will indicate that there is some discontinuity on the surface due to H there is a change in the coil which is being detected in terms of this impedance parameter so that is what this detector is going to sense or going to detect and indicate in this fashion okay.

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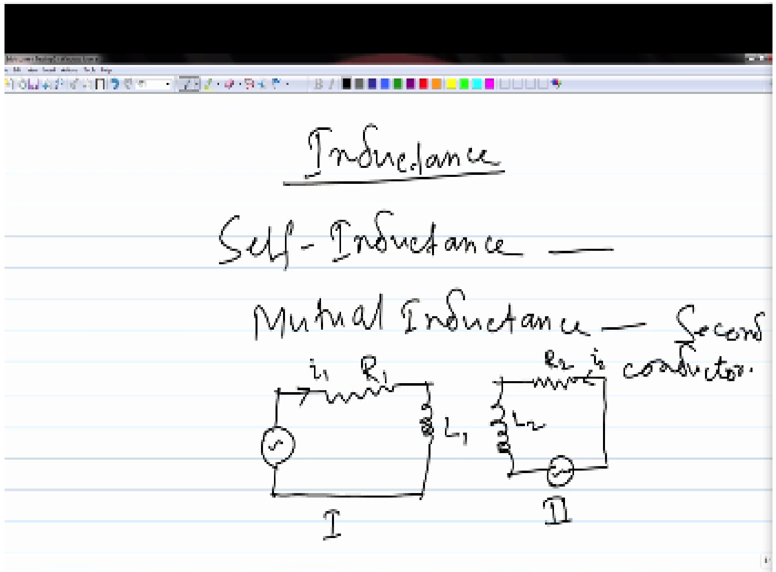

So this is how the whole technique works based upon this okay before we move on I should also tell you that when you talk about inductance as you would have realized by now this whole technique of eddy current is based upon inductance, inductance could be self inductance and it can be mutual inductance self inductance is when it is in the same circuit when you see the change in the voltage due to inductance in the same circuit or in the same conductor then it will be self inductance wherein in case of mutual inductance there will be a second conductor okay.

So in this fashion so let us say you have it circuit like this where you have this register R R1 and the inductor l1 so this is circuit one or conductor one and if you bring another conductor close to it let us say that is carrying a current I2 through this R2 and L2 so these two conductors when you bring them together we will have a mutual inductance effect on each other okay.

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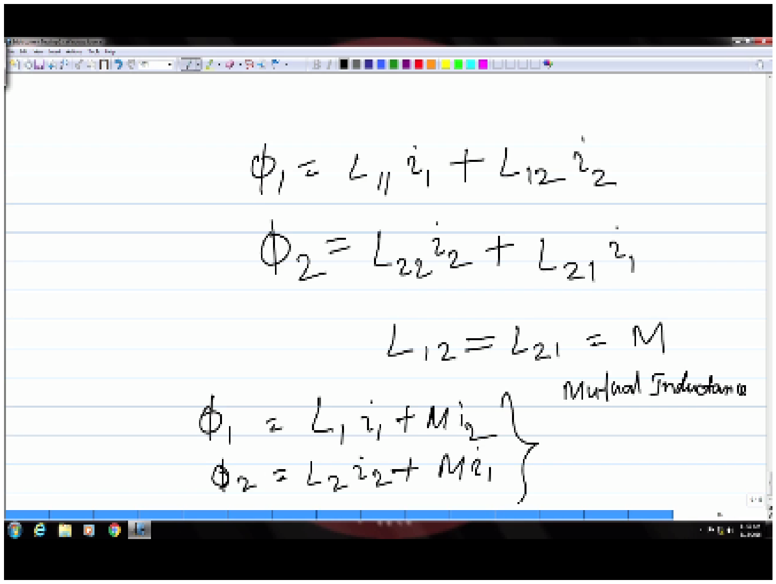

So conducted one we will induce some current on conductor to and conducted to in turn will induce some current on conductor one okay so if you write it in terms of these inductance or the magnetic flux which generates this induction so let us say in the circuit one the magnetic flux 1 will be L1 or L 11 I1 so that is due to the current I1 which is flowing in conductor 1 plus it will have some induced EMF also which will come from the second conductor so that will be L12 I 2 okay.

Similarly in the second conductor if you see the magnetic flux Phi 2 will be the current which is flowing into it due to that L22 I2 plus the inductance which is coming from conductor one which is L21 I1 okay so this parameter L12 and L21 is known as mutual conductance which will call as M sorry mutual is known as mutual inductance okay so if you replace this now with M in these two equations then you have now we can simply call this as L1 I1 + MI2 similarly Phi 2 will be L2 Phi 2 + MI1 so this is the phenomena of mutual inductance and the ethical interesting as you would have realized is based upon mutual inductance okay.

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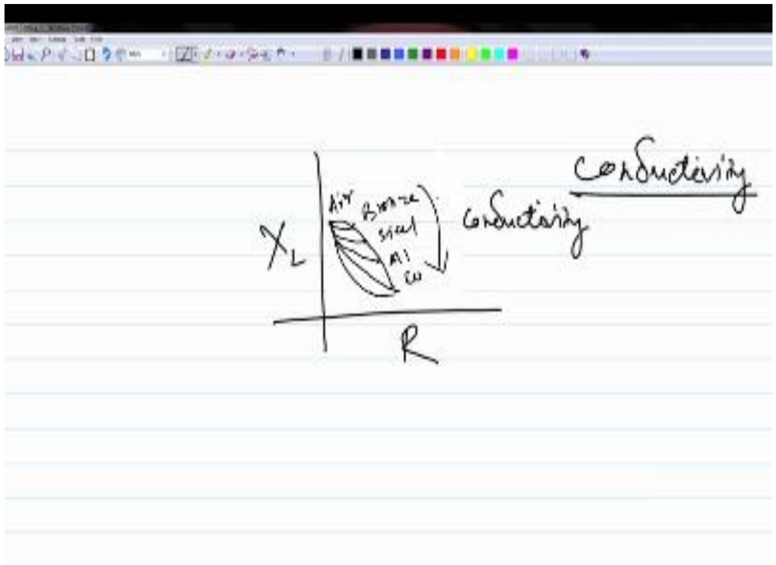

Now let us come back to this lift of curve because that is that will be our basis for doing eddy current testing so whenever we talk about something related to eddy current testing this impedance plane or the or the lift of curve has to come into picture so we will have to come back to this again and again as, as long as we are discussing this particular topic okay so this is the lift top now this will the this lift of curve as to how far this resistance will increase and the inductance will decrease that will depend on the sample properties particularly the conductivity of the sample okay.

So if the conductivity of the sample is high that means it has lower resistance so it can accommodate more current so for a higher conductive higher conductivity sample it will draw more energy or more current from the primary coil and as a result of that you will see a larger increase in the resistive component of the coil okay similarly if you change the conductivity if you reduce it the reduction in the resistance of the coil will be lower right so there is an effect of conductivity so as you increase the conductivity your resistance will increase more and more.

And that is why this conductivity curve will be like this so it conductivity increases in this direction the change in the resistance and the inductance will be along this curve this conductivity curve is obtained because for different materials the lift top curves will be like this and if you join the endpoints of them you get this conductivity curve so this gives you a total picture in terms of both the impedance as well as the conductivity of the sample okay so please keep that in mind.

Because if you have a highly conductive sample like copper the coil will become almost like purely resistive because the change in the resistance of the coil will be very high and similarly if you have a lower conductivity sample the change will be lower okay so this is the effect of conductivity and that is how you get a conductivity curve over the lift of curve okay so this is all I will have for today and rest of the things related to this we will discuss in the next class thank you.

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