Experimental Physics I
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Lecture - 47
To study the current - voltage relationship of an L-R circuit

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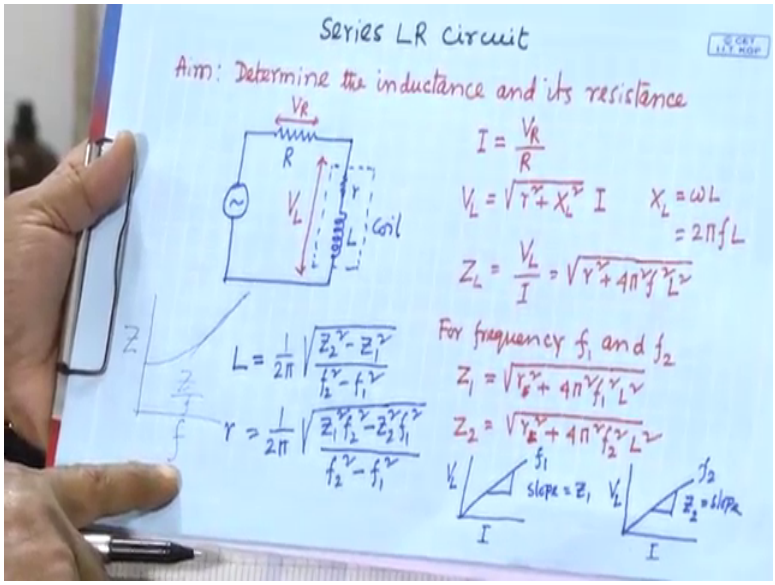

So, today I will discuss about the L-R circuit, series L-R circuit. So, this L inductor and this resistor R so, this these 2 are in series this is the AC power supply this is the AC power supply. So, now, AC power supply. So, if you start from one terminal and it should go through this R and the L and then come back to the other terminal. So, then it is a L-R is a series.

So, if we apply some voltage with some frequency, then there will be current in the circuit AC current in the circuit with the same frequency. And, there will be voltage drop across the resistance and across the inductor. So, this voltage drop is across the resistance is V R and across this inductor coil. So, that is V L. So, then basically this current in the circuit you can find out I equal to V R by R ok.

So, same current we will flow through this through this circuit to the R as well as this conductor inductor right. So, current in this circuit if I can find out if I measure the V R and if I know the R, then from there I will know the current in the circuit, for a particular frequency.

Now, the if you measure the voltage drop across this coil. So, that is V L. So, that V L is equal to square root of square root of small r square plus X L square. So, what is small r small r here we have shown separately. So, basically resistance of this of this of this coil, inductor coils.

So, and this X L is the reactance inductive reactance say reactance equivalent to reactance, inductive reactance this is X L ok. So, this the impedance of this inductor basically the square root of R square plus X L square. So, this is the equivalent to resistance impedance this is equivalent to resistance into I so, that will be the voltage V L.

So, if I so, I can measure the voltage V L and current I will get from here I. So, then I will get this value r square root of r square plus X L square impedance value I will get. So, so that impedance Z L we can write Z L Z L equal to V L by I equal to square root of R square plus X L is omega L so, that is 2 pi f L. So, this 4 pi square f square L square. So, impedance equal to this right.

So, now this as I told for a particular frequency. Now, for frequency say f 1 so, this impedance is Z 1 is square root of R square plus 4 pi square f 1 square L square. And, if then you change the frequency to f 2 or second frequency if you. So, this impedance will be impedance will be square root of r square plus 4 pi square f 2 square L square.

So, so, if you so, basically so, you have 2 equation, you have 2 equation Z 1 equal to this and Z 2 equal to this, or square of Z 1 equal to r square plus 4 pi square f 1 square L square and square of Z 2 equal to r square plus 4 pi square f 2 square L square. Now, if I measure as I told if I measure this V R and V L and if I know the resistance R, resistance R, then I know the Z value experimentally I know the Z value right, I know the Z value.

So, this Z value experimentally I Z 1 and Z 2 I can I can find out, I can find out from this relation for a particular frequency f 1 and f 2, now f 1 and f 2 also known to me.

So, unknown is the small r and this L resistance of the coil as well as the inductance of the coil this 2 are known. So, I have 2 equation 2 unknowns. So, if I solve it then I can find out r and L. So, that is why just if you solve it L equal to 1 by 2 pi square root of Z square, Z 2 square minus Z 1 square divided by f 2 square minus f 1 square. And r small

r equal to 1 by 2 pi square root of Z 1 square f 2 square minus Z 2 square f 1 square divided by f 2 square minus f 1 square ok.

So, f 1, f 2 is known Z 1 and Z 2 we have to know. So, that I will know if I measure I will know Z 1 Z 2, I will know if measure V R and V L ok. So, to determine the inductance and it is resistance ok. In this circuit series L-R circuit series L-R circuit. So, what I have to do I have to measure the this V R and V L for 2 different frequencies.

So, then I can determine this ok. Also, in other way we can you can think that keep the keep a particular frequency f 1 and now you take you take reading of V L varying the current I. So, how you will vary the current I, you just vary the voltage of this source voltage. So, vary this source voltage and take the reading of V L take the reading of V L.

So, you take few data 5 6 7 data you take for few current you take this V L for few current you take V L again for another frequency f 2. So, then you plot them V L versus I for a frequency f 1. So, you will get a straight line and slope of it will give you Z 1 and slope of this 1 for frequency 2.

So, slope of this one will give you a Z 2. So, Z 1 and Z 2 from this graph you can find out and f 1 f 2 of course, is known to you.

So, so, basically so, basically you will get I measuring the V R are divided by this resistance. So, it will give I and V L you will you have to measure across this one. So, basically ultimately we are measuring the V R and V L as a function of I. Also you can measure you can measure V L and V R V R V L and V R as a function of frequency.

As a function of frequency so, this is the relation, as a function of frequency if you measure V L and V R of course, from here you will get I, from here you will get I and V L then you will get V L different V L for different I. And, then basically V L by I will give you V L by I will give you V L by I will you Z L. So, you will get Z L. So, for different frequency you will get that Z impedance right now.

Now, so, you are you are you are collecting the data varying the frequency and you are taking reading for different frequency you are taking reading V R corresponding I and V L ok, and from there you can you will get this impedance. So, then you can plot graph impedance versus this current impudence versus current if you plot. So, what will happen

you know, you know this X L this value this part X L this value depends on f for higher frequency, for higher frequency this X L value will be higher ok.

So, lower frequency this part will be smaller ok. So, this value may be comparable with this with this internal resistance of the coil right. So, but for higher frequency, in kilo Hertz frequency, this value this X L will be very very high compare to this compared to this resistance right compared to this internal resistance.

So, then you can ignore basically at higher frequency you can ignore this R smaller resistance. So, if you want to find out just this X L, if you want to find out the not if you have to find out the measure only inductance, then you can do the experiment at higher frequency. And in higher frequency you can ignore this r, then you just plot Z versus this f it will be I think. So, whatever variation it may not be straight line because f square are there.

So, at higher frequency if we ignore this on then it will be straight line. So, so, there will be a variation of Z and then if you take gradient, if you take gradient of this of this curve, then from that gradient basically you will find out the L value ok, you will find out the L value because f is variable f and Z. So, you will gradient will be basically 2 5 2 pi L gradient will be the square root will go this r square is so, it will be basically 2 pi f L ok. So, Z L equal to 2 pi f L. So, if you plot graph Z L versus f. So, slope of the curve will be 2 pi L ok.

So, finding out the slope you can calculate the L ok. So, this way also you can find out just inductance. So, for that you have to do experiment at higher frequency. Of course, to see the variation to see the variation the of this impudence, you can do the experiment for whole range of the frequency. And, take the take the slope at higher frequencies of directly from that slope you will get this 2 pi L values from there you can find out the L.

So, here just I will show this how to what is the setup and how to do the experiment, I will just show you. So, this is the experimental setup ok.

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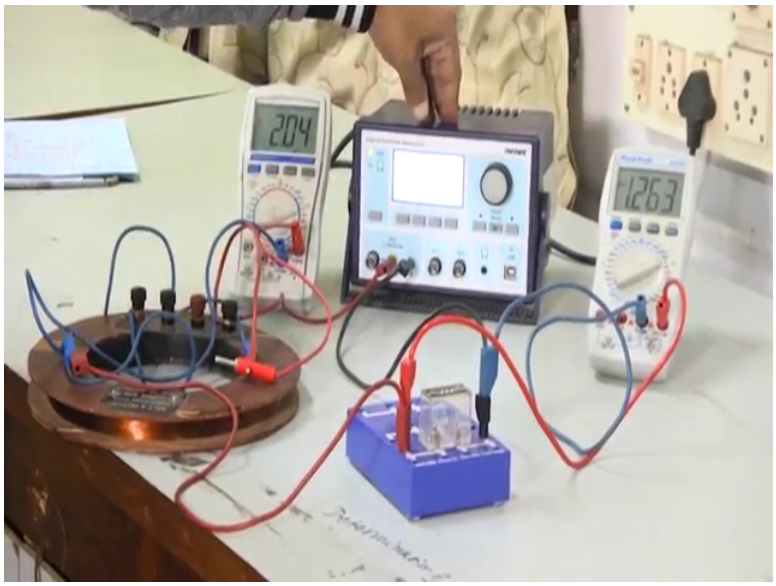

So, this is resistance R so, this resistance R is at 2 ohm this is a 2 ohm resistance, this is a 2 ohm resistance. And, this is our inductor this is our inductor you can coil right inductor coil you can see ok. So, it has option it has option of 100 turns, 250 turns, 500 turns. So, we have taken here for 100 turns.

So, again you can vary L also you know. So, for 100 turns whatever L for 250, it will be different for 500. And so, varying L varying L also you can repeat the experiment , but I will show just for 100 turn. So, it will have I do not know exactly the what will be the inductance, what it will be around 1 milli Henry , but experimentally you want to find out what is the what is the inductance of this of this 100 turns coil and what is the internal resistance of this 100 turn coil ok.

So, that is the experiment you want to do. So, now, I have to make it series circuit. So, this is the power supply this is the power supply AC power supply, you can change the amplitude as well as frequency of this of the voltage. So, this voltage will be. So, these are voltage source AC source.

So, 1 terminal of the source is connected to the resistance and then other end of the resistance is connected to the inductance here inductance. And, then other end the inductance is connected to the other terminal of the voltmeter volt source volt source power source. So, with power this L and R are in series. So, from here I can choose the

voltage means amplitude as well as the frequency, now what I want to do I want to measure V R and V L.

So, I have taken to 2 multi meters. So, we will use this multi meters in I think in voltmeter mode ok. So, and also it has both option AC and DC. So, you have to take dc mode AC mode ok. So, this voltmeter is connected across this resistance across this resistance right across this resistance. So, it will give me V R and this voltmeter is connected across the inductor, across the inductor, I think yes across the inductor this voltmeter is connected to the inductor.

So, so this voltmeter will give me the voltage V L across this inductor L. So, so, let me switch on this voltmeter power on off this one yes and this should be in AC mode, this power is on now and it should be in AC mode.

So, this AC in volt this is 2.0 volt 0 4 volt it is showing. So, this also I have to switch on, this also I have to switch on yes this switch on and it should be in AC mode it has to be a AC mode. So, here this metre is showing this is 1.263 volt this as written volt and this is 2.04 volt. So, this volt voltage drop across this V R and this is V S.

So, here this let us check, what is the voltage amplitude we had given and what is the frequency? Right now, frequency I can see this is 10 this I can see this is the 10 Hertz. So, 10 Hertz and I think I have given the amplitude here it is 10 volt 10 volt amplitude we have given. Now, here it is not the actually 10 volt the AC peak to peak value it is showing AC, AC amplitude. So, peak to peak value

So, then we have to divided by 2 root 2 then it will be RMS value. So, RMS value so, divided by 2 that is 5 10 divided 2 5 then 5 divided by root 2. So, if you calculate it will be around 3.4. If, you calculate it will be around 3.4 volt and yeah around 3 3.3 3.4 volt.

Now, so, this should this source voltage it should be equal to the voltage drop across the resistance and voltage drop across the inductance ok. So, V L plus V R it should be equal to V S so, here this is V R is 1.3 approximately and here it is 2.1 approximately. So, so, 3.4 approximately 3.4 and RMS value of 10 volt peak to peak value this is the divided by 2 root 2 10 divided by 2 root 2 it is also around 3.4. So, this way you can check this is our circuits and connection is all right it is fine.

So, let now do the experiment. What you want to do we want to do experiment this we want to measure the V R and V V L varying the current varying the current. So, how I will vary the current I will vary the voltage, I will vary the voltage and I will take the reading. So, since it is at already in 10 volt. So, it should go to the lower volt first let me start with let me.

So, I am changing you see I am changing the voltage here. So, now, here this reading I will change. So, you should change this voltage. So, let me go to the lower value first let me go to the lower value say this is let me go to the 5 volt. So, at 5 volt we note down then this source voltage is peak to peak value 5 volt and then corresponding this V R is 0.6 3 volt and this is 0.9 8 volt V L is 0.9 8 volt. Now, this is one reading, then you take the second reading.

I will change by 5.5, 5.5 then you note down this 0.69 and here 1.08 ok. So, this way just you vary then go 6, go to 7, go to 8, go to 9, up to 10 ok. So, you will get 10 reading 10 reading. So, for so, 10 reading you will get V L and V R. So, you will R here you should note down this R is 2 ohm capital R is 2 ohm. So, this V R R by R this will give you I ok.

So, now I will plot I so, this measurement I have done for a particular frequency ok. What was the frequency? What was the frequency? I should yes I should see the frequency yes; I have done this experiment for 10 Hertz. So, for 10 Hertz frequency I have V L versus I data, I plot it then it is slope we will give you say Z 1 as I in theory I have mentioned it will give you the Z 1 right then I will go to the second frequency at lower frequency is fine say I will go to 100 frequency 100 Hertz.

Now, in the 100 Hertz again I will vary the source voltage, I will vary the source voltage it is let us start again from 5. So, now, at 5 source this peak to peak value. So, I will note down the V L and V R. So, V L it is again 0.9 8 and it is 0.6 1, I do not know there is no much change let me check it may not because it is a, let us see now I change the voltage and then I should note down this change.

So, if you see this change is not much slope is almost similar then you take higher I have taken 100 Hertz. So, you take 300 400 Hertz of frequency and do the experiment that one should check ok. So, this is for second frequency again I will change the source voltage and I will take reading of V R and V L. So, from V R I will get I V R divided by 2

resistance capital resistance R is 2. So, so, I will get I verses V L for second frequency ok. Again, I will plot it and I will find out Z 2.

Now, if you know Z 1 and Z 2 as I as I showed if you know the Z 1 and Z 2 ok. Z 1 and Z 2 and f 1 f 2 this 2 curve f 1 f 2 also you know so, you can calculate L and R ok. So, as I told you can you can do the experiment as a function of frequency.

So, same way how to change the frequency you know just in that case we will set a particular voltage say will particular voltage let me go to the volt. So, 10 volt we will set a 10 volt peak to peak 10 volt 10 volt I set. Now, I will vary the frequency I will vary the frequency say I will start frequency 10 Hertz 10 Hertz ok. Now, I will change the frequency and note down the V L and V R.

So, from again from V R I will I will know the I basically. So, V R I need for knowing the I. So, basically V L versus I that sorry I think here frequency we are changing frequency. So, so, what I want to do I want to vary the ok. At higher frequency as I tool that higher frequency this will be higher and this I can ignore ok. So, Z will vary. So, Z will vary and R L will vary.

So, basically what I will do I will I can I can vary the frequency, and with that how this impedance changes that we can find how impedance changes that we can find out. So, measuring V R and V L you can find out the impedance. So, impedance versus this frequency you can plot, if you plot at higher frequency side what about the curve. At higher frequency side what about the curve from there if you find out the slope, then no at to at higher frequency I have to find out the slope; that means, I have to plot V L versus I have to plot V L versus I have to plot V L versus just I am confused. So, I want to find fine. So, this Z will be Z will be equal to if you ignore at higher frequency if we ignore this 1 the 2 pi f L.

So, now, if I plot Z L, Z versus this frequency Z versus the frequency, if I plot Z versus the frequency so, generally this type of curve we will get ok. So, at higher frequency if I take the slope if I take the slope I will get basically Z by f ok. So, Z by f is basically will be 2 pi 2 pi L. So, the slope will be 2 pi L. So, from there you will find out the slope by 2 pi slope by 2 pi that will be the L.

So, doing this experiment just varying the varying the frequency, you can note down the V R and V V L ok. And, then basically from there you will you will get this you will get this impedance equal V L by I will get from here and V L you are measuring so, this by I so, the Z L. So, I will plot Z L as a function of f.

And, now at higher frequency side if you take slope and from that slope you can find out the L ok. Also, you can see the variation of the impedance as a function of as a function of frequency ok. So, this is the experiment simple experiment, but this L-R C R L C R these circuit are very importance in electrical instrument. So, so these are the basic understanding of this type of circuit. So, in future in many places you will use this type of circuit. So, I think I will stop here.

Thank you for your attention.