Experimental Physics I
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Lecture - 48
To study the variation in current and voltage in a series LCR circuit

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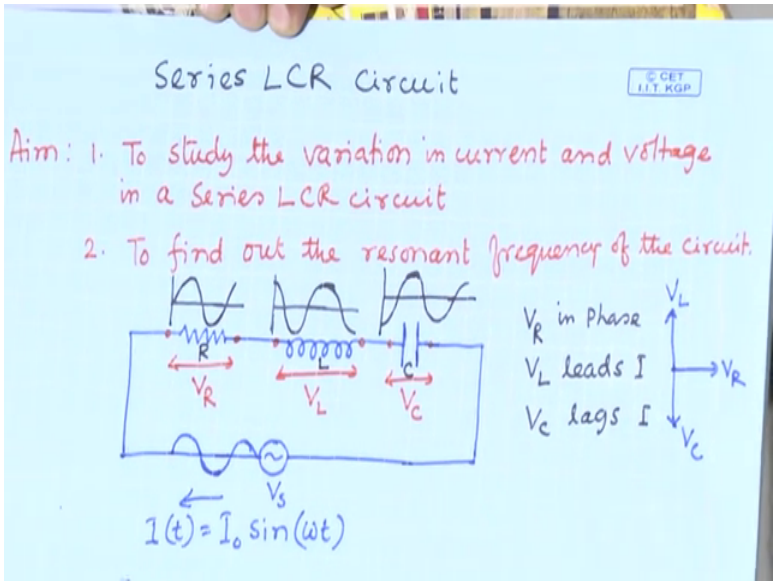

So, today we will perform experiment on series LCR circuit. So, series LCR circuit, you can see here. So, this R, resistance R, inductance L and capacitance C. So, they are connected in a series with this power supply, this is basically AC power supply ok. So, from here this current, we will get in this circuit, because this voltage is this basically AC voltage. So, current you will get of same frequency. This current will vary in this circuit, this I t equal to I 0 sin omega t right.

So, what we will study in this experiment is basically the variation of current and voltage in this is LCR series LCR circuit as well as this is the this circuit is basically is it call this tuning circuit. So, this circuit is used to tune is to used to tune; tune of what. So, basically if you tune, if you just vary the frequency this current, you can maximize the current in the circuit ok, so that is why in earlier days in radio (Refer Time: 02:04) to increase the volume or to just find out the channels, so this whatever this varied, so that is we vary the basically frequency ok.

For a particular frequency, then it when it matches with the signal frequency, then there will be resonance and for that maximum current flows in the circuit means, we will get the strong signal ok. So, here if current flows in this circuit, then you can what we can do, we can measure the voltage across the resistance, so this V R's, we can measure the voltage across the this inductor, so that is V L and we can measure the voltage across the capacitor, so that is V C.

And you can basically if you plot this voltage for say that this V R, V L, V C, then what you will get? So, you will see this V R is in phase with current. V L you will see this V L leads I, this means its phase is basically 90 degree phase this V L ahead 90 degree with respect to the current. And V C lags this lags with phase 90 degree. So, phase difference between this V L and V C basically 180 in opposite direction.

So, you can draw basically phase diagram and from here so now voltage are different across the; across the; across the resistance, inductor and capacitance. So, this is fine resistance. So, this has also it has resistance. So, resistance is we tell as X L, it depends on frequency its a omega L. X L equal to omega L, omega is 2 pi f, f is frequency. Similarly, 1 by omega C that is X C, omega again 2 pi f right. So, 1 by 2 pi f c that will be the X C that we tell the capacitive reactance X C, inductive resistance X L and this is resistive resistance.

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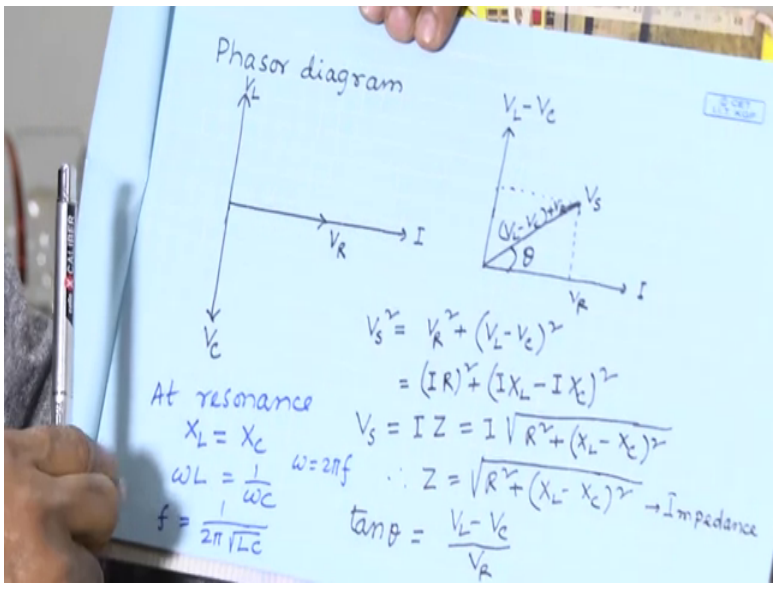

So, what will be the total resistance of this circuit that is called impedance that impedance one can find out impedance of the circuit. So, if you measure the; if you measure the V L, V R, V C as a function of current if you vary current, then if you measure this three and if you plot, then so you will get this type of phasor diagram; you will get this type of phasor diagram.

So, actually we are not going to do that one. But, for calculation if you use this phasor diagram, so then this here so just you can modify this plot, so here V L and V C is a 180 phase difference. So, basically V L V L minus V C can plot V L minus V C, so this lie in the opposite direction, so V L minus V C will be this if so and V R is as it is, then this from this is a phasor diagram vector diagram.

So, this from vector addition basically, you will get; you will get if you add this plus this, so resultant one you will get this line. So, this line will be V L minus V C, this one plus V R, so this is V R and this is V L minus V C. So, this will be (Refer Time: 06:44) this. And this so this, this, this, this, this, this, will be equal to the of course the source voltage source voltage and the angle between this with respect to this I, this angle is called this phase angle ok.

So, in principle you can find out from this triangle from this triangle, so V S so this is basically V S right, resultant on V S so V S square equal to will be equal to the V R square plus V L minus V C whole square right. So, V R is I into R square and V L is I X L; X L as I told is reactance is a resistance inductive resistance is called reactance, so I L minus V C I X C square ok.

So, V so if total resistance in this circuit that is called impedance if it is Z and current flowing in the circuit if it is I, so V S equal to I Z. Z is impedance equivalent to resistance in the circuit, so that will be equal to I, then from here you are getting basically I square, so it will be I, then square root of R square plus X L minus X C whole square right. So, comparing this you can write that impedance is equal to square root of R square plus X L minus 1 X C whole square. So, this is called impedance this is called impedance.

And corresponding this phase that is theta will be equal to tan inverse, from here you can see tan theta equal to this by this, so V L minus V C by V R ok. So, from here, you can get this angle theta, so that is called phase. So, resultant whatever this your this you will

get, so that we have phase. So, these are individual phase, it is in phase V R is in phase V L is leading lagging.

So, for LCR circuit series LCR circuit, so what will be the resultant, this that is basically this is amplitude and this is the angle. So, this theta one we can find out. So, if we measure V L, V C, V R; V L, V C,V R, you can find out theta. And now remember this and you can find out also impedance, we can find out also impedance right, you can find out also impedance.

So, basically X L you will get; X L you will get how will get X L? If you know V L and I, so from there you will get X L. Similarly, V C and I, then you will get X C right. So, if you measure V L, V C and V R, then you will; you will; you will be able to calculate the impedance also the phase. And these for a particular frequency, these for a particular frequency ok. So, current versus voltage or voltage versus current, you can study. And from there you can find out the impedance or reactance and their phase ok. But, our main interest for this experiment is to find out the resonance frequency.

Now, if you vary the resonance, if you vary the sorry if you vary the frequency, then what will happen? If you vary the frequency, then this impedance changes you know impedance changes impedance changes so, your current also will change in the circuit for a particular V S source voltage. So, at which frequency; at which frequency, this current will be maximum that is what our interest and that is called the basically resonance and that frequency is called resonance frequency.

So, we will find out the resonance frequency for this LCR circuit ok. For that what we have to do, I have to measure current; I have to measure current as a function of frequency, then I will plot current versus frequency. And then you will see you will you will get this type of curves, so at a particular frequency, you will get maximum current, so that peak you have to find out. And that actually that corresponding that peak that you will get the frequency.

And that frequency also you can calculate theoretically, because at resonance where you will get maximum, so when this impedance will be minimum ok. So, impudence will be minimum when X L equal to X C right X L equal to X C, so that is the condition of resonance. So, at resonance X L equal to X C. So, this is omega L and this 1 by C. So, basically if you put 2 pi f, so f is equal to 1 by 2 pi square root of L C ok.

If you know the value of L, if you know the value of C, then you can calculate f. And experimentally you can measure measures f, you will find out this f from this curve, I versus f frequency, so that peak value what about the frequency for peak value, so that will be the basically your resonance frequency, then one you can compare with this frequency. Also yes as I told for a particular a particular frequency, you can measure the impedance and you can measure the individual reactance. So, basically in this experiment, I have to measure I varying the frequency f. This is main part of this experiment.

Another part of the experiment is basically you measure V R, V L, V C for a particular frequency varying the current. So, V L versus I, V R versus I, V C versus I that you can plot for a particular frequency. And for that frequency, what will be the X L and X C or R resistance R that you can find out from the slope or it will be straight line from the slope of that curve that part I will not show here, only I will show you, this resonance in this curve ok.

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So, let us go to our setup. So, this is the experiment experimental setup for series LCR circuit. So, this is obviously, you are saying this is L inductor right, this is inductor and its value is written here its written here 9 milli-henry. So, you should note down this value 9 milli henry ok.

Then this is the here a small one that is the basically capacitor this capacitors, so also you can note down this value of the capacitor its written here, I think yes, I cannot see, but anyway I will not disturb it, but its written here. So, this values I guess what is the value again, this capacitor value here we have taken I will tell you, so that you should note down always you should note down this values, this capacitor value 4.7 microfarad. This is the this capacitor; this capacitance is 4.7 microfarad that you should note down.

And this is the resistance and this resistance is 2 ohm ok. So, I have inductance, so that is 9 milli henry. I have capacitance is a 4.7 micro farad and this resistance it is of 2 ohm right. Now, I have connected them in series you see just check it, so to check it series with respect to what series with respect to the power supply right.

So, if you start of one end of the this is the power supply AC power supply ok, here you can vary the amplitude as means voltage as well as; as well as you vary the amplitude you can vary the amplitude as well as frequency ok. So, this option is there. So, AC source, so this so here so this the power supply this AC battery ok.

So, so start from one electrode, then it is connected to the one end of the inductor, and then other end of the inductor is connected, we have used bread board you know we have used bread board, so it is connected with one leg of the; leg of the capacitor ok. So, then through capacitor another leg is connected to the resistance here. And then another end of this resistance is connected to the another electrode of the power supply ok. So, these three are in series. So, we have to check this circuit or you have to made yourself, I can open and just connect it by to save time that I am not going to do it, but I showed you this connection ok.

Now, this is AC ammeter this AC voltmeter yes. So, this is this will be used for measuring the voltage of what measuring the V R, V L and V C right. So, this actually two wires is coming from here ok, so this is the two say so just this is the; this is the voltmeter AC voltmeter, it is giving you the rms value; rms value V rms ok.

So, just if I want to measure the voltage across the; across the resistance, then this is V R, so I have to connect here; I have to connect here ok. So, if current flows AC current flows through the circuit, the current is same in the circuit. So, if you measure current at any point ok, so either across this; across this resistance, if you measure voltage across

the resistance, inductance or inductance or capacitance ok, so that voltage the reading you will get from here ok.

Now, I need to know the current in the circuits. So, these if I just take the voltage across the resistance and resistance value is known to me, so this resistance value here this is 2 R equal to 2. So, this whatever reading here, I will voltage divide by V R dived by R, so that will be the current. And this current is same for this for the circuit.

So, this current is passing through inductor, passing through the capacitor, so and why we are taking this voltage across this resistance, because this current whatever we will get from here. So, this is this voltage reading will vary, if I change the frequency, because that is for the frequencies X L and X C that will vary, but this R will not vary ok. So, R all the time it is 2, so that is why for measuring current, actually we will measure the voltage across this V R and just divide by 2 that will give me current.

If I measure the voltage across the X, across this L and C actually this X L and X C will vary with the frequency. So, all the time one has to find out the reactance of reactance X L and X C and so that will be complicated. So, for knowing the current, we will measure the voltage across this resistance. And resistance R is known to us, it is a equal 2. So, from there I will get the current, so that is I rms value I will get ok.

So, now let us so now if you want to measure the voltage V R, so you have to connect here you have to connect here this voltmeter or if you want to measure the; measure the; measure the of voltage across the capacitor, then these two I will connect here; these two I will connect here ok, because this is across the; across the capacitor ok.

And here also if you want to measure the voltage across the this inductor, so this I will connect this ammeter voltmeter with this ok. So, here you can study; here you can study the variation of; variation of V L as a function of current, if you vary the current; if you vary the current ok, so then what will be the variation of V L or what will be the variation of V C or what will be the variation of V R as a function of current that you can measure ok, so that would be the one experiment that has to be done for a particular frequency.

So, we will fix frequency; here say frequency is 100 Hertz ok. So, we will fixed frequency, then I will go to; I will go to the amplitude. Now, here amplitude is 5 volt, this is now remember this 5 volt, it is showing this peak to peak value. So, AC voltage you

know this the ok, so in positive side one peak and negative side one peak. So, this peak to peak value, so that is showing this is 5 volt.

So, now but we have to take rms value, of course this I do not have interest for this one, because I do not need that one. But, you should know this rms value of this one is basically this peak to peak value divided by 2 root 2 ok. So, whatever value here, so divide by 2 root to that is actually rms value of the voltage, so that voltage. Now, what I will do, I will measure V R, V C, V L ok. So, either you need 3 voltmeter or 1 voltmeter, you can just one after another, you have to you have to do the experiment.

So, now I will vary; now I will vary the amplitude this amplitude means voltage peak to peak value. And for each voltage, so current will vary in the circuit and corresponding voltage drop, I will measure for this three ok. And if I measure automatically current I will get; automatically current I will get, just whatever V R I will, so V R divided by this two that will be the current ok.

So, for a particular current, I will measure V L V L, V C and V R. So, then I will change the change the voltage V S source voltage and again I will repeat the experiment. So, I can connect current versus V L, V C and V R. Now, if you plot them; if you plot them V L versus I, V C versus I, then what you will get? You will get basically straight line. And from the slope, you will get basically X L and X C.

And frequency is known to you I have set at 100 Hertz see frequency is known to you, say X L equal to omega L 2 pi f L ok, so f is known. And from there basically you can find out L. Similarly, you can find out C; of course, R is known to us as I told 2.

So, in this way we can measure the capacitance and inductance also right. So, this part I will not show you, but my interest is to show you the resonance. So, for resonance what I have to do? So, for resonance I have to actually I have to measure the current. So, I will measure the voltage across this resistance, I will measure V R. If I measure V R, here I will get V R, so I will divide by these two, you will be it will be the current ok.

So, now this current I will so current how current varies in this circuit with frequency that is what I want to do experiment. So, here this is a 5 volt that I will keep fixed. Now, I will go to the frequency; I will go to the frequency; I will go to the frequency, (Refer

Time: 26:57), then I will start this experiment from 100 Hertz frequent. So, I will note down this frequency is 100 Hertz ok.

And corresponding what is the V R what is the V R? So, I have to connect it with a V R, here across this ok. So, I have connected; I have connected in electrical circuit always you have to see this, there should not be any loose contact yes is the connected ok. So, I have to note that this is; this is let me put in ok, this is a 7 milli volt, this is 7 milli volt, so, for frequency 100 Hertz.

So, you have to make table this frequency versus V R versus V R and resistance is 2 so this basically V R by R that will be I. So, frequency versus current that you have to make table. So, I will note down; I will note down this for 100 Hertz, this is 7.1 millivolt. And then I will change to 200; I will change to 200 110 120, so I will change to now this frequency is 200. Then I will take reading now, it is 14.7 I will note down this reading.

Then I will go for 300 and then it is 330 ok. Now, it is 300, this reading is 300 that is 23.9 milli volt ok. So, this way I will continue; I will continue to 400, 500, 600 ok. So, now I am it is 600 ok, so 87.3 reading is 87.3. Then I think I am close to the resonance, so I will increase the range of the voltage I kept it at two volt range ok. So, it is in volt range we say 88 volt ok. So, then I will change; I will change I am changing its 670, 680, you see this now it is increasing very fast, this current is increasing very fast.

For slight change your frequency, now 720, 730, it is 200 200, 740 Hertz 216 millivolt, then 750, 236 7 you see earlier with respect to 100 variation of Hertz, whatever change now with respect. Here now with 10 variation of frequency this change is similar. So, 760 770 780 790 you see this 810. So, it will come around 800. Since, I have done this experiment earlier so its the near out 300 near out here 290, 90 290, 292, so at 790, it is 290 at 780 at 780 to 87, so its decreasing.

So, if I go increase it 800, it is 287 or 290 around. So, now 810, now started to decrease 820 it now decreasing. Now, I am increasing 830, 840, 860, so its decreasing know. So, peak so we saw that peak is around 800 Hertz the frequency. When it is 800 hertz is a maximum, it is the 292 millivolt. Then below this, lower side of this frequency, its decreasing. And higher side of the frequency, it is increasing. The also this current is decreasing. This voltage is decreasing means this is the volt, so divided by 2 that is the current.

So, this you have to take this data and then plot it. And then you will see the peak, and then corresponding what is the frequency of that peak that is the that is your resonance frequency. Now, in resonance condition this X L equal to X C that is the condition right. So, X L are in reactance, so I into to X L is the V L, I into X C is the V C ok. So, X L equal to X C means V L equal to V C. So, at resonance condition V L equal to V C it has to be, so that I want to show you ok.

So, let me go to the resonance condition at 800 Hertz at 800 Hertz ok. So, this is its a change earlier it was 292, but here now its the 280, 85, 86 ok. We have to give time to stabilize it. So, sometimes is reading changes because of heating effect if you pass current for longer time, so no it is a it has come nicely 292 ok.

So, now this is the V R. Now, what is the; what is the V C and V L that I want to measure. So, I will disconnect from here; I will disconnect from here, let me connect here. So, this is one end of the capacitor, this is the other end of the capacitor. And I want to measure, I have to go to the what happens. So, you can see this it is around 9 is the it is in volt it is a coming sorry, we should not disturb the circuit, then it is coming around say 10 volt 10.2 volt ok, so its a in its a in volt range ok. So, its the 10.22 volt. So, this V C is 10.22 volt at resonance condition.

So, now let me measure the V L, let me measure the V L and check it. So, I want to measure V L, so I have to connect with this ok, but here I will feel difficulties to connect probably ok. Let me just hold it; let me just hold it, but it should be it is a small voltage, so it should not be problem, if I hold with hand.

So, you see that V C was, but it should not so it is 9.22. Earlier it was 10.22, it is 10.22, but I should connect properly, because some resistance is coming in probably I should here, now it is a 9.34. Anyway, so 10.22 10 volt, and this is 9.3 volt; 9.3 volt. So, it may not be these resonances perfectly at this frequency, so it can be probably 800 something ok, 805 or 795 so one has to tune.

And you have to; you have to, but I could show you properly, but unfortunately its an no my hand is touch here 9.44 and 10.22 is very close. So, it has to be equal V L and V C has to be equal. So, this difference it may be due to the just my connection, it is a loose connection. It may be for due to that or we have to slightly adjust the frequency, it may

not be 800 exactly maybe 800 3 4 5, because at the peak position this is very sensitive this current is very sensitive.

So, more or less I could show you that this V L and V C means, X L is equal to X C at the resonance frequency ok. So, for this the experiment about the LCR main interest is to show the resonance and you could show the resonance, and this resonance is frequencies around 800. So, if you plot it and then accurate frequency can find out from the peak of this plot. So, that if I was doing that one, but I do not think this I cannot open that is the problem this ok, so but I say if I want to show you this ok this is very tight ok.

So, yes now its a 9.9 10.2 now it is 9.9, so that is what here this connection is factor ok. So, I think this 9.9, I could show you, but only problem is we have to; we have to do proper connection you have to do proper connection, otherwise yeah let me just leave it here. Yes it is varying, because this connection is not so strong, it is a loose that is a so forget, but this X L is equal to X V. So, V L is equal to V C. So, more or less that I could show you. And that it will be if exactly equal, when you will be at exact frequency, so one has to tune and find out. So, I will stop here.

Thank you for your attention.