Fundamentals of Electrical Engineering
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Lecture – 45
Resonance and Maximum Power Transfer Theorem (Contd.)

We are back again, now next is that parallel resonance that is two branch circuit.

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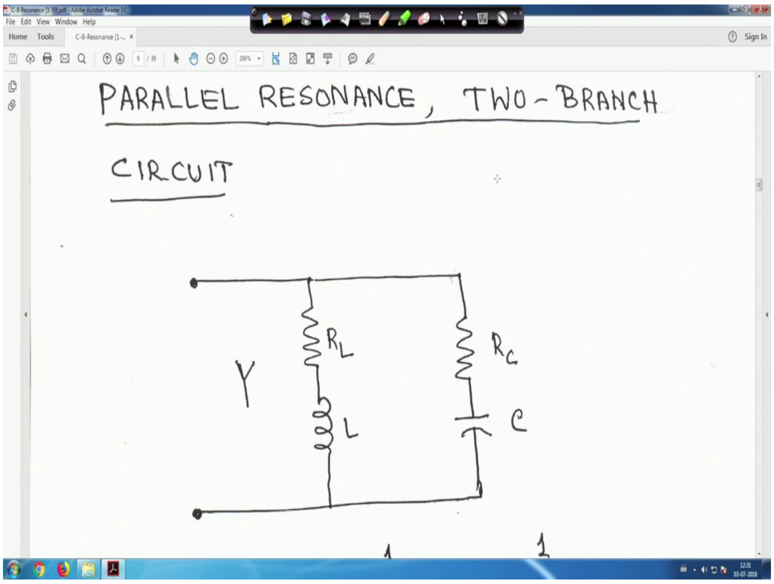

We have taken a simple two branch circuit right. So, your this is R L over L that is one inductive branch and this is one capacitive branch right. So, it is R L L omega and it is RC your XC right. So, this is you have to see the parallel resonance of the circuit. So, Y is the admittance right. So, Y is equal to your Y is equal to that admittance is equal to Y L plus Y C right.

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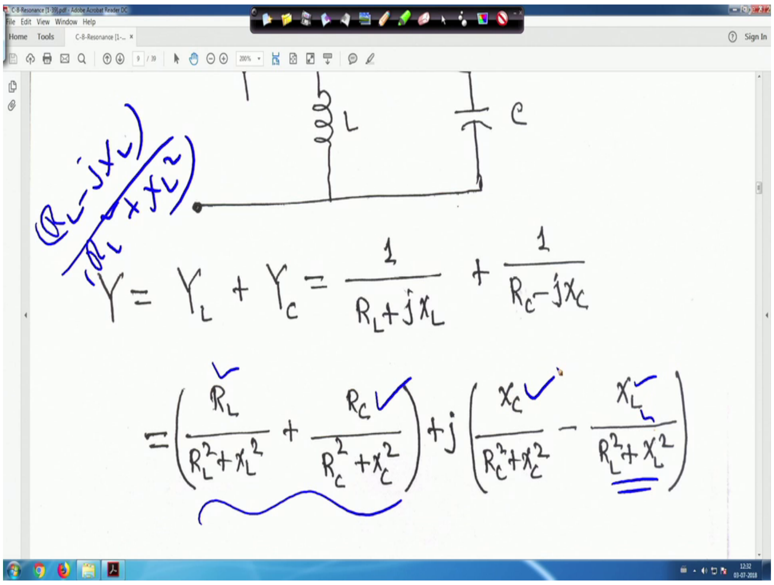

So, Y L is that admittance of this inductive circuit. So, it is 1 upon RL plus j XL and this is your plus 1 upon RC minus j XC right. So, now this one numerator and denominator this one you multiply by your RL, this term we multiply by your RL minus j XL; that means, this one will be RL minus j XL right divided by RL plus XL into RL minus j XL that is RL square minus j square XL square. So, j square is minus 1 so, it will be your RL square plus your XL square. So, just separate it will be RL upon RL plus XL square and this one your what we call this will be your my here it is taken common.

So, here it is minus XL upon RL square plus XL square imaginary side right. So, this is actually this two are real parts. So, real part is RL upon your RL square plus XL square imaginary part is minus XL upon RL plus XL square. So, here it is minus XL upon RL plus XL square, similarly for RC minus j XC numerator and denominator you multiply by RC plus j XC. So, real part is here and imaginary part is here right. So, let me clear it.

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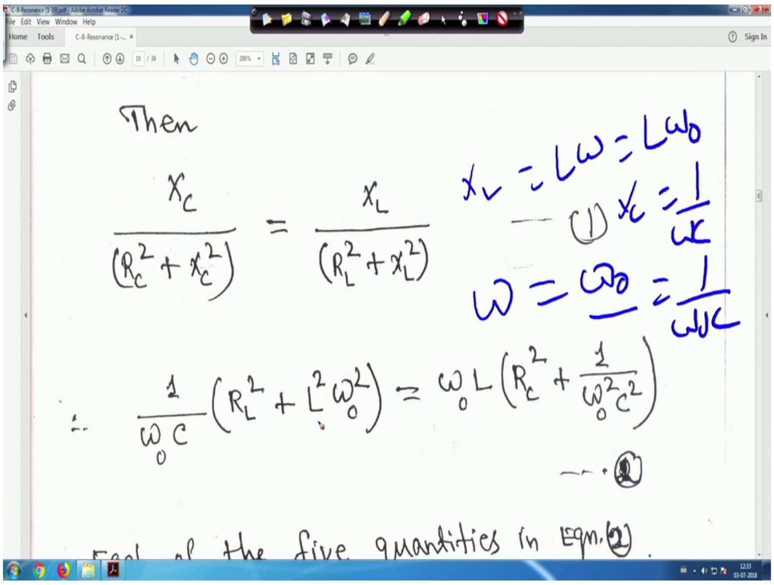

So, this means; that means, circuit is at resonance when the complex admittance is a real number; that means, this one this imaginary part we set it to 0, this one we set is to 0. If you do so, it will become XC upon RC square plus XC square is equal to XL upon RL square plus XL square right. This is actually at omega is equal to this is at omega, omega is equal to omega 0 the resonance frequency, that is why that wherever we make it XL is equal to L omega that is your L omega 0 right and XC is equal to 1 upon omega C that is your 1 upon omega 0 c right.

So, this one you put it here that XL is equal to your l omega 0 and XC is equal to 1 upon your omega C that is omega 0 C and just simplify right let me clear it.

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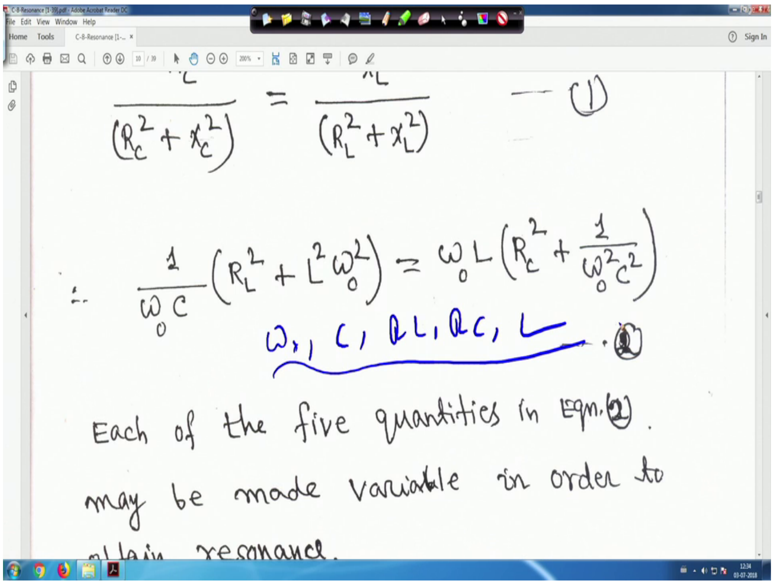

So, this way if you just simplify that is alright cross multiply this one you cross multiply and then you put it. So, each of this five quantities in equation may be made variably in order to obtain resonance there are five variables right, there are five variables one is omega 0 then C then RL then RC then L. So, there are five variables right.

So, in this case that is each of the five quantities in equation 2 right. So, this is equation 2 this is equation 2 right, may be made variable in order to obtain resonance. Now, solving equation 1; that means, rather than I will say equation 1 or equation 2 rather than I will say equation 2 from equation 1 we got equation 2 so, you will get omega 0 is equal to 1 upon root over I mean what you do is you from this equation say from this equation 2 find out omega 0.

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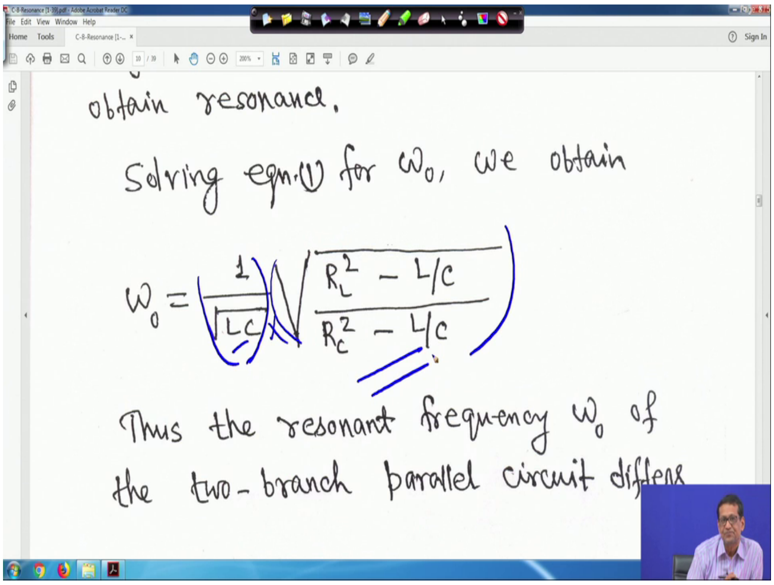

You do little bit of mathematical gymnastic right and then from that you simplify and then you do omega 0 is equal to 1 upon root over LC then root over RL square minus L by C by R C square minus L by C. From this equation 2 you will get thus expression I suggest you please do it I have given you the final expression. So, that one you get 1 upon root over LC the root over RL square minus LC by then divided by RC square minus LC.

Now, circuit will be are loop for series circuit that omega 0 this sub series circuit omega 0 was that your 1 upon root over LC only, but the parallel circuit right so for series RLC circuit, we have seen 1 upon root over LC for parallel circuit. One factor is multiplied and this is this factor right.

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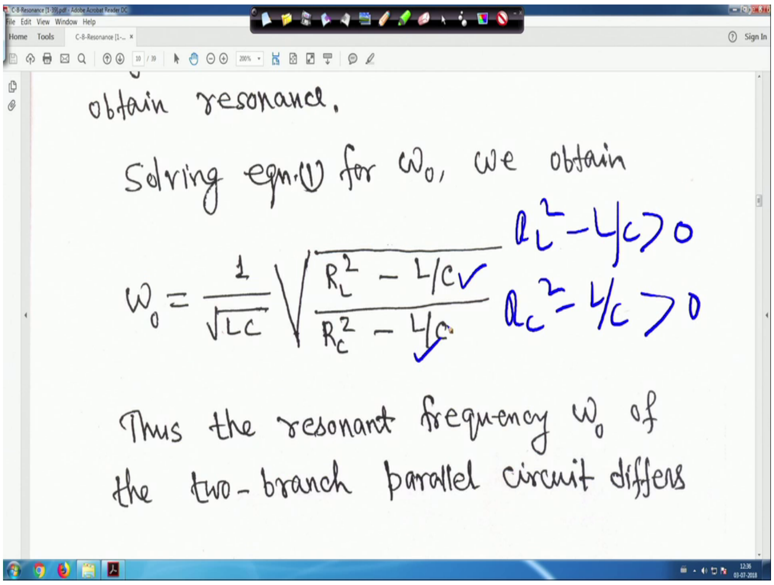

So, now resonance when resonance will occur that one condition is that your RL because your square root term you are you are under the root this term have to be positive. So, one condition is RL minus RC it has to be greater than 0 sorry RL square minus L by C it has to be greater than 0, another thing is that RC square minus L by C also greater than 0 this is one condition for resonance right.

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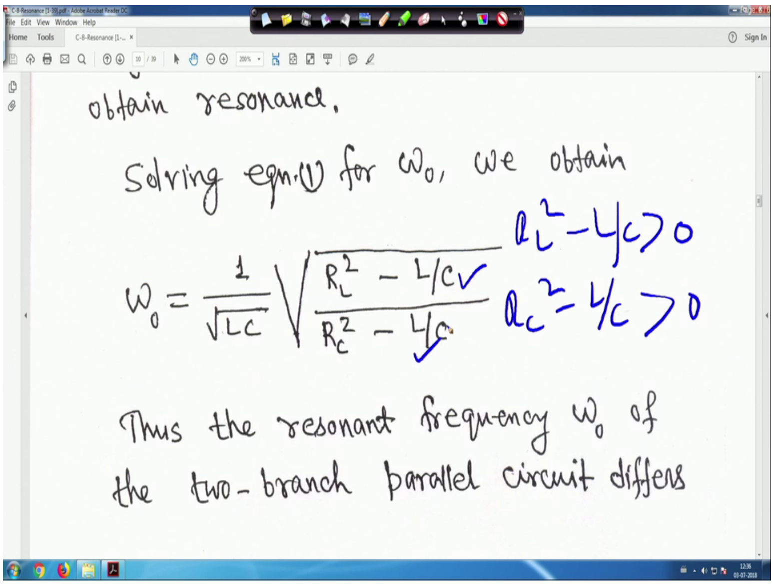

So, we will get some value that because this has to be positive this has to be positive or this one has to be negative this one has to be negative, such that RL square minus L by C less than 0 and your RC square minus L by C less than 0 if both are negative then it will be positive. Then you will get some value of resonance frequency right.

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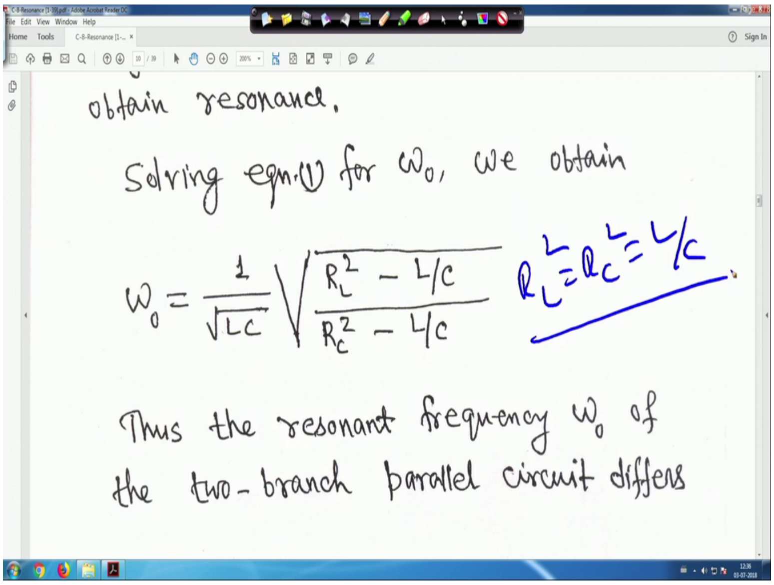

But if let me clear it, but if your what if it happens that your RL square is equal to RC square is equal to L by C; if this condition happen then it will resonate at every all frequencies right.

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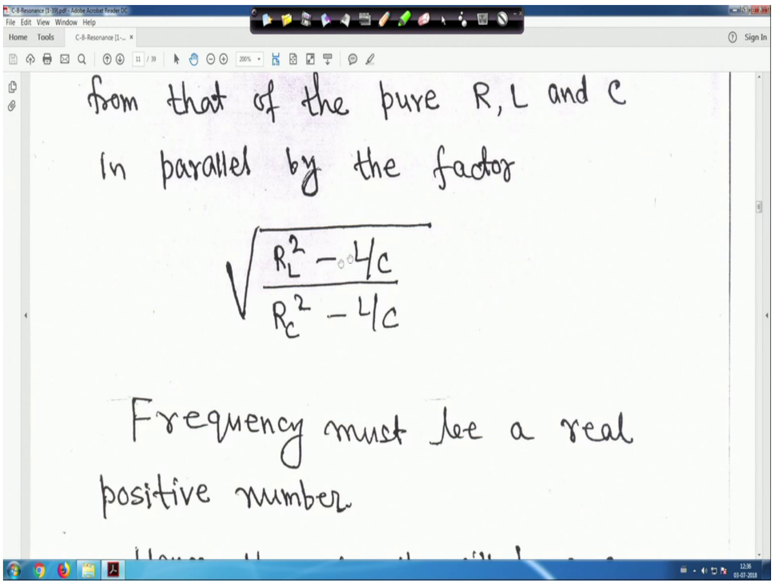

So, now let me clear it. So, this is your; that means, does the resonance frequency omega 0 of the two branch parallel circuit this is one condition right. It is your what you call this factor has been multiplied, when the series RLC circuit is a 1 upon root over LC, but with this factor this has been multiplied that is I told you these are multiplied right.

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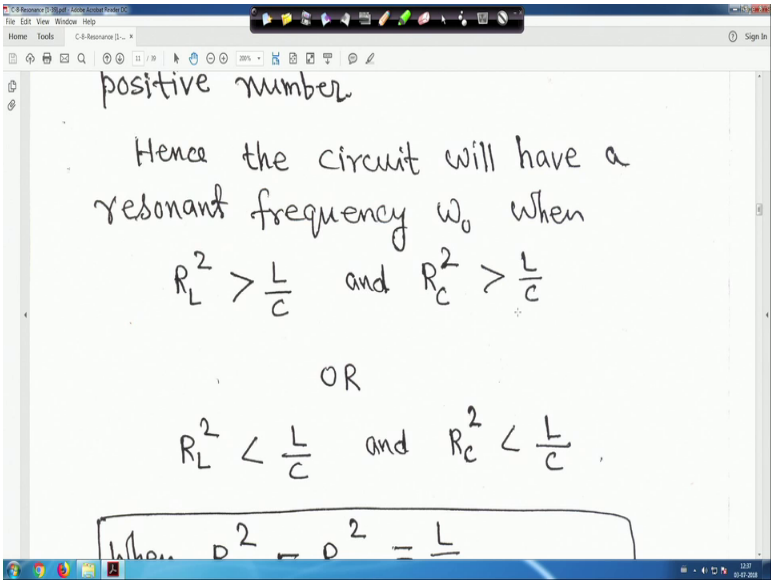

So, now for resonant condition I told you that R L square minus L by C greater than 0 and RC square minus L by C greater than 0 both has to be positive; that means, RL square greater than LC and RC square sorry L by C and RC square greater than L by C.

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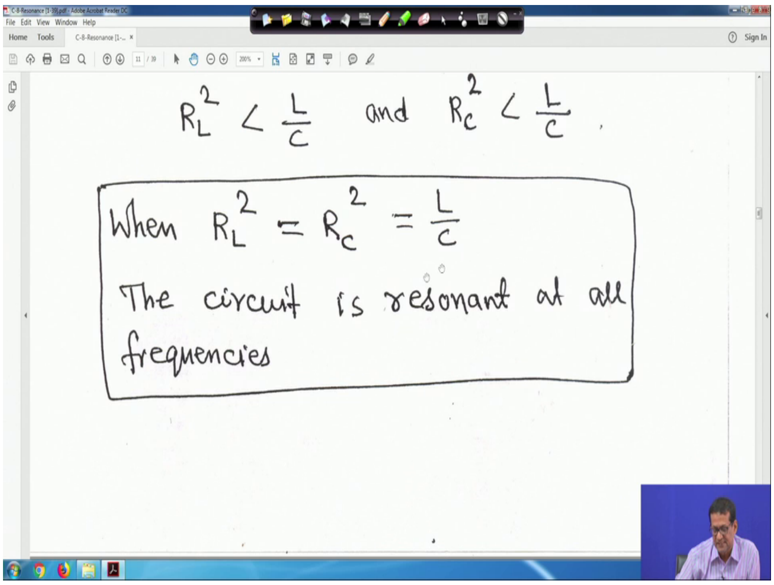

Or RL square minus L by C less than 0 that is RL square less than L by C similarly RC square minus L by C less than 0, that is RC square less than L by C. So, this way resonant will happen right, but when RL square I mean is equal to RC square is equal to L by C the circuit is resonant at all frequencies right that also I told you because, that factor tau will vanish right.

So, now question is that, if you solve equation 1 right for your what you call for L you will obtain something like this. I mean if this is equation 1 it is very interesting suppose from equation 1 right from equation 1.

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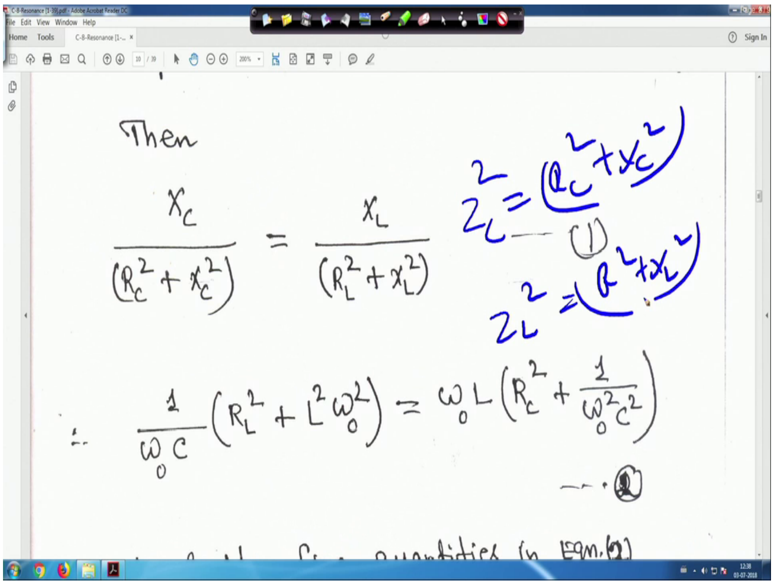

So, your this one we call ZC square is equal to your RC square plus XC square this is my ZC square and ZL square is equal to R square plus XL square right.

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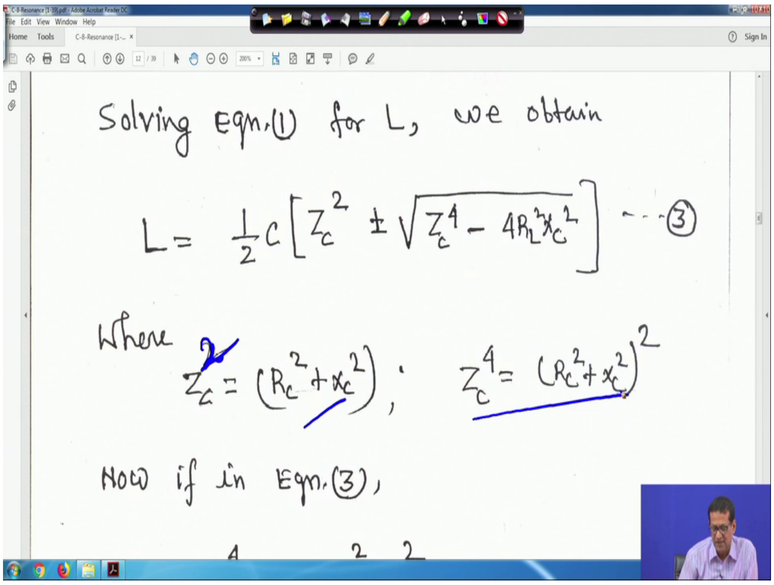

So, now let me clear it therefore, from this equation 1 from this equation 1, we will see this one that if you solve for L you will get this you solve it, I have done it for you, but this will solve it you will get L is equal to half into C half C bracket that ZC square plus minus root over ZC to the power 4 minus 4 RL square XC square this is equation 3 right, where ZC square is equal to this is square right. This is square, this is square Z C square is equal to RC square plus XC square therefore, ZC 4 is equal to RC square plus XC square whole square. So, from equation 1 you please solve this one, you please solve this one for your L. So, let me clear it.

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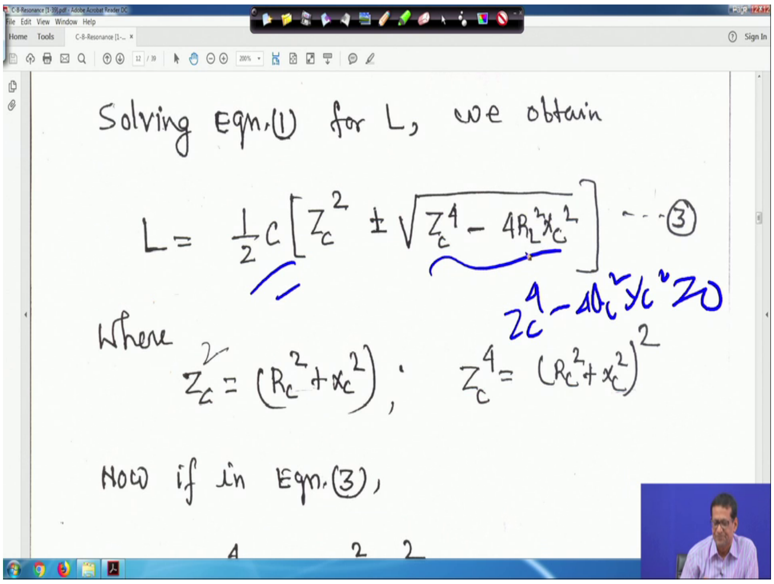

So, in this case what is happening that from this equation 3 that for resonance it has to be ZC 4 ZC to the power 4 minus 4 RL square XC square it has to be greater than 0 because it is square root so, it has to be positive right. So, in that case you will get two values of L right, two values of L for which circuit will your what we call resonance will happen right.

So, another this is one another thing is let me clear it another thing it if ZC to the power 4 minus 4 RL square XC square with these term if it is equal to 0, you will have only single value of l right, but if ZC to the power 4 if this term become negative, then there will be no resonance right. So, let me clear it so, that means whatever I told that ZC to the power 4 has to be greater than 4 RL square XC square the required root this under the square root term has to be positive right. So, we obtain two values of L for which the circuit is resonant right.

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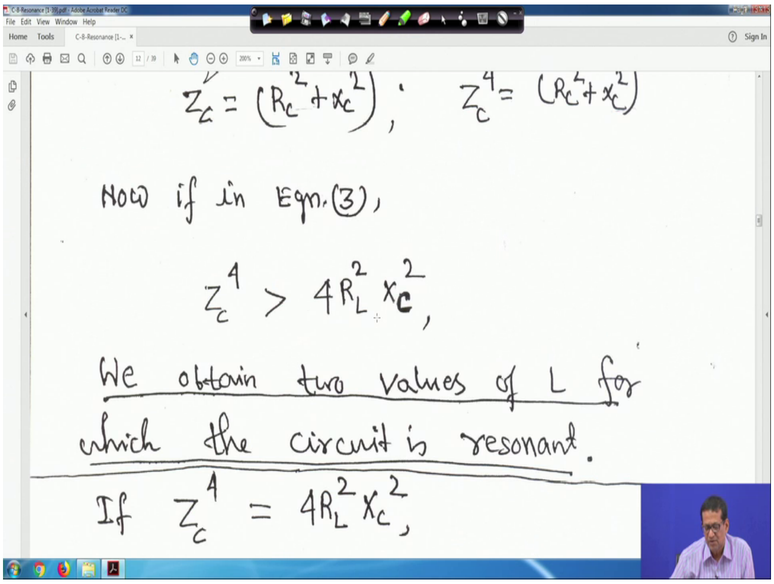

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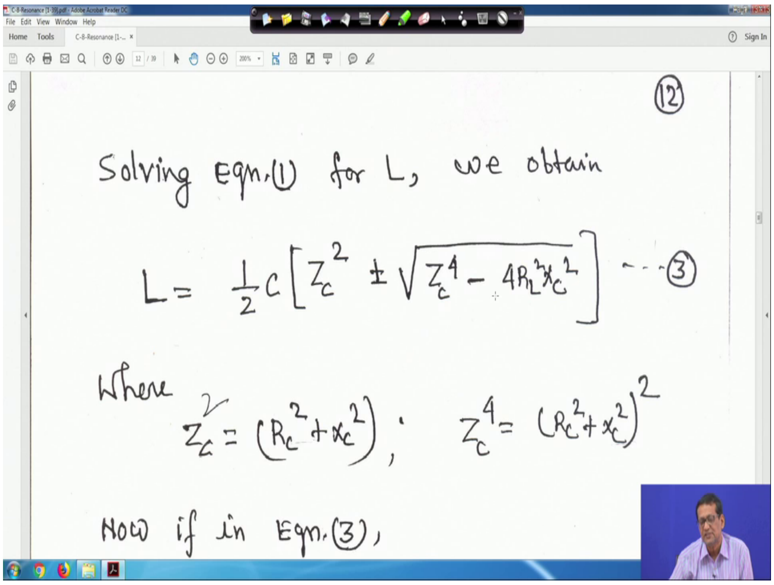

So, that is if ZC to the power for two values means because here plus minus is there plus minus is there. So, if ZC your what you call your if ZC to the power 4 is equal to 4 RL square XC square.

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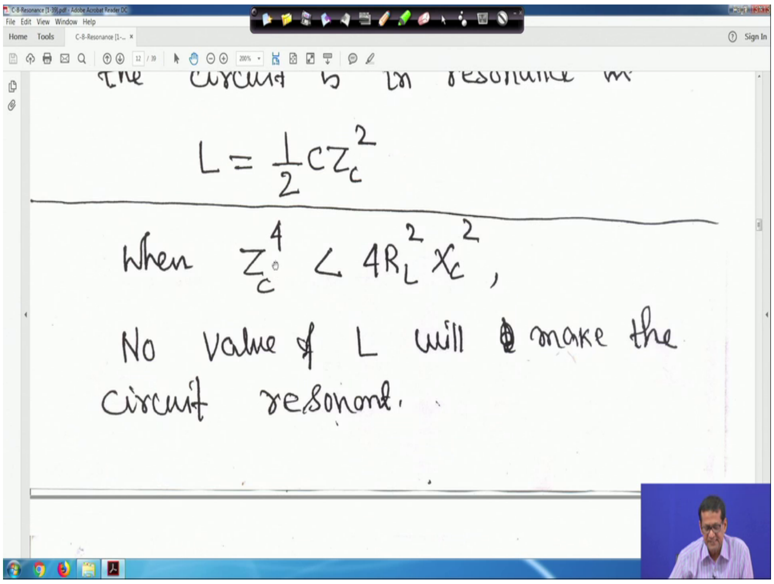

The circuit is in resonance at l is equal to half C ZC square, I mean if ZC to the power 4 is equal to 4 RL square XC square means this term will be 0 so; that means, L will be half C into ZC square right. So; that means, the circuit is in resonance at L is equal to half C ZC square and when ZC to the power 4 is less than 4 RL square XL square no value L will make the circuit resonant. So, if this condition is there; that means, under root comes square root of is negative then this question is what there will be no value of L will make the circuit resonance right. So, this is for L.

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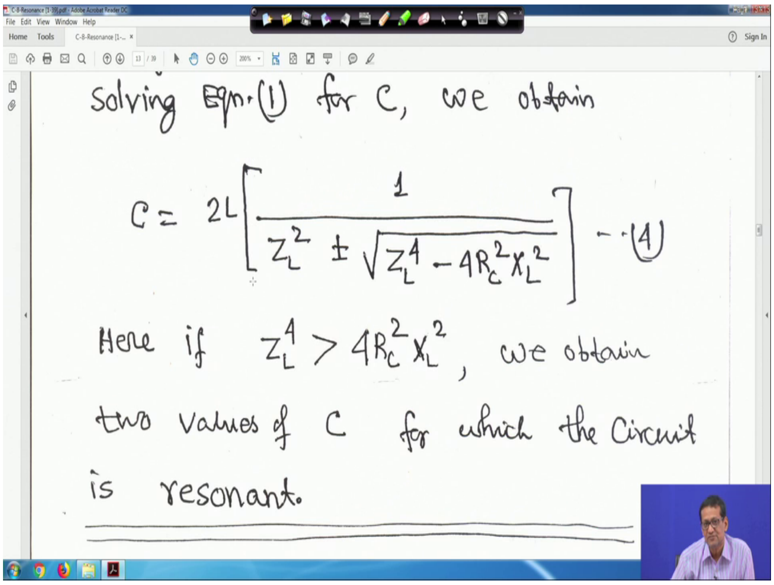

Similarly, from equation 1 solve for C this is I have written, but I suggest you to solve. So, again from equation 1 you solve for C you will get another expression 2L into 1 upon ZL square plus minus ZL 4 minus 4 RC square XL square if the square root term is positive right, you will get two values of it for which circuit will resonant right. So, and if Z L to the power 4 minus 4 C square XL square is equal to 0 you will have only one value of C right 2L upon ZL square at which circuit your what we call is resonance circuit right, but if this term becomes negative there is no value of C that circuit will become resonant.

So, this is the condition right. We obtained two values of C for which the circuit is resonance and if this one is equal to this one ZL to the power four is equal to 4 RC square XL square the circuit is resonance at C is equal to 2 L upon ZL square right again this is for L this is for C.

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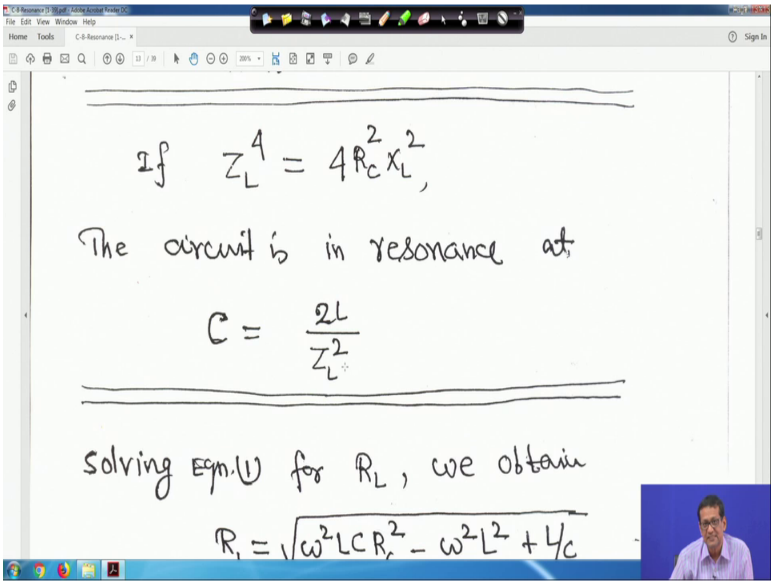

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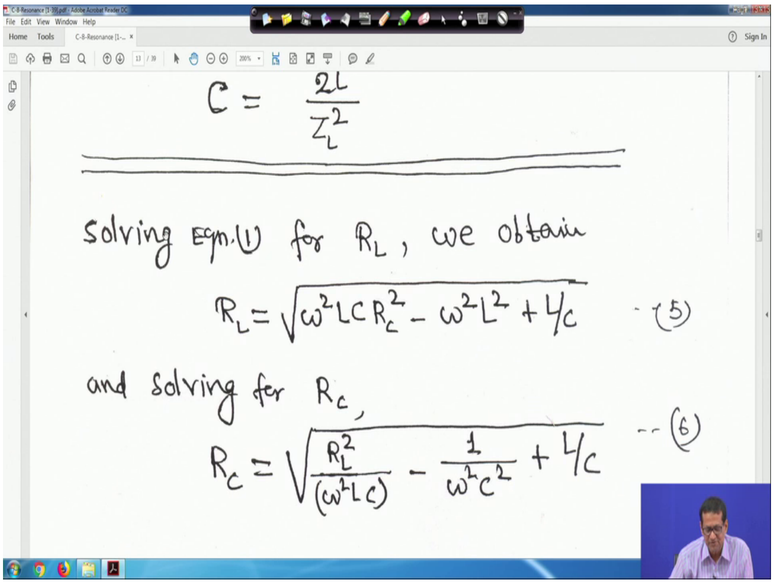

Now, again if you solve from equation 1 in RL if you solve for RL in terms of other quantities, what we are doing is each con variable we are trying to find out in terms of others right. So, if you so, solve equation 1 for RL you will get RL is equal to this expression, this we do it in simple and that your what we call if omega square LC RC square minus omega square L square plus L upon C if it is greater than 0 then circuit is at resonance right.

So, this is for RL and similarly if you solve for RC of the equation 1 only you will get RC is equal to square root of RL square upon omega square LC minus omega square C square plus L by C. So, this is actually your what we call greater than 0 has to be greater than 0 for which circuit is at resonance right. So, L C RL your what we call RC right all these things in terms of remaining variables we got it right, now question is that in this two in 5 and 6 I told you.

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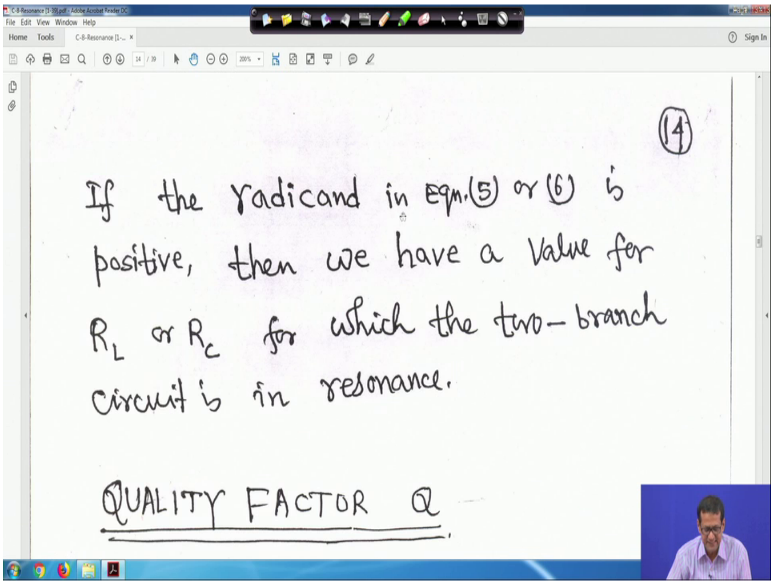

But here it is written here whatever I said here it is written here right. So, this is your what you call that your resonance of your parallel circuit simple inductive and capacitive circuit.

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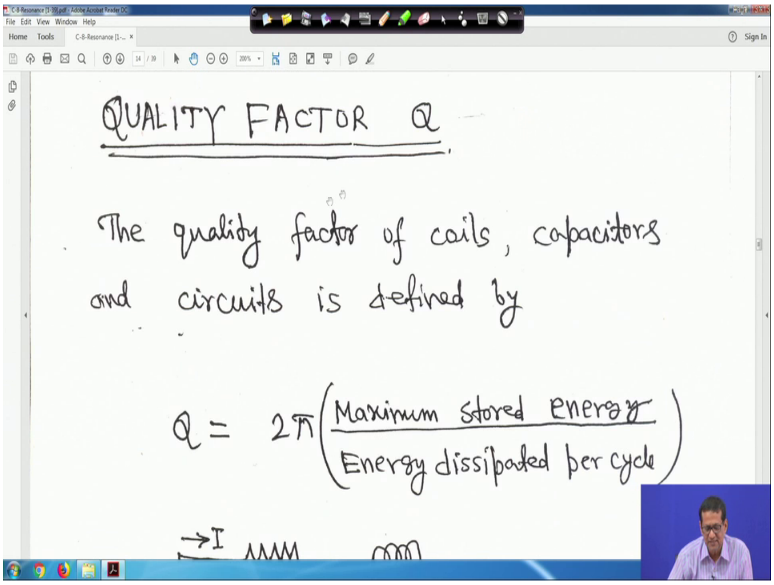

Next another term we define the quality factor it is called Q right. So, the quality factor of coils capacitors and circuit is defined by.

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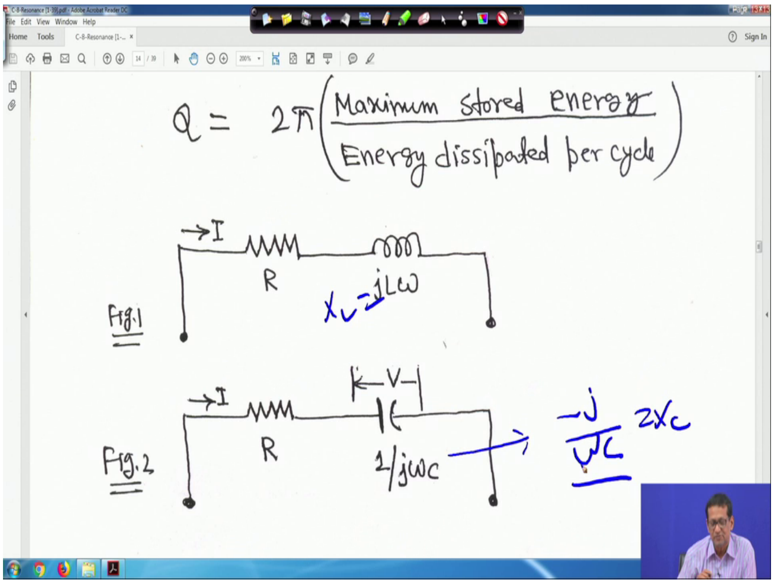

So, quality factor sometimes for a circuit is defined by 2 pi into maximum stored energy divided by energy dissipated per cycle right. So, for example, it is called quality factor right of the coils capacitors and circuit. So, in general Q is equal to 2 pi into maximum stored energy divided by energy dissipated per by your what you call per cycle. Now for example, consider a simple your what you call your inductive circuit that is this is resistance R this is your XL is equal to JL omega and this is current flowing through I.

Similarly, in figure this is figure 1 say this is figure 2 say it is a capacitive circuit it is R current is flowing I and it is your what we call1 upon j omega C that is 1 upon j omega C means it is minus your this one upon j omega C means it is minus j by omega C right. So, and this is your this is your this is your coil XC and this is your XL, XL is equal to JL omega and XC is equal to your minus j upon omega C right. So, separately we are considering.

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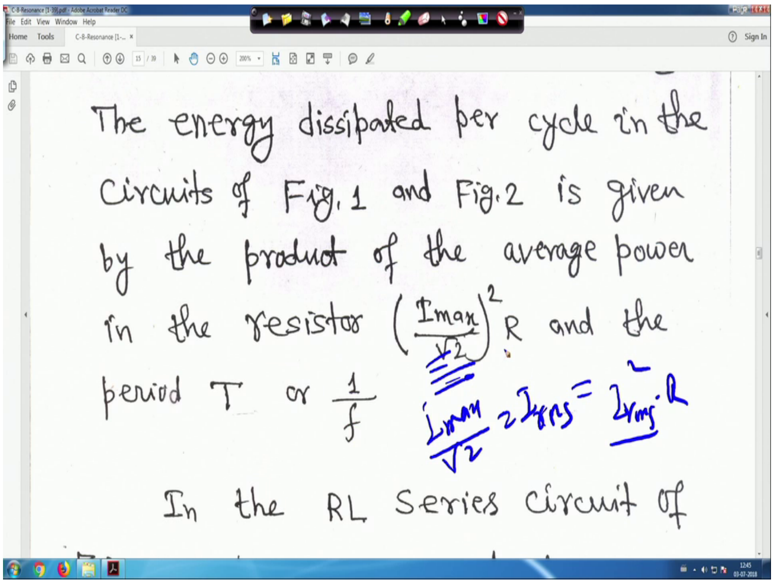

Now, now the energy dissipated per cycle in the circuit of figure 1 and figure 2 is given by the product of the average power of the resistor and a your what you call that is your I rms square r and the period T or 1 f; that means, that means this is we are writing I your what we call I max by root 2. Actually I max by root 2 is equal to basically your rms value I rms value right. So, it is rms value.

So; that means, power loss is equal to actually this is rms value. So, I rms square into R this is that your what you call that average power in the resistor that is I rms square into R. So, we are putting it I max by root 2 square into R right.

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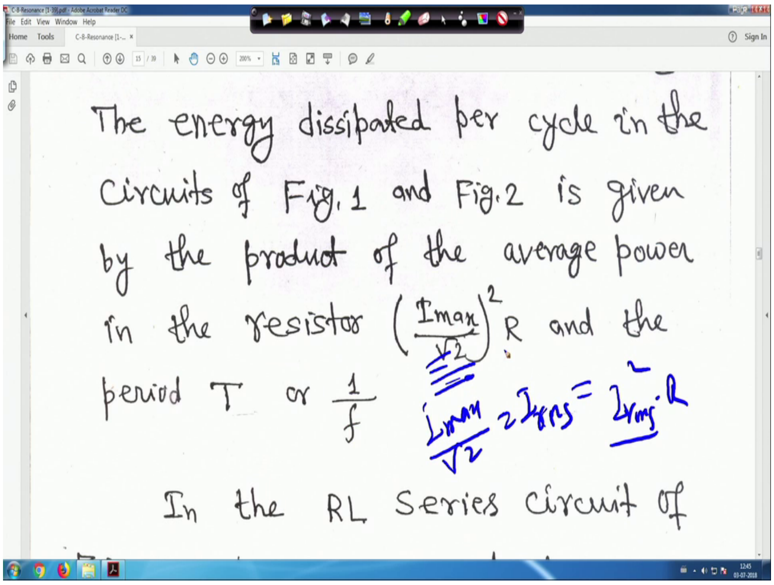

So, and it is your what you call that power your average power of the resistor and the period T or 1 or 1 1 upon f. That means if this is your what you call this is your average power say I max by root 2 square in to R right and per cycle means is multiplied by this thing. So, this is your divided by f right. So, it is your energy dissipated per cycle in the circuit of figure 1 and figure 2 figure 1 is inductive circuit and figure 2 is a capacitive circuit right.

So, in this case in the case of RL series circuit figure 1 the maximum stored energy we have studied earlier half l I max square that you have studied right. Therefore, that Q is equal to 2 pi it is maximum stored energy half I max square; that means, where we have written here the q is equal to that Q is equal to maximum stored energy by energy dissipated per cycle.

So, in this case your this one is 2 pi half l your I max square divided by I max square by 2 because it is I max by root 2 square, so, whole square. So, I max square by 2 in to R into 1 upon f right, because this is actually energy dissipated your per cycle right. So, f is the frequency that is your say frequency 50 hertz means; it is 50 cycles per second right.

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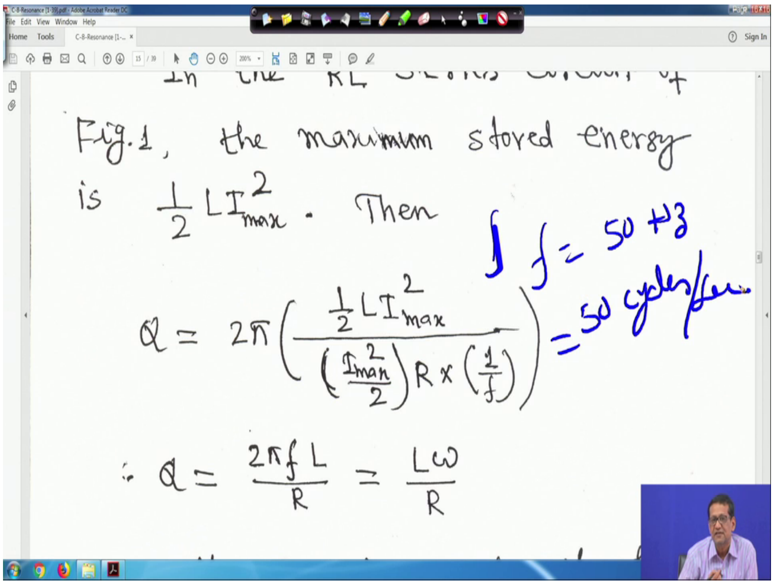

Whenever we say whenever we say f is equal to f is equal to 50 hertz; that means, it is 50 cycles per second right. So, it is per cycle, so it is divided by f right. So, if you after simplification after simplification simply you will get Q is equal to 2 pi f L upon R that is your L omega by that is your L omega by R right.

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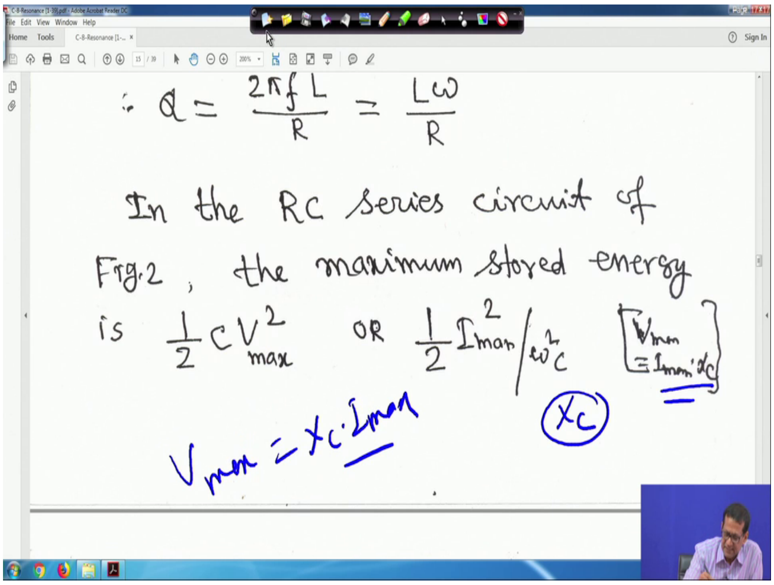

So, that is Q for inductive circuit right similarly in the RC series circuit of the figure 2 the maximum stored energy half CV max square or and another thing is that in that your what you call your what you call that your V max if you took XC is the if XC is the your what you call the reactance of the capacitor magnitude will take therefore, V max right is equal to your XC in to your I max right that is written here V max is equal to say I max into XC.

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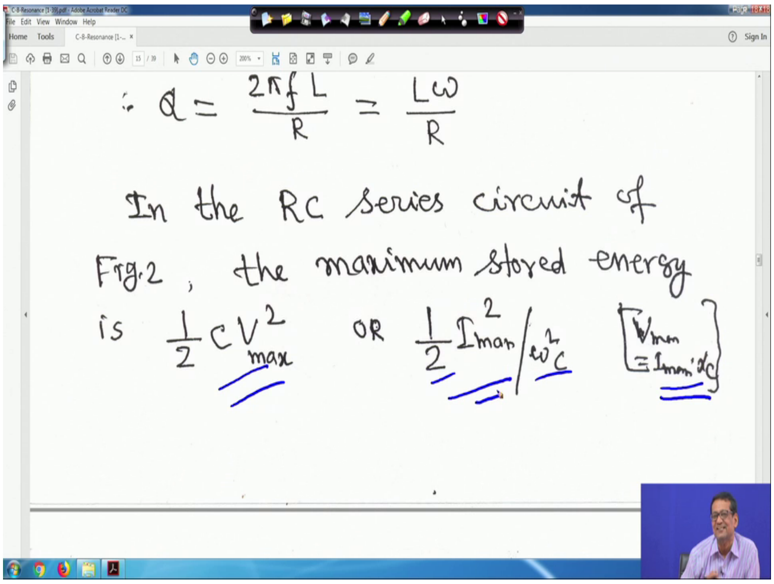

Now, in that let me clear it so, this is actually half C V max square capacitor your what you call energy stored is a capacitor or if you use this relationship you will get half I max square divided by omega square C right. So, in that case your what just you substitute and put XC is equal to 1 upon omega C and just simplify you will get this am not doing it is understandable right.

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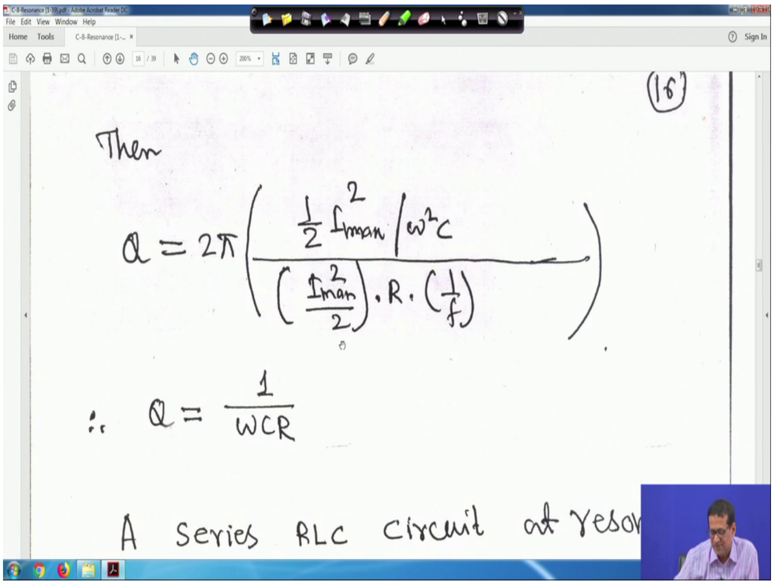

So, this in that case for in the case of capacitor; so, 2 pi half I max square upon omega square C divided by same thing I max square by 2 into R into 1 upon f right. So, if you do, so Q will become one upon omega C R right; that means, this for quality factor for inductive circuit is Q is equal to L omega by R and for capacitive circuit it is Q is equal to 1 upon omega C R right.

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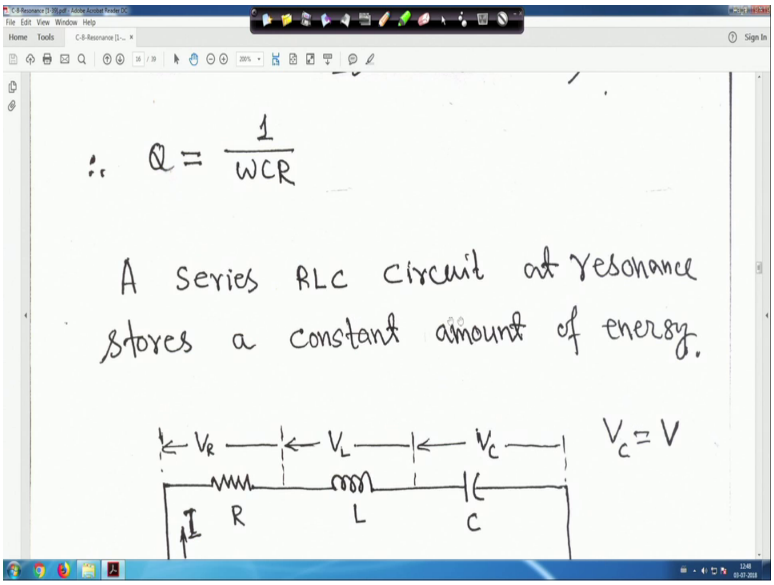

Therefore a series RLC your series RLC circuit at resonance stores a constant amount of energy right. Now let us consider a series RLC circuit at resonance stores a constant amount of energy.

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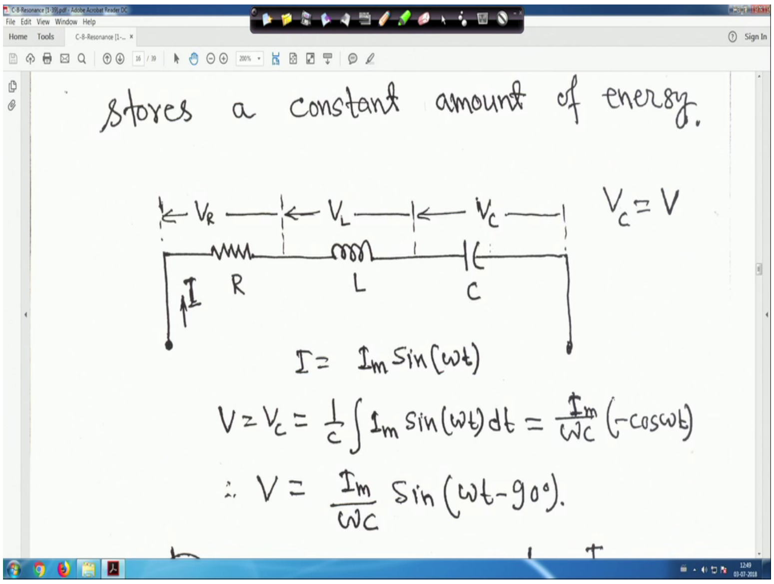

Now, suppose this is series RLC circuit say VR is equal to VR is equal to I into R current going through this is I right and this is my l. So, VL is equal to this voltage across inductor is VL and voltage across capacitor is VC and we are assuming that your what you call say for example, VC is equal to v something am writing here right say VC is equal to V.

Now say this I is equal to say I m sin omega t right this is ac quantity. So, so I m is equal to sin omega t, now voltage across the capacitor that is VC is equal to V V is equal to VC just you have to integrate 1 upon C I m sin omega t dt if you integrate it will be I m upon omega C minus cos omega t.

So, we can write that your this cos omega t is sin 90 degree minus omega t, but 1 minus sin is here; that means, it will be I m by omega C sin omega t minus 90 degree. That means, here your what we call that current I is equal to I m sin omega t right and V voltage across the capacitor V actually it is I m by omega C sin omega t minus 90 degree; that means, current actually is leading because it is omega t plus 0 and leading this voltage V is equal to VC and voltage across the capacitor.

So, we are so, that is why I m by omega C sin omega t minus 90 degree, now if you if this is sin omega t plot I m I is equal to I m sin omega t plot.

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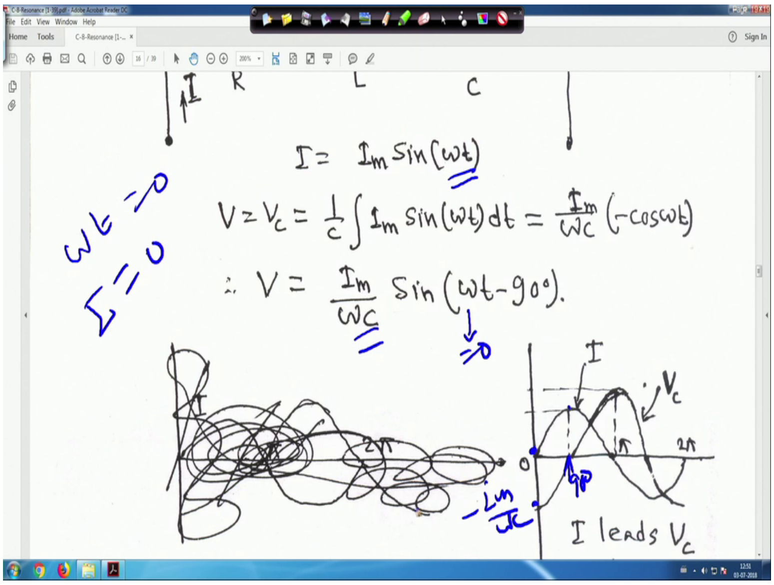

So, if in this case this is starting from 0 so, it is your I right. So, I is reaching the peak first right. So, and in this case when omega t is equal to 0, when omega t is equal to 0 say when omega t is equal to 0 so, I is equal to 0. So, this is starting from here 0. Here when omega t is equal to 0 V is equal to I m by omega c sin of minus 90 degree when omega t is equal to 0 right. So, in that case sin of minus 90 minus 1. So, V will be V is equal to VC right that voltage across the capacitor. So, it is minus I m omega C.

That is why this so, this point is your minus I m by omega C right. So, when current is when current is reaching its peak; that means, this angle is 90 degree. So, when omega t let me clear it, let me clear it.

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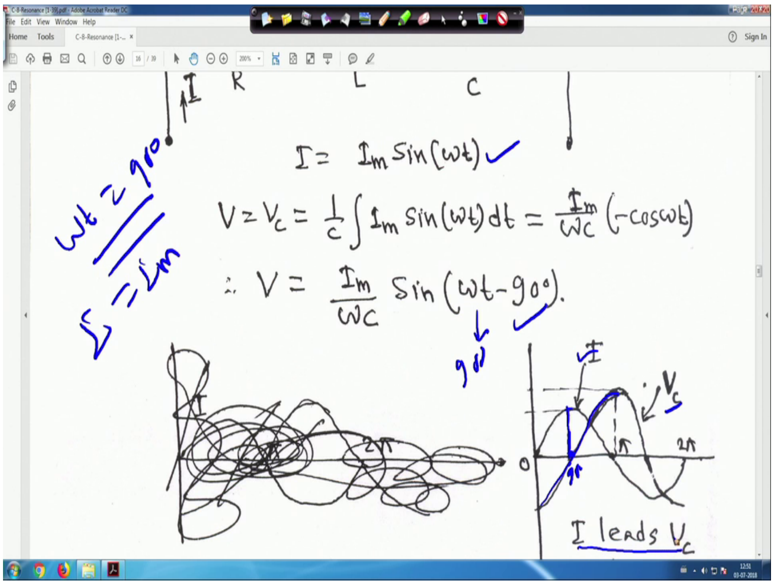

So, when omega t is equal to 90 degree then I is equal to I m right. So, this is my omega t (Refer Time: 20:28) this is my your 90 degree I is equal to I m. But when omega t is equal to 90 degree if you put 90 degree then V is equal to 0. So, that is why V is equal to 0 because this is the curve for V so, V is equal to 0. So, current actually reaching it is peak faster than the voltage. So, this current is leading the voltage by 90 degree from this from this we can make it out easily right. Therefore it is written I leads VC by an angle 90 degree.

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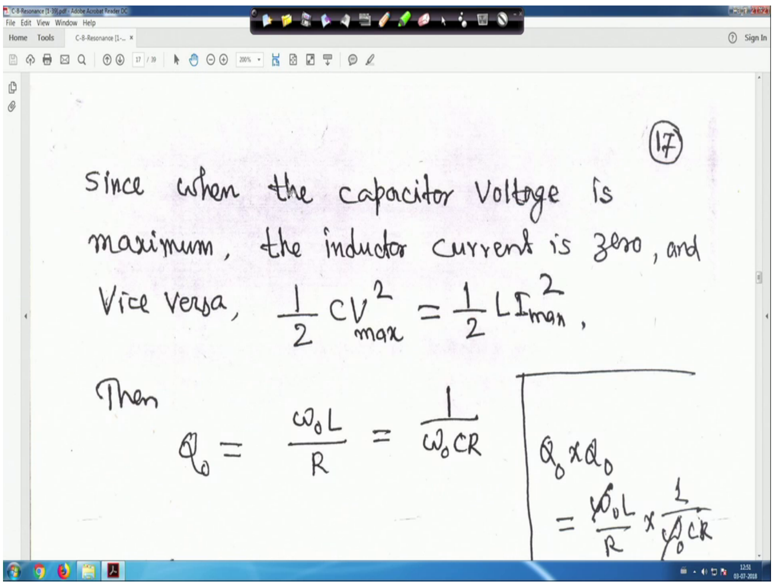

So, therefore, since when the now when the capacitor voltage is maximum the inductor current is 0 and vice versa when; that means, when capacitor voltage here it is this point 0 in this your what you call this inductor current is maximum or when inductor current is 0 this point capacitor voltage is maximum vice versa. So, from that your from that we can write that half CV max square is equal to half LI max square, from which we get right then Q 0 is equal to may be written as omega 0 upon L by IR that is one upon omega 0 CR right.

So, actually your what you call from if half CV max square is equal to half LI max square from that you then you Q 0 is equal to your L omega 0 by R is equal to 1 upon omega 0 CR right. So, from this your what we call what will do right.

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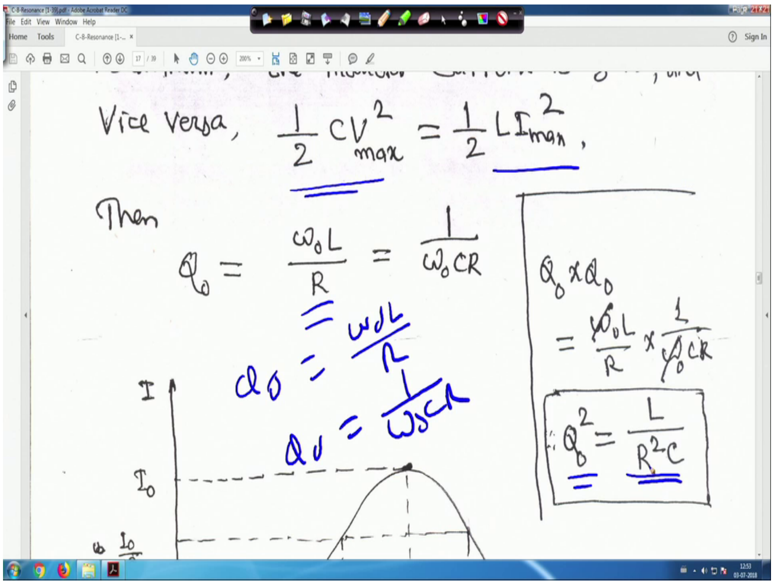

This is my equation this is the equation right. So, little bit little bit you try to do it yourself right. So, many things I have done I have been spending lot of time right little bit you do that, but one or two thing I am telling.

Suppose this is my Q 0 is equal to I mean you write separately say Q 0 is equal to omega 0 L by R and again you write Q 0 is equal to 1 upon omega 0 CR. Now Q 0 into Q 0 that is Q 0 into Q 0 then omega 0 l upon R into 1 upon omega 0 CR. So, omega 0 omega 0 will be cancelled right and finally, it will become L upon R square C the Q 0 square will become l upon R square C.

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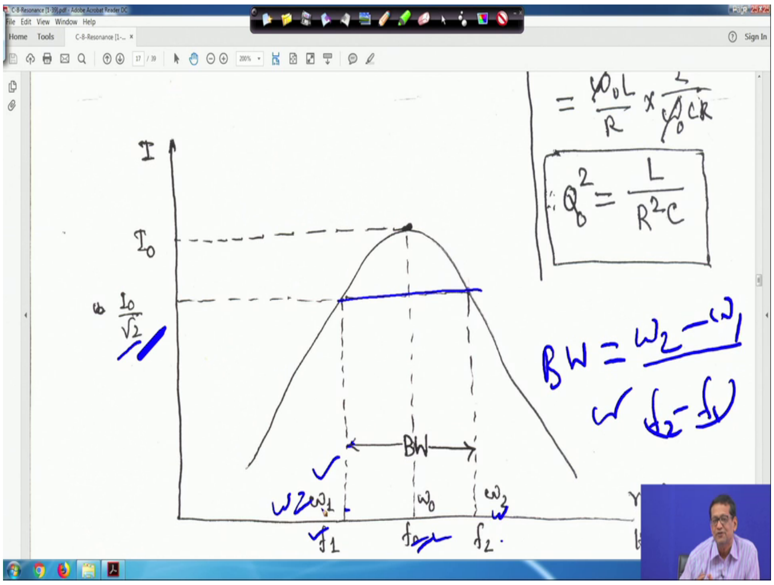

So, let me clear it, this is an exercise for you this is an exercise for you to do this little bit right. So, now if you now so, this is your Q 0 right. Now question is that suppose before coming to this figure suppose at omega 0 current is maximum because for your what we call for resonance circuit, we have seen that your the resonant frequency series R LC circuit say that XL is equal to XC. So, in that case that your current is maximum and these current say it is I 0 I 0 is the maximum current at resonance frequency when omega is equal to omega 0 or f is equal to f 0 right.

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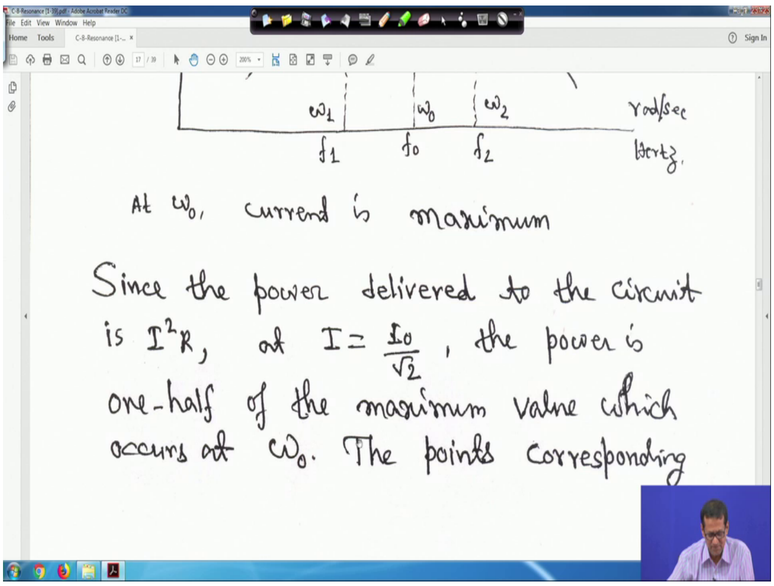

So, since the power delivered to the circuit is I square R therefore, at I is equal to we know that power I square R is the power delivered to the circuit therefore, suppose at I is equal to I 0 by root 2 say the power is 1 half of the maximum value which occurs at omega 0 right suppose your this one we know I square r right, now when I is equal to say I 0 by root 2 then if this is the power loss P, P is equal to I is equal to I 0 by root 2 then it will be I 0 square R by 2 that is it will be half P by 2 right. So, let me clear it. So, this is I 0 this is your I 0 and this is your I 0 by root 2 right I will come to this so.

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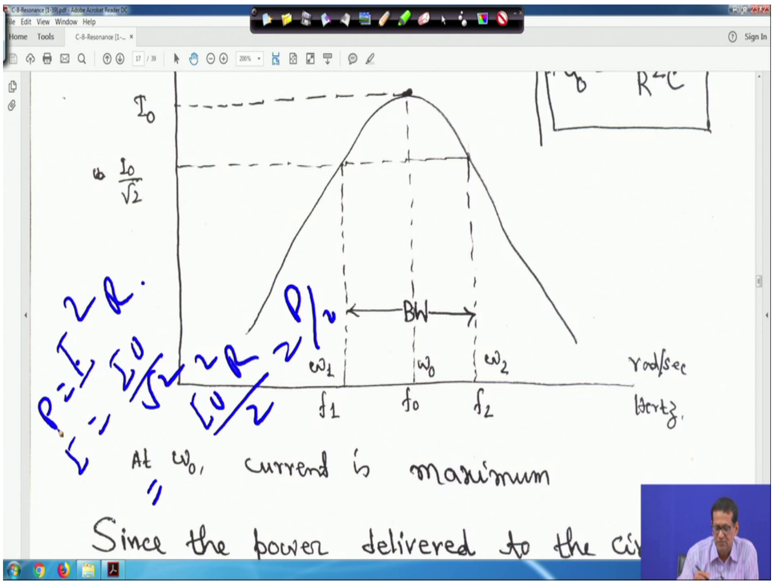

So, power delivered to the circuit the power is 1 half of the maximum value which occurs at omega 0 right therefore,; that means, whatever resonance at resonance power is I 0 say R I I square R is equal to if I is equal to I 0 then I 0 square R, but at I is equal to I 0 by root 2 it will be half right. So, the points corresponding to omega 1 and omega called the half power points.

So, this is actually this 1 this 1 this is your I 0 by root 2 this is this is called half power point because I power loss is I 0 square R, but if it become I 0 by root 2 it will be I 0 square R by 2. So, t by 2 so, this is called half power point. So, this is at frequency Z this is your omega is equal to say omega 1 it is intersecting two point of this curve and this is your what we call omega 21 f 1 f 0 f 2 or omega 1 omega 0 omega 2.

The difference between these this one this difference between this two that is your what we call this from this two I mean this width from here to here it is called your bandwidth right. So, that is your omega 2 minus omega 1 or if it is in radian per second or if it is hertz it will be f 2 minus f 1 right and this is your resonance frequency this is called actually bandwidth time and this omega, when it your omega is equal to omega 1 means for series RLc circuit we have seen right, that your what you call that your XL and XC XC is your what we call greater than XL or RL square your what we call XC than your XL that we have seen.

So, this two point call half power point and the and this distance which we call bandwidth right, and this is if it is omega radian per second if it is frequency then it will be in hertz, so.

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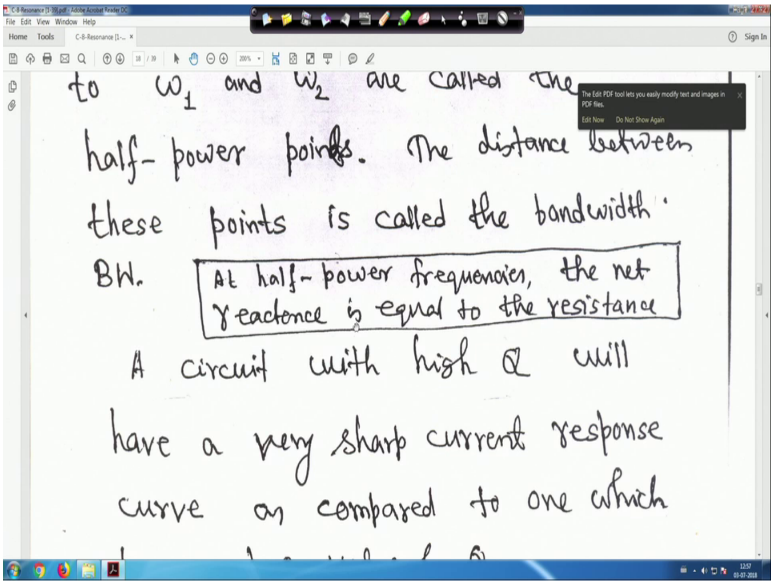

So, this is so, at half power frequency the net reactance is equal to the resistor this is written at half power frequency net resistance your what we call is equal to the resistor because here am making it for you.

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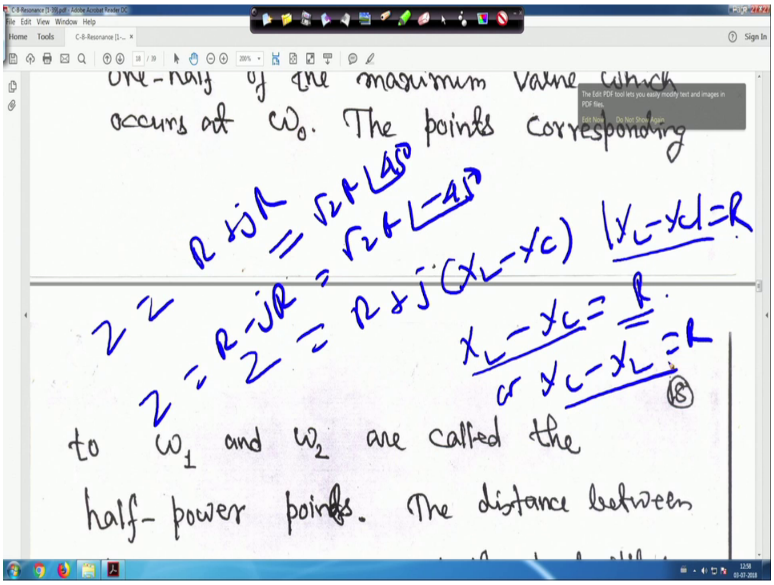

Suppose Z is equal to your R plus j for series RLC circuit XL minus XC two things can happen; if one is XL minus XC equal your what we call it because it is half power frequency root 2 has to come right. So, it will be your XL minus XC may be R or XC minus your what you call another thing will be XC minus your XL may be at two condition may happen right. So, in general if we take first condition that XL minus XC is equal to R ultimately mod XL minus mod XC is equal to actually R right.

Therefore Z is equal to one condition if you take it will be your what you call R plus jR; that means, this one will be your what we call root 2 R angle 45 degree. And, if Z is equal to R minus jR it will be root 2 R angle minus 45 degree either of these because, mod XL minus XC is equal to r this is either one condition this is another condition right.

So, let me clear it therefore, your therefore, at half power frequencies the net reactance is equal to the resistance right. So; that means, a circuit with high Q will have a very sharp current response and response curve that is compared to one which has a low value of Q. So, we this your what you call several admittance verses angle other graphs are shown frequency right from that you can easily you can easily justify this one.

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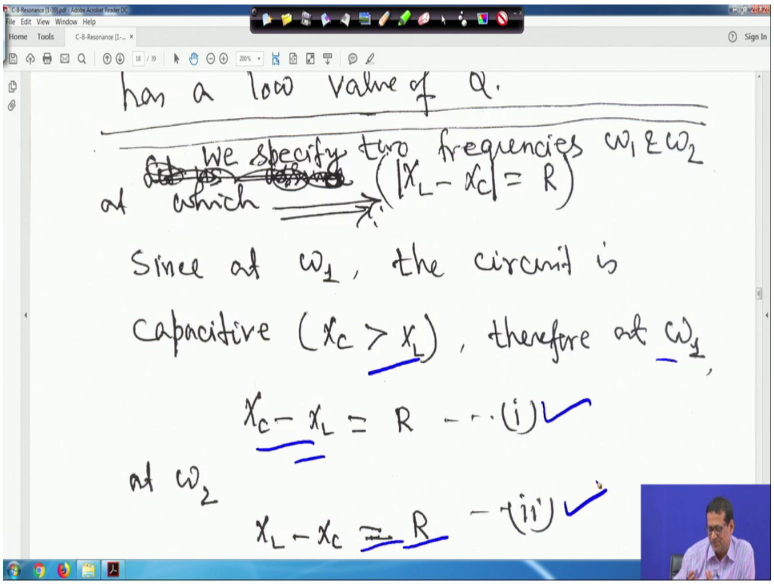

Similarly, that I told you it will be mod XL minus XC is equal to r since at omega 1 the circuit is I told you have to very very beginning of this topic, again I am not going to the figure when your omega is equal to your what we call at omega 1 which is on the left hand side right of that curve. So, at that time XC greater than XL right XC greater than XL. So, XC your greater than XL therefore, at omega 1 XC minus XL is equal to R right.

And similarly at omega 2 when is going to the other side XC less than XL or XL greater than XC. So, in that case XL minus XC is equal to RC this is equation 1 this is equation 2. See previously I have explained this right whenever you I suggest whenever you go through a video lecture first draw those diagram and after that you just go through these that video lecture then it will be easy for you to make it on the notebook. So, if these two conditions hold therefore, the corresponding impedance I told you.

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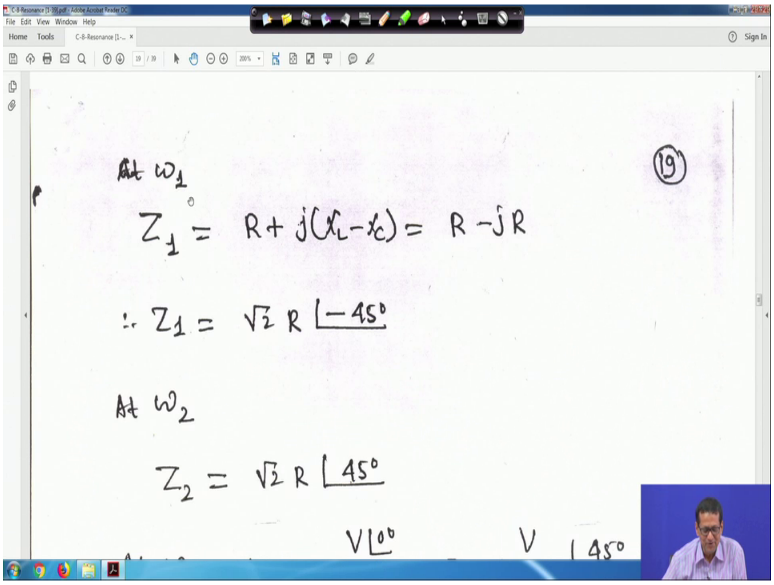

One will be at omega 1 Z 1 will be R plus j XL minus XC that will be R minus jR that will be Z 1 will be root 2 R angle minus 45 degree because, on root over R square plus R square and angle will be tan inverse minus 1 because it will be tan inverse your minus R by R. So, it will be minus 45 degree.

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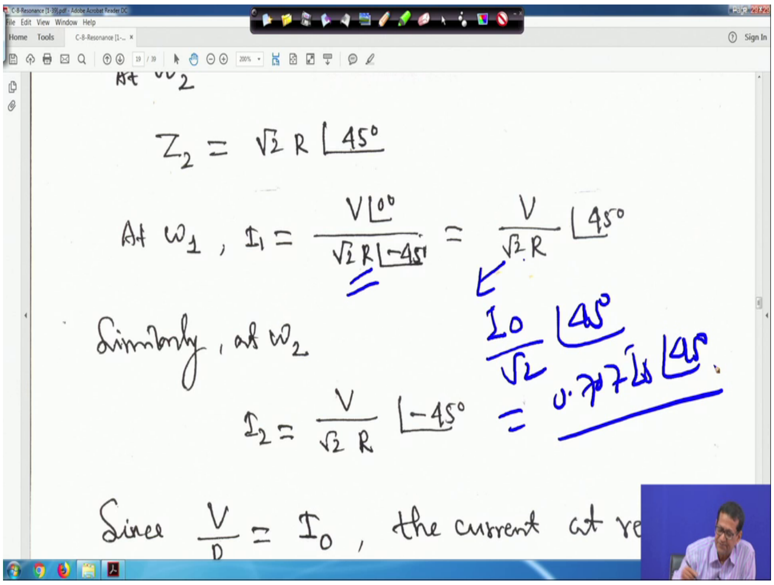

Similarly, at omega 2 Z 2 will be root over 2 root 2 R and will be 45 degree right therefore, at omega 1 I 1 will be that V angle 0; this is the voltage reference right divided by your impedance root 2 R angle minus 45 degree that will become V upon root 2 R and angle 45 degree right.

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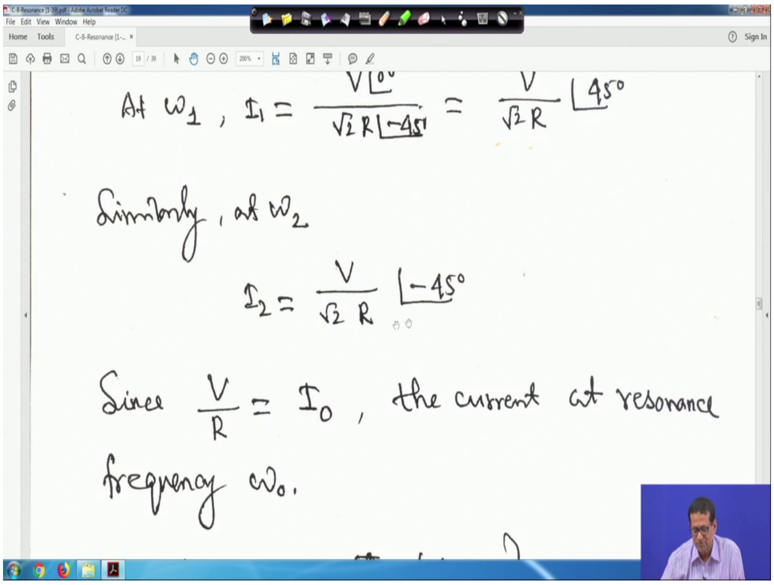

Similarly, at omega 2 your I 2 is equal to V upon root 2 R angle minus 45 degree. Since V by R is equal to I 0 because at resonance XL minus XC is equal to 0 and for which current is maximum if XL minus XC is 0. So, Z will be simply R therefore, I 0 the maximum current right. So, at resonance that is V upon R. So, the current at resonance will be your frequency at omega 0 therefore, we can write I 1 is equal to your 1 upon root 2 is there. So, and I mean this one 1 upon your this term, if you can write it will be basically this term will look at this term if you see it will basically V by R equal R upon I 0 divided by root 2 angle 45 degree that is your 0.707 I 0 angle 45 degree right.

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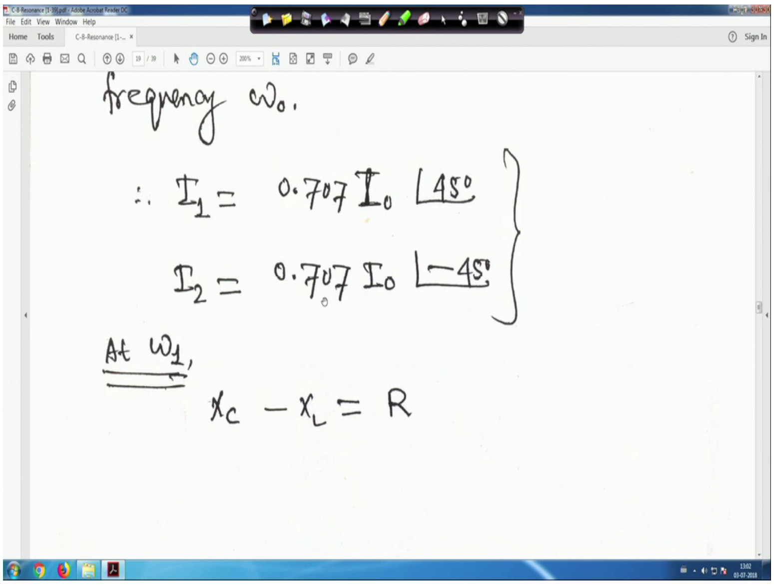

So, this one therefore, I 1 is equal to 0.707 angle I 0 angle 45 degree similarly I 2 is equal I 0.707 angle minus 45 degree, but at omega 1 at omega is equal to omega 1 XC minus XL is equal to R right.

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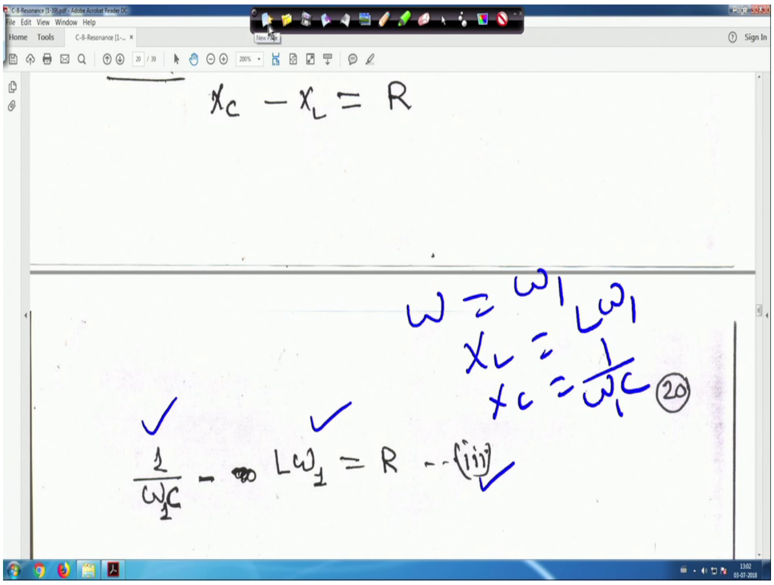

Therefore, that means, whenever that is at omega is equal to omega 1 right. So, omega is equal to omega 1.

So, in that case your XL will be L omega 1 and XC will be 1 upon omega 1 C. So, here you put this, here you put this is say equation 3 right. So, let me clear it. So, similarly at omega is equal to omega 2 similarly. So, XL will be l omega 2 and XC will be 1 upon omega 2 see this is actually whenever writing at omega 2 means it is omega is equal to omega 2.

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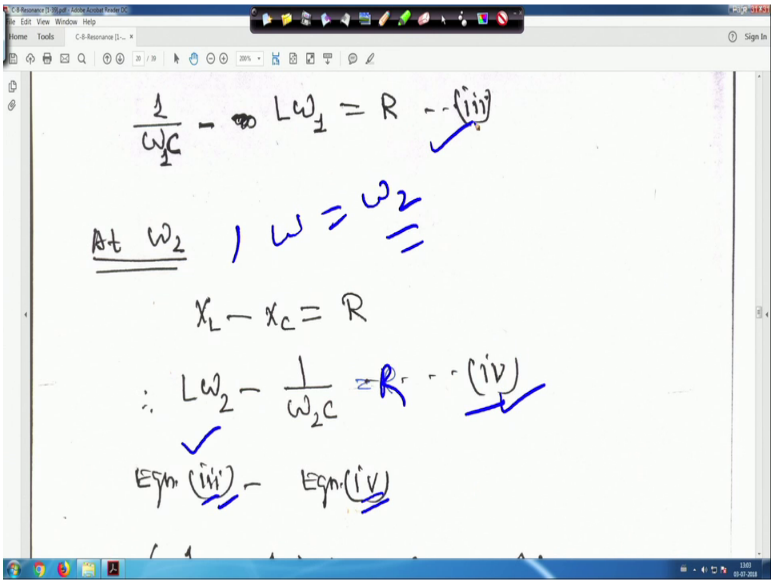

So, this is equation 4 and this is equal to R actually right. So, now what you do subtract equation 4 from equation 3, I mean this equation you subtract from this equation if you do.

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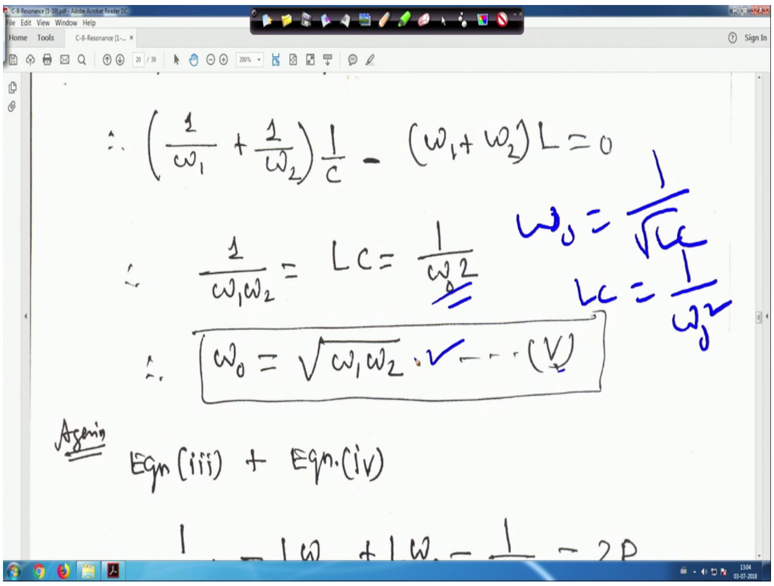

So, if you do so, you will get 1 upon your 1 upon omega 1 plus 1 upon omega 2 your by C minus your what you call omega 1 plus omega 2 into L is equal to 0 or simply you will get 1 upon omega 1 omega 2 is equal to LC is equal to 1 upon omega 0 square. Because, your because omega 0 is equal to resonance frequency is equal to 1 upon root over LC.

If you take the square of it so, LC will be is equal to 1 upon omega 0 square. So, that is what we are writing here therefore, omega 0 will be is equal to root over omega 1 into omega 2. These are good your relationship and easy to remember that omega 1 is this side another side. So, omega 2 minus omega 1 is the bandwidth and omega and omega 0 will be what your we call root over omega 1 omega 2 very geometric meaning right.

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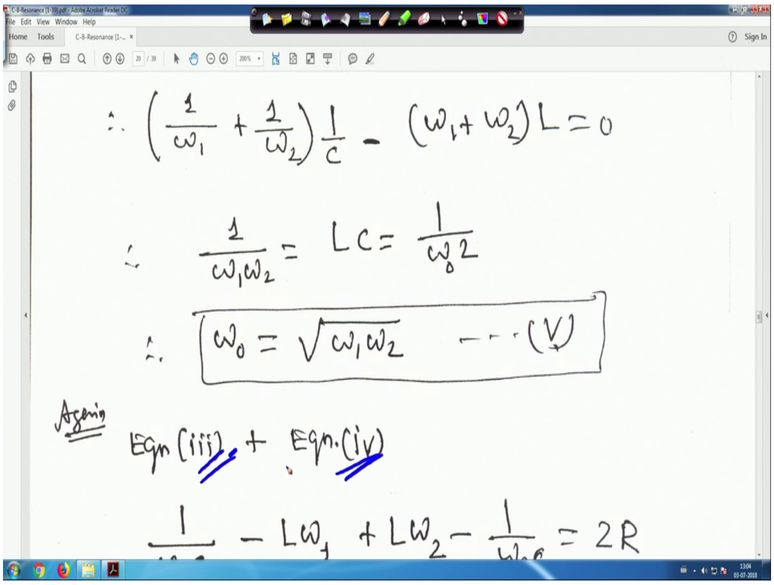

Similarly, you add equation 3, equation 3 and equation 4 already equation 3 equation 4 we have got it. So, add these two equations if you do.

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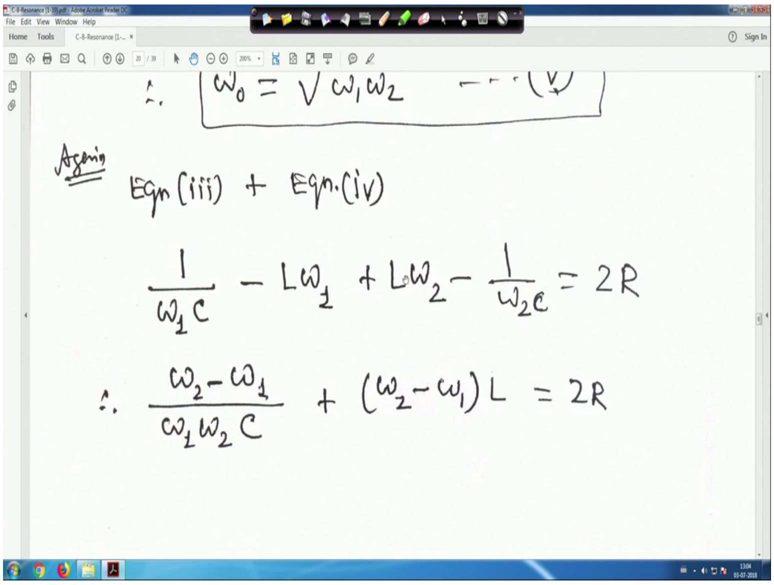

So, if you do so and simplify you add and simplify you will get omega 2 minus omega 1 upon omega 1 omega 2 C plus omega 2 minus omega 1 L is equal to 2 R right.

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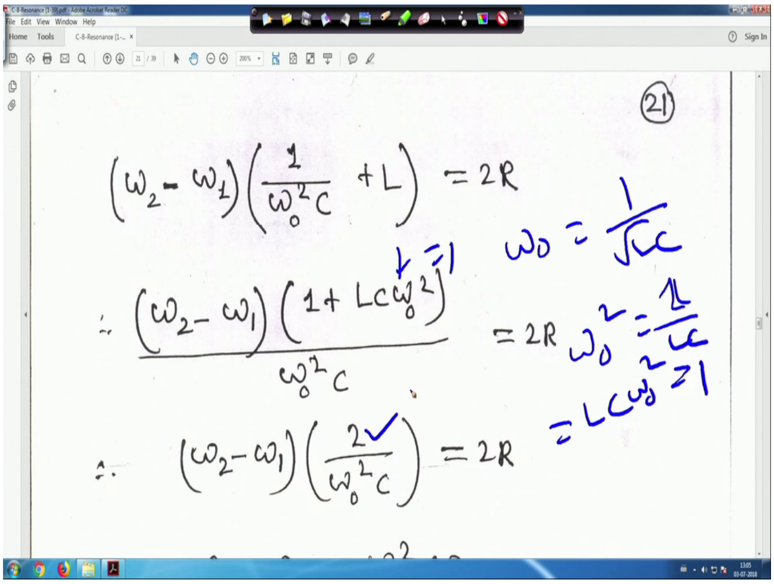

Therefore your omega 2 upon simplification you take omega minus omega 1 common. So, you will get omega 2 minus omega 1 your 1 plus LC omega 0 square divided by your omega 0 square C. Now, LC omega 0 square is equal to 1 because omega 0 is equal to 1 upon root over LC you know. Now, therefore, square it omega 0 square is equal to 1 upon LC therefore, cross multiplication omega LC omega 0 square is equal to 1. So, this term you put is equal to 1 such that 1 plus 1 you are getting 2 right. So, let me clear it.

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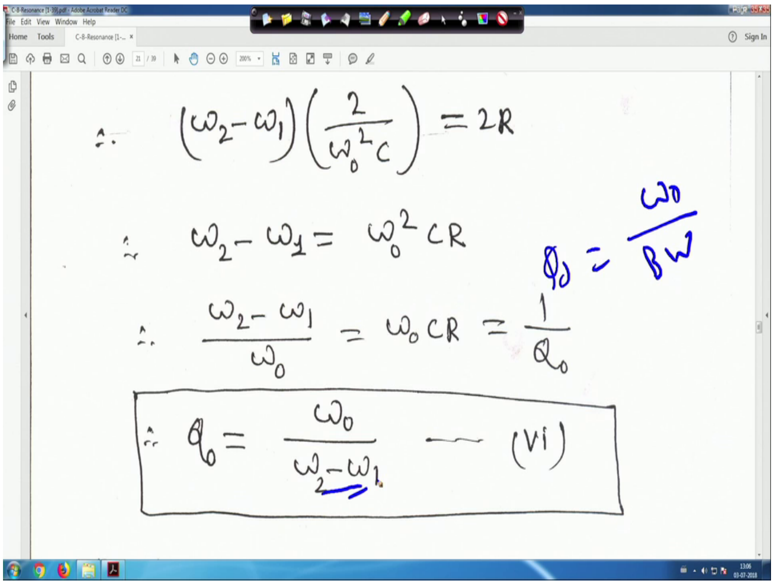

So, if you put that omega 2 minus omega 1 is equal to 2 2 both side will be cancelled it will be omega 0 square CR right or that it is omega 0 so, divide by omega 0. So, omega 2 minus omega 1 upon omega 0 is equal to omega 0 CR this we have seen is equal to Q 0 we have seen one upon omega 0 CR. So, it is 1 upon Q 0 or Q 0 is equal to W 0 another expression of Q 0 is equal to W 0 divided by W 2 minus W 1 right. So, it is basically W 0 by BW bandwidth. So, this is equation 6 right.

So, this are your what you call these are the things certain things it is very simple thing only thing is that that little bit of understanding and mathematical your what you call mathematical exercise there, but these are the very simple thing right. So; that means, we get this equation that omega 2 minus omega 0 this one or this thing what you call this Q 0, your Q 0 also can be written as omega 0 by BW that is the bandwidth and BW is equal to omega 2 minus omega 1 right.

Thank you very much we will be back again.