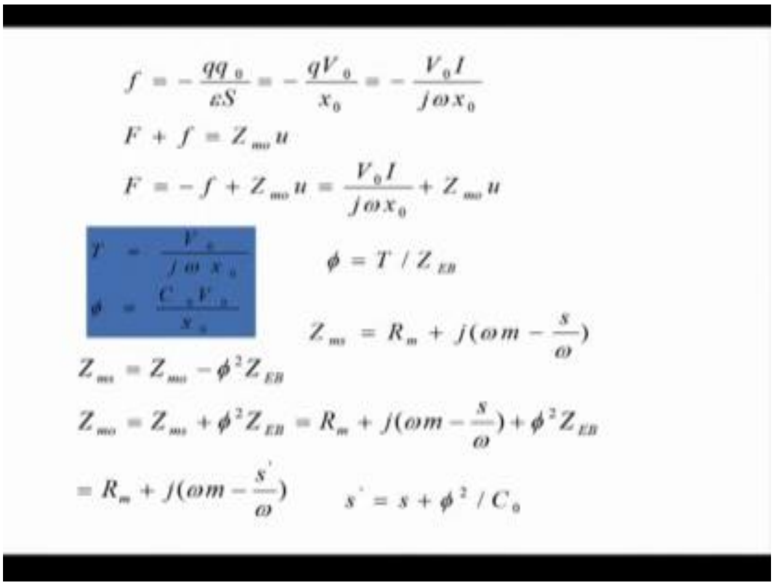
Audio System Engineering
Prof. Shyamal Kumar Das Mandal
Department of Electronics and Communication Engineering
Indian Institute of Technology, Kharagpur

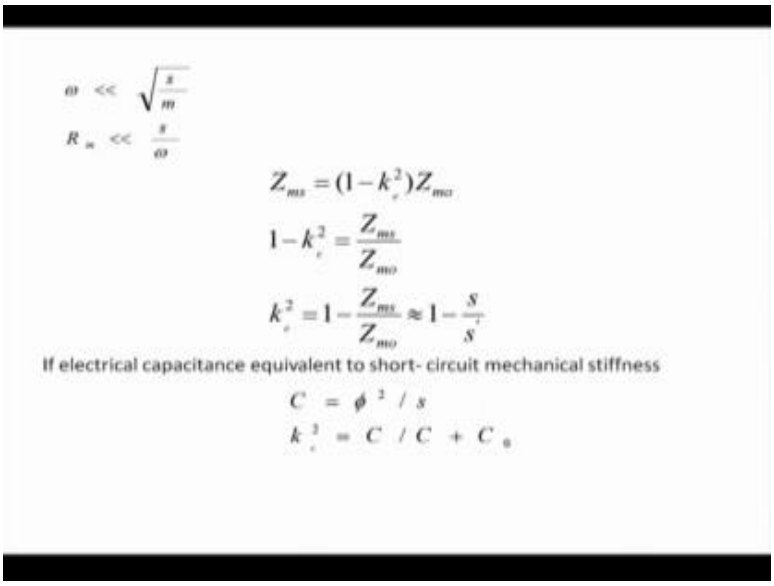
Lecture - 21
Transduction – III

(Refer Slide Time: 00:27)



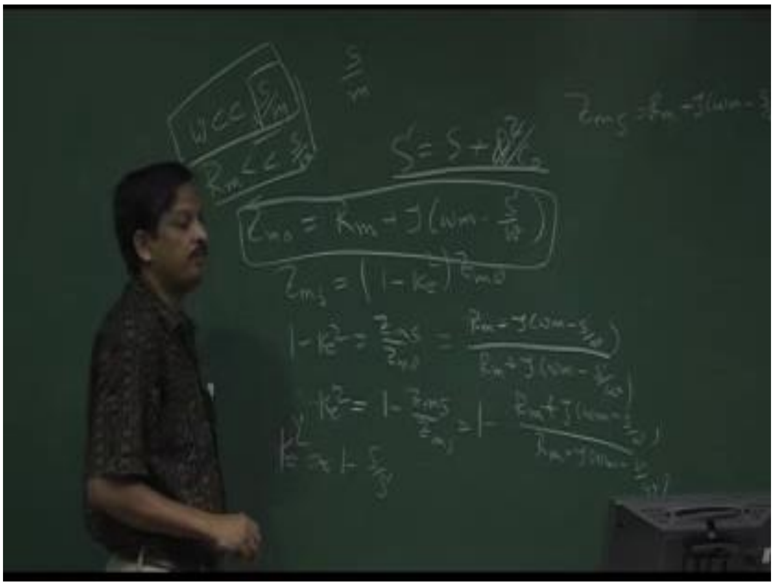
So, last class, we have derived that for the reciprocal acoustic electrostatic transducer that S dash is equal to S plus phi square by c 0; and we said that Z mo is equal to R m plus j omega m minus S dash by omega and S dash is equal to this one.

(Refer Slide Time: 01:06)



Now if I consider for electrostatic transducer if I said that this omega is much, much less than this omega is much less than s by m what is the meaning that meaning is that operating the frequency of operation just a minute. The frequency of operation root over of s by m. So, I said that if I operate the electrostatic transducer below the, this is the s by m nothing, s is the stiffness of the diaphragm m is the mass of the diaphragm. So, if it is said that the omega is much below the root over of s by m that means, the operating frequency is much, much below the resonance frequency.

(Refer Slide Time: 02:01)



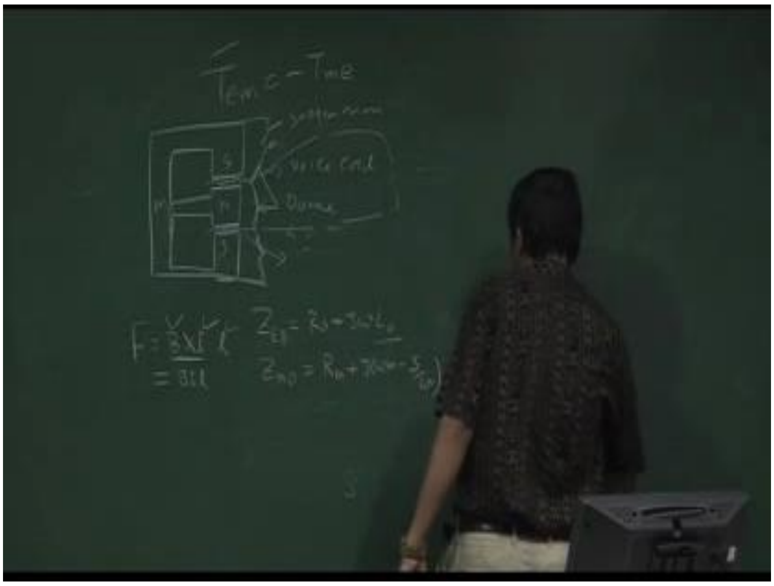
And that mechanical resistance R m is much, much less than the s by omega that means, that I should not housing the diaphragm such a mechanical resistant then it does not vibrate so that means when R m should very low and the operating frequency should be much, much less than the resonance frequency of the diaphragm. So, if I consider these two limitations then this will become; so, then what is Z m s, Z m s is nothing but a 1 minus k c square into Z m o. So, I can say 1 minus k c square is equal to Z m s by Z m o I know what is Z m s and what is Z m o. If I put those two values, what is Z m o, I know that Z m o we had Z m o is nothing but this one is Z m o.

Now, what is Z m s, Z m s is nothing but a R m plus J omega m minus s by omega. If I put the value of Z m s and so I put the value of Z m s is nothing but a R m plus J omega m minus s by omega divided by Z m o. What is Z m o? R m plus j omega m minus s dash by omega; if I simplify that two things with the condition that this is the condition than 1 minus k c square or I can say the k c square will be then k c square will become 1 minus Z m s by Z m o, which will become 1 minus R m plus j omega m minus s by omega divided by R m plus j omega m minus s dash by omega. Within these two limitations k c square will approximately come 1 minus s by s dash.

So, if the electrical capacitance is equivalent to short circuit mechanical stiffness, we have studied that that s and c is the relationship the c is equal to 1 by s or s is equal to 1 by c. So, if the electrical capacitance is equivalent to short circuit mechanical stiffness then I can say the c is nothing but a phi square by s, phi square is the term transformation coefficient to convert the electrical side. See here is we have been studied that equivalence electrical capacitance is equivalence to 1 by s. Now, if the electrical to mechanical transformation coefficient is phi square, so it is c is nothing but a phi square s. If c is nothing but a phi square s, then I can write the k c square is nothing but a c by c plus c 0, because s dash is s plus phi square by c 0 and s is nothing but a 1 by c. So, I can write c by c plus c 0.

So, coupling coefficient k c square is nothing but c by 1 plus c plus c 0. This means this is the ratio what is k c square means, this is the ratio of the stored mechanical energy to the total energy, the ratio between of the stored mechanical energy to the total energy. So, this is the basic derived principle for reciprocal transducer or electrostatic transducer.

(Refer Slide Time: 06:38)



Now, we go for another kind of transducer, which is anti reciprocal. What is the anti reciprocal transducer where T m e and T m e, T e m electrical to mechanical and is minus is equal to mechanical to electrical. So, antireciprocal transducer, example is moving coil transducer. Let us I draw a moving coil transducer. If I draw, it will be nothing but it a magnetic field. So, let us a magnetic field sorry come here then I can draw it here and here then I can draw here, here and here. So, this is the magnetic. On the magnet, I housing a moving coil; the coil is connected to the coil is covered by dome and I can said this is the diaphragm. So, this coil is called voice coil, this is nothing but a voice coil and this is nothing but a suspension. And this is N, this is S, this is S, and this is a magnet. And this is called dust cover or dome, dome and diaphragm. So, there is a suspension diaphragm is suspended diaphragm and dome.

So, if you see in any normal moving coil loud speaker, I will show you in the next class that normal moving coil loud speaker. So, there is a magnet; on the magnet, there is a coil is suspended and the coil is connected to the diaphragm if you see. And if I apply a voltage on the coil, if I apply alternatively voltage on the coil then the coil will move or if I move the coil a current will be induced. So, both ways it is this transaction is possible. So, what is the basic principle, the basic principle is that, first of all what is the coil electrical impedance, why it is called the electrical coil if I not allow the movement of the diaphragm what I said the mechanically I am not allowing the movement of the diaphragm that means, diaphragm is blocked. So, then the electrical impedance of the coil Z E B blocked electrical impedance is nothing but a R 0 plus J omega L 0; R 0 is the resistance of the coil and L 0 is the inductance of the coil.

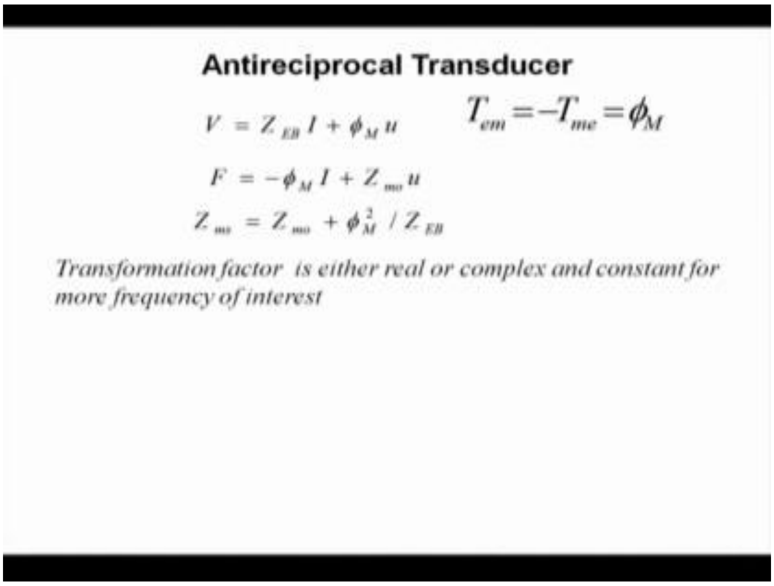
So, if I not allow the movement of the diaphragm. So, I pick the movement of the diaphragm then that means, I block the diaphragm not allowed to move it, and then block electrical impedance is nothing but a R 0 plus j omega L 0. Now, if I say that I allow I current on the coil, if I pass I current on the coil, then what will happen depending on the magnetic field, so there is magnetic field, if the current passes through the coil a force will be induce. So, that force is nothing but a F is equal to B cross I into l, where I is the current, B is the magnetic field strength and l is the length of the coil. Now, if I b cross I is the vector. So, let us I take the positive reaction only then I write B I l is the force.

So, if I apply a I current then these force will be acting on the diaphragm, because the coil attached to the diaphragm. So, this force will be acting on the diaphragm then if it is there then what is the mechanical impedance. If I say mechanical impedance how do I find out mechanical impedance from the diaphragm only? So, if I open the electrical circuits that means, I am not disturb that mechanical system with an applied electrical voltage then Z m o mechanical open circuit, mechanical Impedance is nothing but a R m plus J omega m minus S by omega. So, it is nothing but a diaphragm nothing but a spring mass system; it is suspended with the mechanical resistance R m and the mass of the diaphragm is m, and stiffness of the diaphragm is s. So, it is nothing but a Z m o R m plus j omega m minus S by omega. So, these two things I got and I got work, if I apply a I current now then I got a force acting force F is nothing but a B l I.

Now, if you see, if I apply I current, diaphragm start movement; if I want to stop that movement then I have to apply a another force lets the force inducting on the this force acting on the force the magnetic due to the I current that force want to move the diaphragm in this direction. So, the direction of the force is this direction. Now, if I want to do not allow the movement of the diaphragm then equal amount of the force in reverse direction to hold the diaphragm. So, I can say the total electrical voltage or total force acting on the diaphragm in equilibrium condition is nothing but a minus B l I plus Z m o into u. If the particle velocity, so to oppose the electrical force I require these force, or I can say the resultant force is nothing but I require this force and lets u is the particle velocity of the diaphragm then it is nothing but a minus B l I into Z m o into u. So, this is the one canonical equation of antireciprocal transduction.

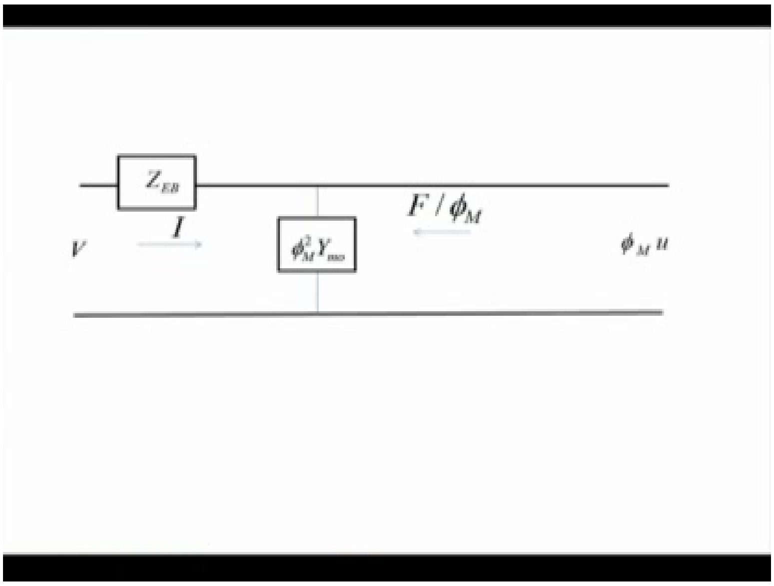
Now I want to derive that reverse string. Reverse string means I apply a force from the diaphragm, the motion will be there then the coil will moved. If coil moved in a magnetic field then voltage will be induced from the coil. So, what is the voltage will be induced. So, I can say that if the motion is u then the induced voltage will be B l u velocity of the diaphragm is u, and then the induced voltage on the coil will be B l u. We will oppose the electrical voltage. So, I can write v is equal to B l u plus Z E B into I. So, this is the canonical equation 2. So, force minus B l I plus Z m o into u voltage B l u plus Z E B into I, which is the canonical equation of the antireciprocal transducer.

(Refer Slide Time: 15:34)



What is there canonical equation of the antireciprocal transducer, if you see the slides; this is nothing but a Z E B into I plus B l u. So, I can write phi m is nothing but a B l. If you see this equation, so Z E B into I plus phi m here phi m is nothing but a b l u and here it is minus b l u. So, canonically equation supports. So, phi m is nothing but a b into l, phi m nothing but b into l, which is real and constant. For the magnetic B is the, once the magnet is fixed I am not changing the magnet, so B is fixed. Once I moving the putting the coil will be in the fixed length. So, I cannot change the l after that. So, B and l product of B and l is a real and constant. Now, this is the phi m.

(Refer Slide Time: 16:34)

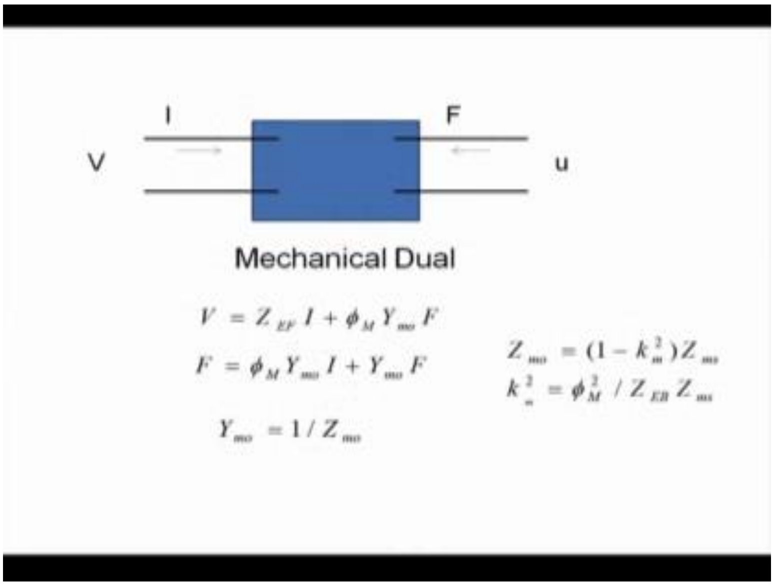


So, now, can I say what should be the equivalence circuits if this is the equation? So, what should the equivalence circuits of this transducer, equivalence electrical circuits of this transducer. So, I have to draw it. So, what is there I said I apply a V voltage here. Now, what is Z E B is nothing but a R 0 plus J omega L 0, so R and L in series. Then anti reciprocal transducer equivalence circuits, phi square if you see the slides Z E B R 0 and L 0 in series then I require a phi square Y m o and then this is nothing but a phi m u and this is nothing but F by phi m.

So, what is phi square Y m o, phi square Y m o is nothing but a phi square by Z m o admittance becomes if it is impedance there is Y m o is nothing but a 1 by Z m o. So, I can say that in case of a Z m o, Z m o is nothing but R m plus J omega m minus S by omega. So, phi square y m o can be thought as a resistance, capacitance and inductance spring mass system. If you solve this equation, this will come let us this is R m, this is C m, this is L m. Then R m will be becomes phi square m divided by this R plus of capital m write capital M because R M I have written already L capital. So, R capital M is nothing but a phi square by this R m; and L M capital m will be phi m square by s, in admittance if it is capacitance, then it is becomes inductance. So, L M since s is equivalent to capacitance then here since it is admittance y m o, it is becomes capacitance. So, phi square L M is nothing but a phi m square by s. And C m will be m by mass by phi m square this is the equivalent circuits of the antireciprocal transducer.

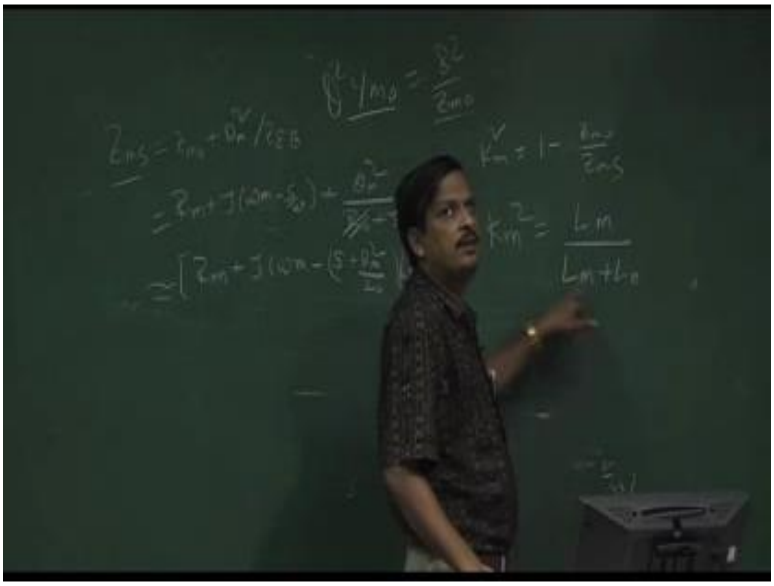
So, how it is work if I apply a electrical voltage then coil will be in motion; if I apply a pressure in diaphragm, coil will be the motion and it induce a voltage. So, what I have to find out I have to find out K c or here instead of antireciprocal transducer in K m. So, I have to find out what should be the K m. Let us find out now Z m o I know, but I do not know Z m s. Z m o means open circuit mechanical impedance I know, what is the closed circuit or short, if I apply a current that means, I connect the electrical circuits then what should be the mechanical impedance.

(Refer Slide Time: 21:08)



So, Z m s is nothing but a Z m o as per these slides. If you see these slides Z m s is nothing but a Z m o plus phi m square divided by Z E B. What is Z m o? R m plus j omega m minus s by omega; what is Z E B? Phi m square divided by Z E B is nothing but a R 0 plus J omega L 0. If I simplify this things what I will get I will get Z m s is equal to I can say then I have to find out, so Z m s will be R m plus J omega m minus s plus phi m square divided by L 0 whole divided by omega, this will come. If I consider if R 0 is much lower than omega L 0; if R o is much lower than omega L 0 then I can remove this R 0. So, I can say it is nothing but upside J will be multiplied. So, it is nothing but a s plus phi m square by L 0 divided by omega into this.

(Refer Slide Time: 21:10)



Now, if I want to find out K m, what is K m? So, I can say K m is nothing but a 1 minus Z m o, K m square is nothing but a 1 minus Z m o divided by Z m s Z m o divided by Z m s. So, K m square will become same as reciprocal transducer is nothing but L M by L M plus L 0. Like see L M by L M plus l 0. Same case I can say this is nothing but a ratio of the mechanical energy divided by the total energy. So, this is the theory for antireciprocal transducer.

Next class, I will go for the transducer design.