Fundamentals of Acoustics
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Lecture – 44
Noise Reduction by Mass Attenuation

Hello, welcome to Fundamentals of Acoustics. Today is the second day on the eight week of this course. What we will do today is continuation of our discussion which we were having yesterday, we had started discussing how using a wall which has a non zero mass and which is free to move, can be used to reduce the sound pressure level on the transmitted side.

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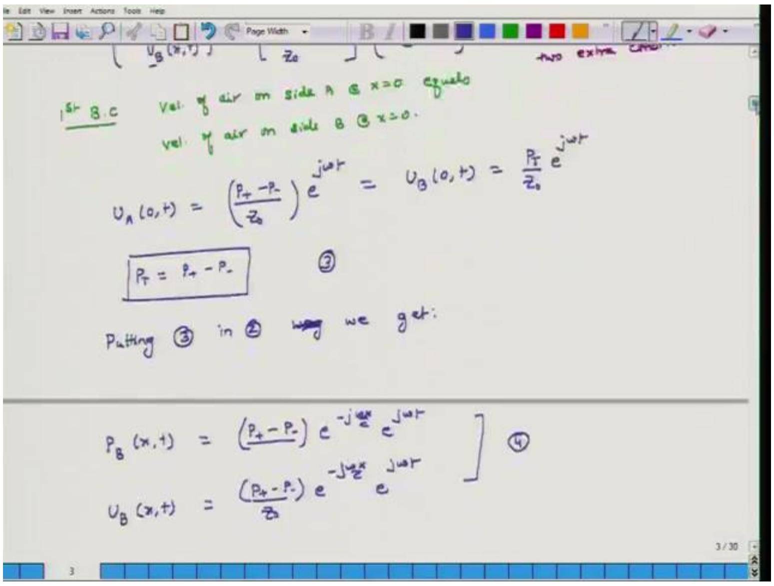

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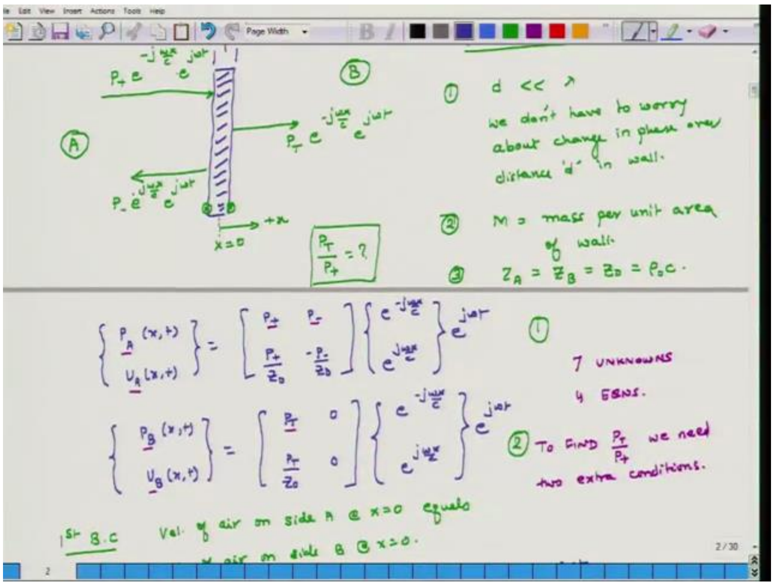

So, that is the mathematics which we are trying to develop and in that process yesterday what we had accomplished was we had developed a relation for P B and U B in terms of P plus and P minus, where P B and U B are complex pressures, for pressure and velocity on the transmitted side and P plus and P minus are magnitudes of complex incident pressure and complex reflected pressure, so that expression has been shown here and it is done by that is four.

Now, so once we have done this we have eliminated P T and to get to about ratio of P plus P T and P plus we have to apply one more condition. So, and once we applied one additional condition then we will be able to eliminate p negative also and we will be able to get the relation between P plus and P T. So, that is what we planned to do in today's lecture.

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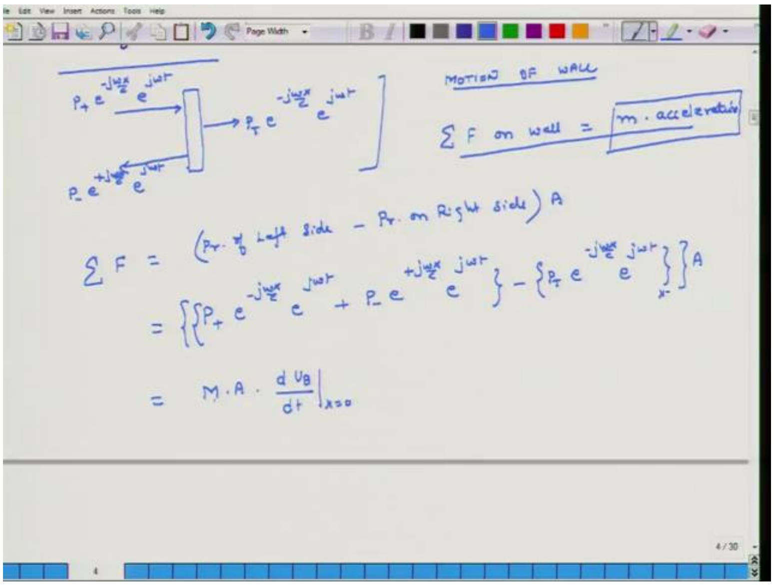

One condition is what we have already applied, but then there is another condition and the condition is that this is the wall it is being incident, it is being struck. So, the incident complex pressure is P plus, e minus j omega x over c, e j omega t reflected pressure wave in complex terms is P minus e minus j omega x over c, e j omega t and transmitted pressure is P T; e minus j omega x over c, e j omega t and this term should be plus.

Now when this wall has been acted by pressure on in the transmitted side and pressure on the incident side because if the pressures are different then this wall will move because it is free to move, so the motion of the wall how do we figure out, what is the nature of this motion it is equal to total force on the wall and that is equal to mass of the wall times acceleration.

So, this is the equation we will develop total force on the wall is sigma f and that equals pressure on left side, minus pressure on right side times area. So, the pressure on left side is going to push the wall in the positive x direction, pressure on right side is going to push the wall on the negative x direction. So, that is why I have a negative thing and times area of the wall.

So, what is pressure on the left side it is equal to incident pressure plus reflected pressure, so it is P plus e minus j omega x over c e j omega t. So, this is on the left side incident component plus P minus, e minus, e j omega x over c, e j omega t. So, this is on the left side of the wall minus P T, e minus j omega x over c, e j omega t times a. So, this is the sum of forces and so this is the complex pressure. So, when I add this up it will be complex force and this equals. So, this is sum of forces and then what is the right side. So, right side of this equation is mass times acceleration, so this has to equal mass of the wall and what is mass of the wall, it is m times a because m represents mass per unit area.

So, there is one more bracket needed and then I multiply it by a. So, on the right side it is mass times acceleration, so mass is m times a here; a is the area of the wall, times d U B over dt and this has to be evaluated at x is equal to 0 and also right side also has to be evaluated, x is equal to 0.

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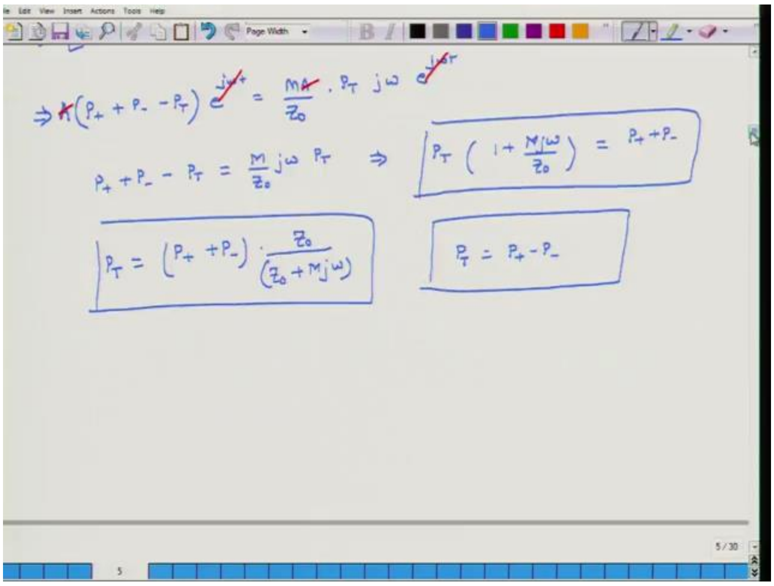

So what do I get; I get when I put x is equal to 0 in this entire relation I get P plus plus, P minus minus P T, e to the power of j omega t times a and that equals mass times mass per unit area times area and what is U B; U B you use this relation U B is P T divided by Z naught in to e to the power of minus j omega x times e j omega t. So, it is e to the power of minus j omega x over c, e j omega t, but then I have to differentiate it and for differentiating I did not leave a lot of space. So, I am going to re write it, so MA d over d t this entire thing and this also I have to evaluate it, x is equal to 0.

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And there is of course, P T, so what I get is; so, P plus plus, P minus minus P T, e j omega t equals MA over Z naught times P T and when I differentiate the term in the bracket only this thing gets effected. So, I get j omega; e j omega t and this term becomes 1 when x is equal to 0, so I am just omitting that out.

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And then of course, here is an A.

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I am sorry, so there is also an A here, so A and A cancel out, so the e j omega t. So, I get P plus plus, P minus minus P T is equal to m over Z naught, j omega P T this gives me now. So, P T into 1 plus m j omega over Z naught is equal to P plus plus P minus. So, this is another expression or I can say that P T equals P plus plus, P minus times Z naught divided by Z naught plus m j omega.

So, this is another expression for P T, so we had developed one expression for P T which was from 3 P T equals P plus minus P minus. So, we will rewrite that equation again, so the other expression for P T was P T equals P plus minus P minus.

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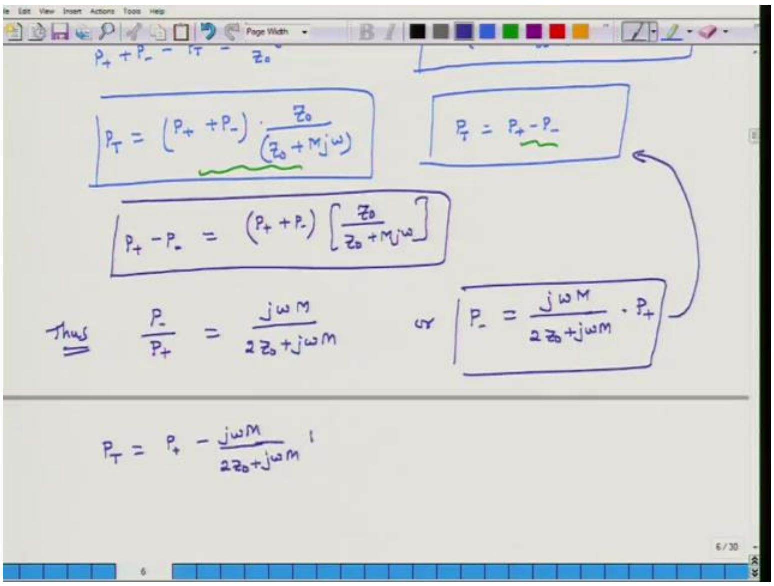

So, if I equate these two, so if I equate the rhs of both of these equations then what do I get, I get P plus minus P minus is equal to P plus plus P minus divided by Z naught divided by Z naught plus m j omega.

So, now this equation has only P minus and P plus, so if I do the math for this equation I can get the ratio of P minus over P plus. So, if I do the math what I get is P minus over P plus is equal to j omega m divided by 2 Z naught plus j omega m, so this is what we get, P minus over P plus is this thing or P minus equals j omega m divided by 2 Z naught plus j omega m times P plus, but our goal is to find the ratio of P T and P plus. So, what I do is I put this back in this relation, so what do I get.

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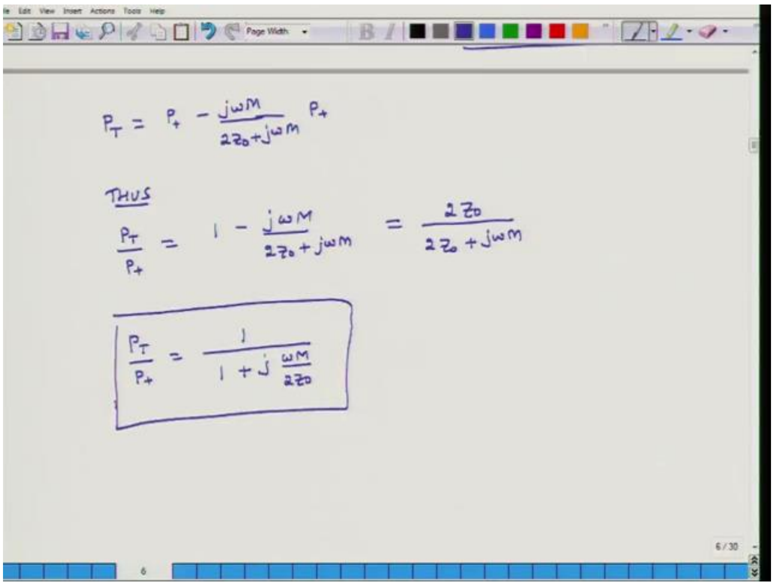

So, what I get is P T equals P plus minus P minus and P minus is j omega m divided by 2 Z naught plus j omega m times P plus. So, ultimately what I get is P T equals. So, I will write down the ratio.

So, thus P T over P plus equals 1 minus j omega m divided by 2 Z naught plus j omega m and that equals 2 Z naught divided by 2 Z naught plus j omega m or finally, we can write P T over P plus is equal to 1 divided by 1 plus j times omega m divided by 2 Z naught. So, that is my ratio, so what does this say what does says is what this equation tells us is that as omega. So, consider the fact that there is a wall with the fixed value of m and if omega is extremely low.

Suppose omega is theoretically let us say it is 0 hertz, if omega is 0 then no matter how heavy the wall is and is can be extremely heavy, but the ratio of P T and P plus will be 1 which means that if frequencies are extremely small then even heavy walls will not be able to stop sound from propagating from one side to the other side and as omega goes up this P T over p m it becomes less than 0.

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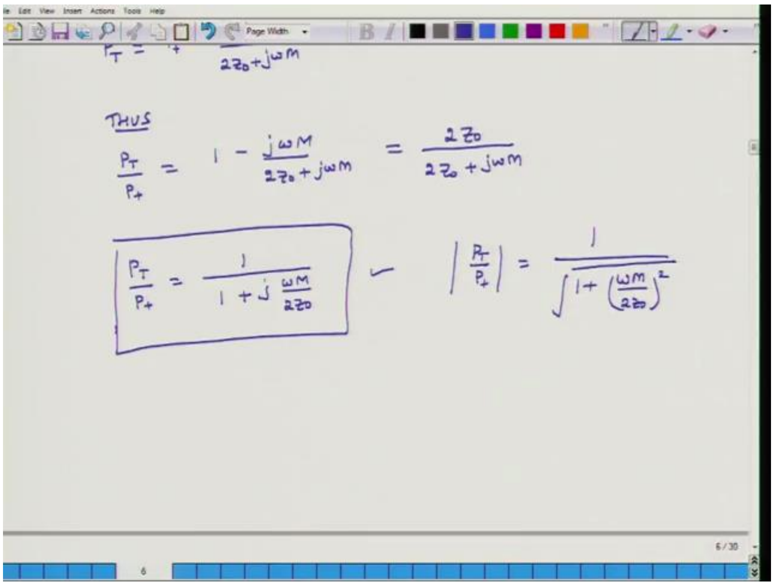

Why because the negative of P T over pm or P plus is equal to 1 over 1 plus omega m by 2 Z naught; square this thing. So as omega becomes higher, this ratio becomes less than 1 and the higher I go up in frequency, the more efficient a wall becomes in terms of stopping the sound, it becomes less efficient.

So, that is the discussion I wanted to have today. And what we will do is tomorrow is continue this discussion, and we will also develop bode plots for transmission of sound associated with this type of a situation.

Thank you and we will meet once again tomorrow. Bye.