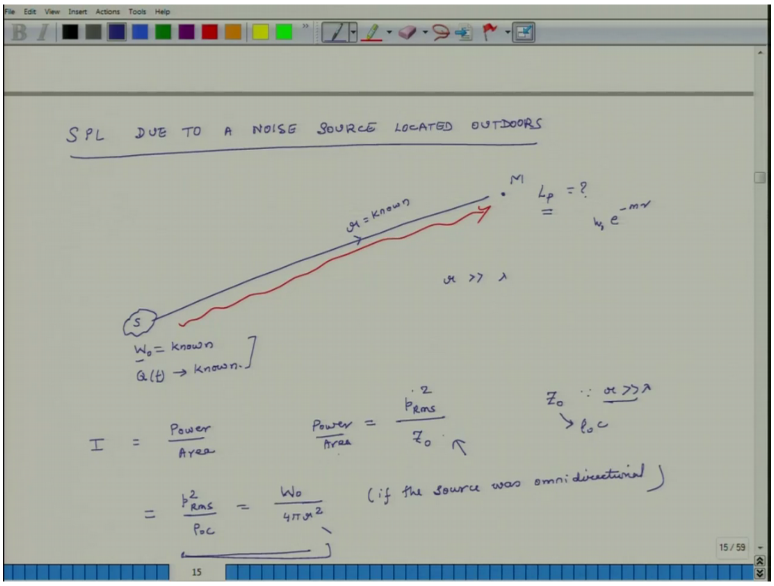
Noise Management & Its Control

Prof. Nachiketa Tiwari
Department of Mechanical Engineering
Indian Institute of Technology, Kanpur

Lecture - 41
Noise Source: Sound Pressure Level due to a Noise Source Located Outdoors

Hello, welcome to noise control and its management. Today is the fifth day of this course. And starting today we will be discussing the basic problem which we had described a couple of lectures earlier. That if there is a sound source which is nonomni-directional in nature in either outside or inside a room then what how do I figure out what is the value of sound pressure level at a distance r away from that as sensed by a microphone, so that is the question we are trying to figure out. So, we will break this problem into two parts. The first part of the problem would be when the sound source is located outside it is not inside a closed room and then for that we will solve that problem first. And then once we have solved that problem then we will go to the next problem where the sound source is located inside a closed room and that is the other problem we will try to solve.

(Refer Slide Time: 01:29)



So, sound pressure level due to a noise source located outdoors, this is what we are going to compute. Now, even here first we will make a very simplistic or simple assumption which we and it is like an idealization. And we will consider that there are no reflecting surfaces, where the sound source is located and also in the neighborhood. So, essentially you have a sound source, and it is not a point, it is some complicated job object and because it is complicated in safe shape it will not be producing spherically symmetric waves, it will be a directional source and it is in free space. So, there are no reflecting surfaces.

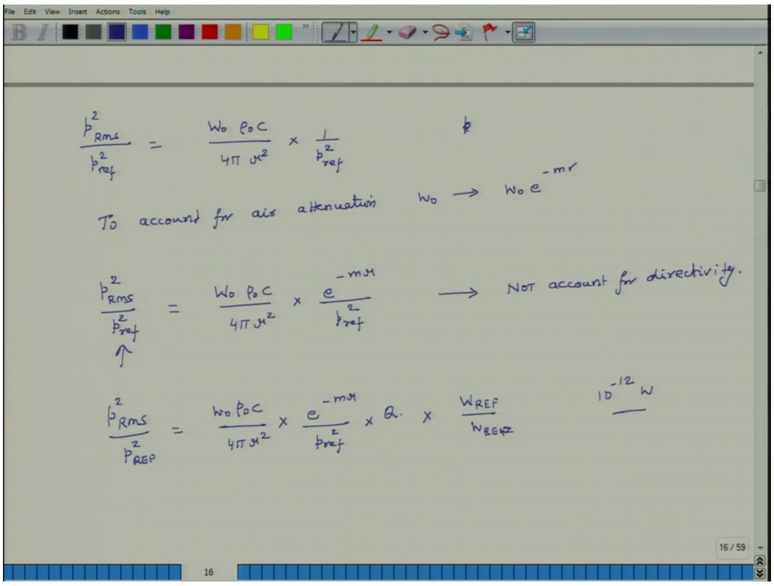
Typically you have what you have you have a football field, and you have a motor on a football field, but then when you have a football field the field acts as a reflecting surface. Here we are assuming that there are no reflecting surfaces whatsoever. So, essentially this sound source is located in infinite space infinite space, the only thing which is there around the sound source is air through which sound can travel. And we are interested in finding at a distance r away, here is our microphone. So, what is the value of sound pressure level?

So, we are interested in finding out the value of L P, we want to know what is the value of L P. The other thing is that this sound source generates W watts of energy each second it generates W joules of energy, so its power is W watts. So, again we know W and because it is an not an omni-directional source we also know, so W is known and we also know its directivity, which is a function of frequency. So, this is also known. These are the two things, which we know about it. So, this is known, this is also known, and we do not know L P. So, we will calculate L P, this is what we plan to do. And assumption is that r is very large compared to lambda; we are assuming this r is very large compared to lambda.

So, we know that intensity, what is intensity, it is the amount of power flowing through per unit area. So, intensity is equal to power per unit area. And what is power, so using analogy, electrical power is what V square divided by R, it is V square divided by R, where V is the voltage across a resistor. Similarly, acoustical power per unit area acoustical power per unit area is p square divided by impedance z naught. And why do I use z naught, I use z naught, because R is very large compared to lambda. And we have discussed earlier in one of our earlier lectures that as I am very far away from a source the waves become more and more like planar waves and the impedance of a planar wave is z naught and that equals rho naught c.

So, using the analogy from electrical world, power in electrical world is what V square divided by R; in case of acoustical world, power per unit area is p square divided by z naught. So, I acoustical intensity is what p RMS divided by rho naught c and that equals W naught. So, this is producing W naught of watts divided by area. And what is area 4 pi r square. Now, here if the source was omni-directional, if there was an omni-directional source now this particular source, which we are discussing, it is not omni-directional, but if the source was omni-directional and it produce W watts of power or watts of energy every second. Then at a distance R away from it what would be the intensity w naught divided by the surface area of the sphere which is 4 pi r square, so that is how I get this right side of the equation. And the other side of the equation I have already calculated which is p square RMS divided by rho naught c. So, right now we are just discussing omni-directional and then we will introduce directivity into it that is a simple thing.

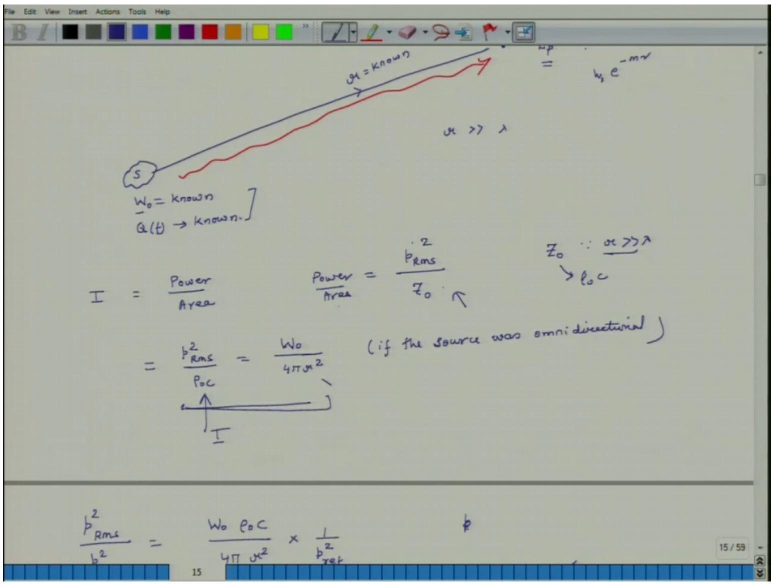
(Refer Slide Time: 08:20)



So, from this one, from this equation, I can rewrite this as p square of RMS square of RMS pressure divided by square of reference pressure is equal to what W naught rho naught c divided by 4 pi r square into 1 over p reference square. But in this case, so all this is assuming that the source is omni-directional even though the source if the source is omni-directional and as sound travels from this point to this point, and if this distance is very large, what will happen to that sound it will go down in energy. So, we know that p this. So, it will so sound source will emit W naught watts here, but what will the sphere here receive it will be W naught times e to the power of minus m r at the receiving end, which is r which is a sphere with radius r. The total amount of watts which will cross that will be w naught times e to the power of minus m r.

So, to account for air attenuation I multiply W naught by I replace W naught by W naught times e times m r. So, I will rewrite this equation as ratio of RMS pressure and reference pressure square equals W naught rho naught c by 4 pi r square times e to the power of minus m r divided by e ref square. Now, this is the equation, it has accounted for airs attenuation, but it does not account for directivity. And how did we define directivity, we said directivity is the ratio from the 0 degree direction to the what whatever direction we are interested in and we have defined. So, this is where we had defined directivity. And directivity is what it is a ratio of intensities. So, we come back to here to this. And what do we see; in this case intensity is square of RMS pressure.

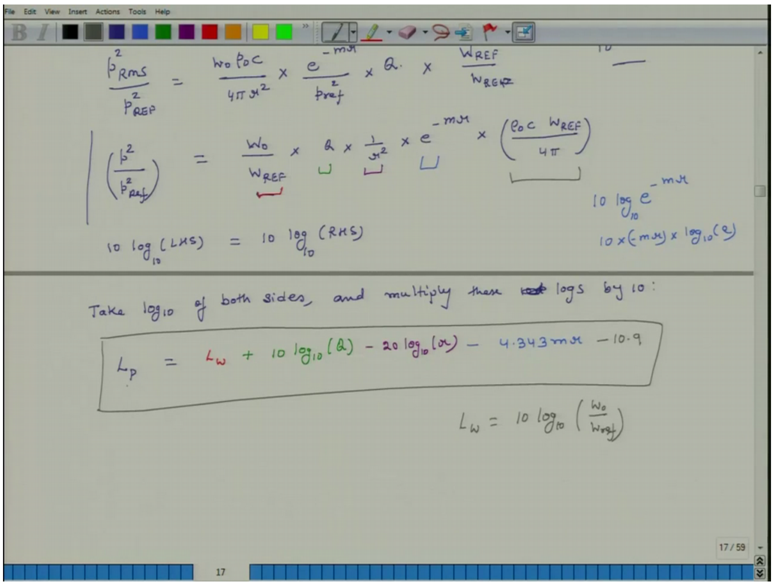
(Refer Slide Time: 11:38)



This is intensity. So, intensity is proportional to square of RMS pressure. And what do we hear see this is the square of the ratio of square of RMS and square of reference pressure. So, I can also call this as the ratio of ratio of intensity is also. So, this is also the ratio of intensities and if the sound object is directional then the only thing I have to do is I have to multiply this by Q. If it is an omni-directional source then the value of Q is going to be 1; if it is a directional source, and I am in a direction where there is lot of sound then the value of Q will be more than 1. If it is if I am in a direction where there is very little sound coming out then Q will be less than 1 and so on and so forth. So, to account for directionality I have to just do this Q.

So, this thing accounts for directionality the last manipulation, which I do is I multiply and divide it by a same number called W ref reference power level. What is reference power level, reference power level is 10 to the power of minus 12 watts. So, I just multiply and divide it by reference power.

(Refer Slide Time: 13:39)



And what I do is I just reorganize this. So, I call it W naught by W ref times Q times 1 over R square times e to the power of minus m r times W ref rho naught c times W ref divided by 4 pi in parenthesis. So, this is p square by p square ref. So, this is an important equation. And this is an important equation. And then next step I do is I take log of 10 of both sides and also multiply these logs by 10. So, what do I do, I do 10 this is what I do I take 10 log of LHS at base 10 is equal to 10 log or RHS this is the operation I do. So, if I do the LHS what do I get 10 log of p square by p square reference it is the SPL and I designate it as L P, it is L P. What is the RHS, so first I take the log of this guy 10 log of this guy is L W, this is how we have to find it, it is the sound power level. So, sound pressure level is equal to sound power level then I take the 10 log of Q. So, I get 10 log 10 of Q.

What is Q, directivity. So, this is the impact of directivity on the sound pressure level plus I take 10 log of. So, this third term it tells us it tells us the influence of the distance.

If you are far away from the source, your sound pressure level L P will go down. If you are very close then the sound pressure level will not go down that much. And then I take 10 log of the next guy, so I get minus, so I take 10 log of e to the power of minus m r. So, 10 log of e to the power of minus m r. So, this is log to the power of base 10. So, it will be what 10 times minus m r times log 10 of e. And if you do the math, what you get is 4.343 m r, and finally, I take 10 log of this guy.

Now, we know all the parameters in this case, this last term is a constant term, we know rho naught rho naught is the density of air, we know c typically c is about 344 meters per second, and what is W ref it is 10 to the power of minus 12 watts. So, if you take multiply all these terms and you divided it by 4 pi and take 10 log of that whole thing what you end up getting is minus 10.9. So, this is your long expression. And what this long expression tells you is that sound power level excuse me sound pressure level which is L P is equal to the sum of sound power level L W plus the effect of directivity which is in green 10 log of Q plus the effect of distance. If you are far then your sound pressure level will go down which is minus 20 log r minus the effect of what is 4.343 m r what does it indicate it tells us the influence of sound attenuation. How much sound gets absorbed, so this is minus 4.343 m r minus 10 point nine a constant number.

So, the point is that if I have in free space again remember we had said there are no reflecting surfaces. In free space a sound producing object, which is directional whose directionality is Q, which we know and which produces W naught watts of power. Then the value of L P at this location m can be calculated by this simple formula. As long as we know the directivity how do we know m, the value of m it we will see that it depends on temperature and relative humidity and there are charts from which you can find out the value of m.

So, if you know Q, r and L W, you can calculate L P. And how do you calculate L W, L W is what is L W, L W equals 10 log of 10 W naught by W ref. So, you can calculate the value of L P, this is how you calculate. So, if you have just one sound producing object in free space then at a distance r away, you can calculate the value of L P using this longish relationship. We will do one simple example, which will tell us how this parameter changes or what is the role of this parameter. So, that is what we will do in the next class; and if we have time we will further discuss some more details about it. So, I think that concludes our discussion for today. And tomorrow we will continue this discussion for outdoor situations, and with that we will conclude our week. And with this I say goodbye to all of you and I look forward to seeing you tomorrow.

Thank you, bye.