Architectural Acoustics
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Lecture – 05
Near and Far Field Propagation and Loudness

So, welcome to the NPTEL lecture on Architectural Acoustics the 5th lecture today. The fifth lecture is all about the Near and Far Field Propagation and Loudness. And this 5th lecture is the last lecture of our first week course and you will go to the some other topic in the second week. And the architectural physics the architectural in the building physics is going to be end with this lecture.

So, if you remember in the last lecture what we discussed is the sound pressure level, sound intensity level, and how they can be added and what is the way? The particular conversion from the level to the intensity or from the intensity to the level is going to concern I am going to happen.

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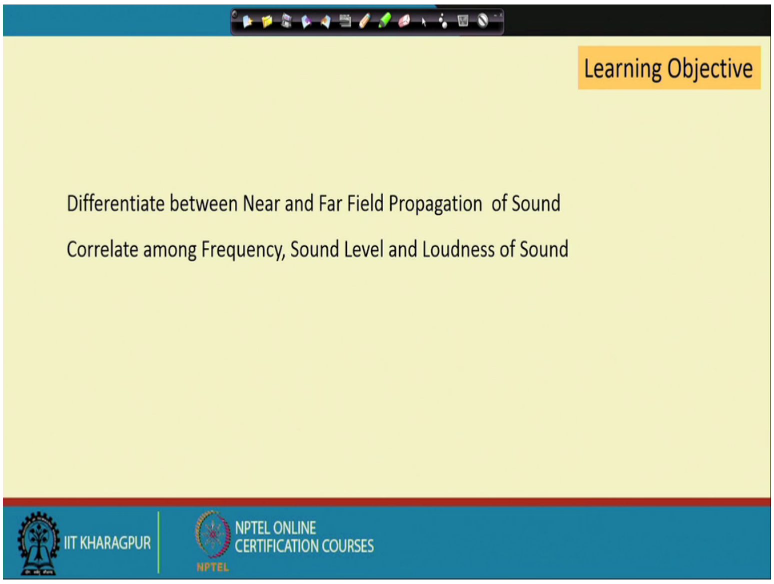

So, in this lecture number 5 again I have to learning objective, the first 1 is you have to differentiate the near and far field propagation of the sound by this lecture can you differentiate I mean after the this lecture, if you are going through properly you must differentiate between that.

And, then you must correlate between the frequency sound level and this loudness of the sound. And, that will be the main major focus to this particular lecture.

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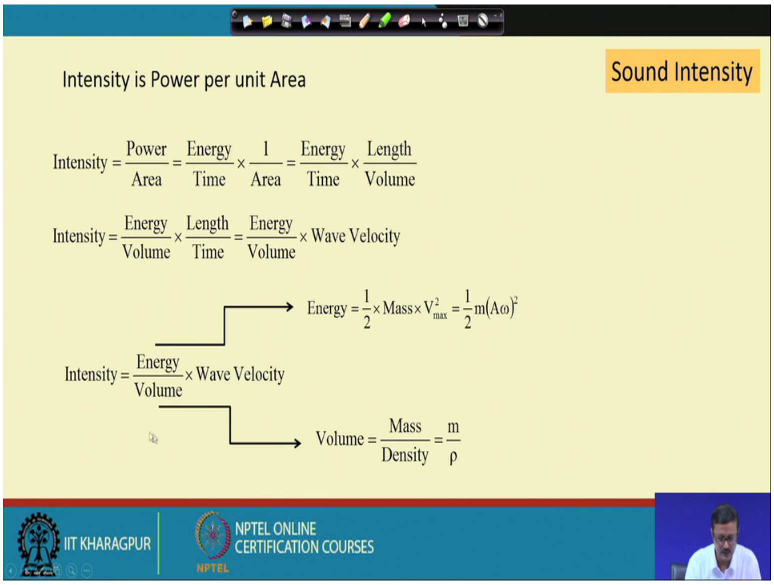

So, let us go to the sound intensity once more in a different way. What is intensity? Intensity is nothing, but the power per unit area. So, I can write like the power by area is equal to the intensity. And, if the power is now further converted to the energy part time, because the energy per time is your joule per second, which is your watt which is your power and power per area that is watt per meter square is your intensity.

Now, this area can be rewrite as the length by volume. Now, further if I see this total things can be rewrite like this volume can be taken into the below this. So, the energy by volume into length by time and length by time is nothing, but the velocity of the wave.

So, let us now see how this conversion of the energy and volume can be done. As, we know that the energy is nothing, but the kinetic energy of the particles, which is under the motion. So, it is half into mass into V max square, because the velocity of the particle also we will fluctuate and it is minima and there is a maxima.

So, the maximum velocity of the particle is A into omegas omega and the this is square of that and the volume of mass in into density.

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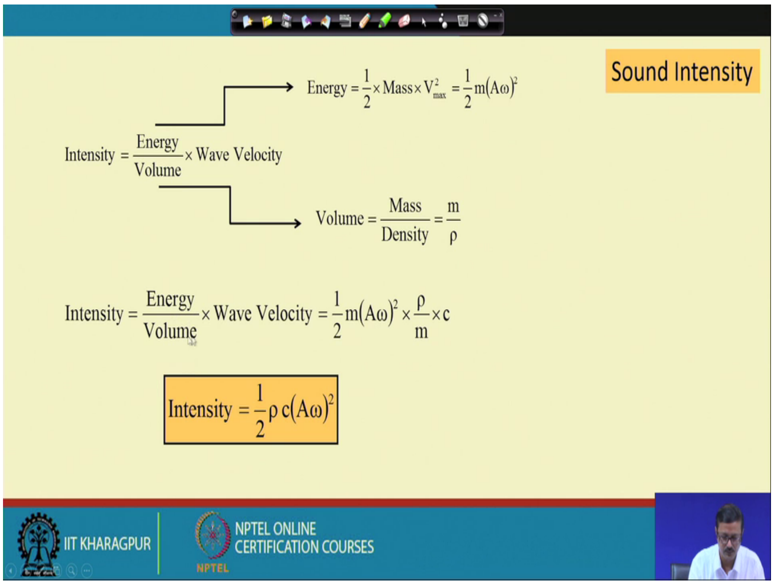

So, if this 2 are added together in this particular form, then the intensity can be rewrite as half into m A omega square into rho by m because it is volume now and into cc is the wave velocity. So, the intensity can be written in this form. So, you see this is very interesting formula and you see the intensity of sound is depend upon the velocity, is depend upon the rho density of the media, it is depend upon the amplitude of the motion amplitude of the propagation and also it is depend upon the frequency or the angular the velocity omega and this 2 are in square term.

So, if I know the frequency, if I know the amplitude and velocity of the sound and the density of the media, I can actually find out what is the sound intensity; Now, go further head.

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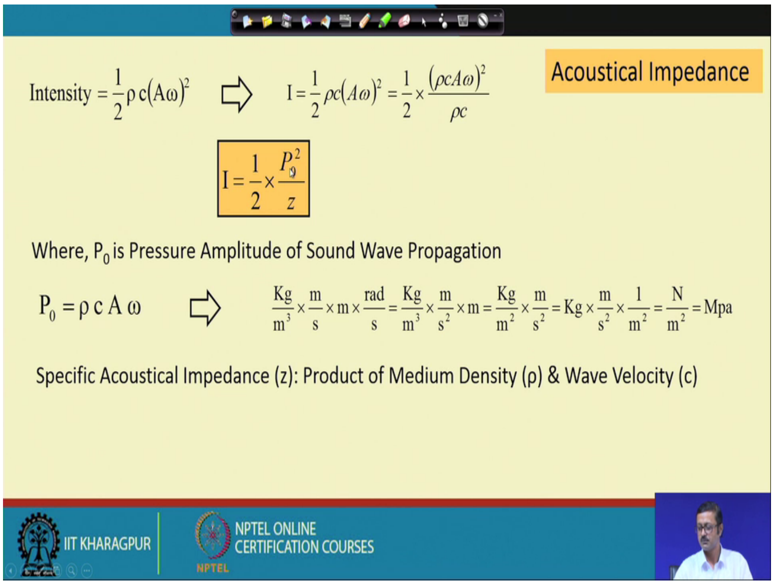

So, this intensity is again rewrite as the same equation can be rewrite as this rho c A omega square by rho c, because the I have taken another rho c in the here and the and dividing that by the numerator. And, here that I can get 2 such product and 2 such parameter separately, and I can write is half into rho P square P 0 square and Z, what is this 2? The P 0 or the P 0 is the pressure amplitude of the wave propagation, which is nothing, but your rho c A and omega and this is Z is called acoustical impedance which is the product of the medium density rho and the wave velocity.

Now, why it is wave this pressure? So, let us find out from the units of them rho is kg per meters cube, and the c is meter per second velocity amplitude is meter and this is radian per second is the omega. So, if you just finally, come into that I mean if you just finally, rewrite those things and rearrange the units finally, you can come down to the Mpa, the mega Pascal the mega Pascal is nothing, but your pressure.

So, you can see from this particular equation that the I the intensity is proportional to square of the pressure and that is why if you remember in the last lecture number 4, we have discussed that the pressure square are the intensity is proportional to pressure square. And, that is why if the if you convert the pressure level to the decibel level, you have to multiply that by virtue of 20 not 10.

And, if you convert the intensity to the intensity, level you have to multiply that by 10 and if it, because it is logarithmic.

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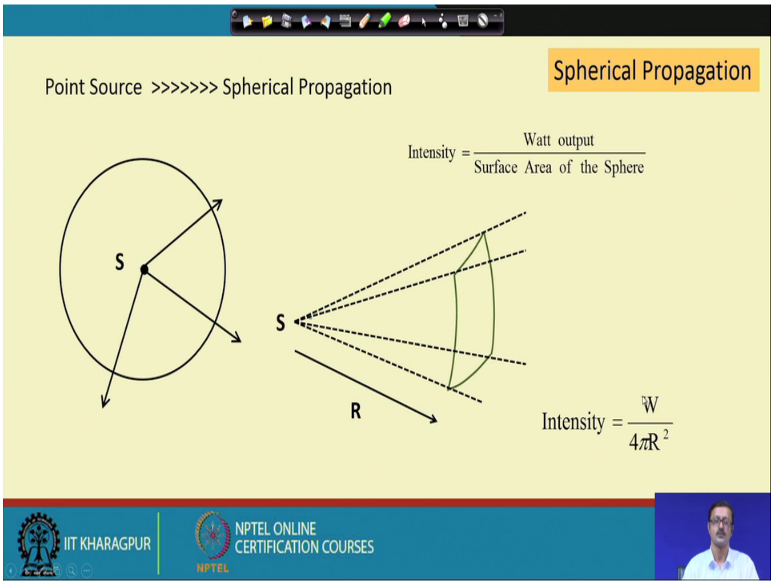

So, next slide in this slide we will see the how the propagation of the sound is occur. The propagation of sound is spherical; it is from a point source and it is going in a spherical way. So, in a air or in a space it is going in a spherical way. So, from this particular point s source is going in 3 dimension in this spherical way.

So, the intensity is the what output divided by the surface area of the sphere and as in when you go move further from the source to the sum further distance, your radius of the distance is assume as a radius your total sphere, that is going to increased, your surface area of the sphere is going to increased and your total intensity is going to decrease.

So, if you are very near to the source the density is very high, because of sphere the area of sphere is very small, if you go higher distance larger distance further more from the source or so, your sphere is bigger, your radius is bigger, your surface area of the sphere is bigger, your intensity is go going down and you hear less amount of sound in the level point of view.

So, the intensity is can be written as W is the output watt by 4 pi R square as you know the 4 pi R square is the surface are of a sphere.

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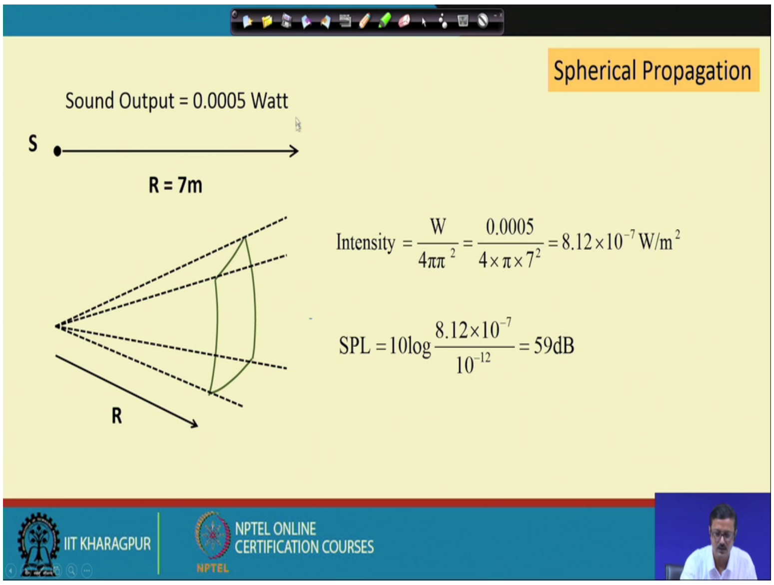

Let us see small problem suppose this is a sound source of sound as and it is giving a sound output as 0.005 very very small wattage. And, you are standing at the receiver is standing over here which is 7 meter away. And, if it is so, I will find out what is the surface area of a sphere, which is having 7 meter of radius.

So, that is why I am finding out the intensity as this W by 4 pi R square and this is like this and finally, it is 8.12 into 10 to the power minus 7 watt per meter square. And, as and when you got this intensity, which you are actually experiencing here at a distance 7 meter by virtue of a sound output of 0.005 here, it is easy to convert these to the sound level. In that very old formula the 10 log I by I reference is now your here and your listening 59 dB sound.

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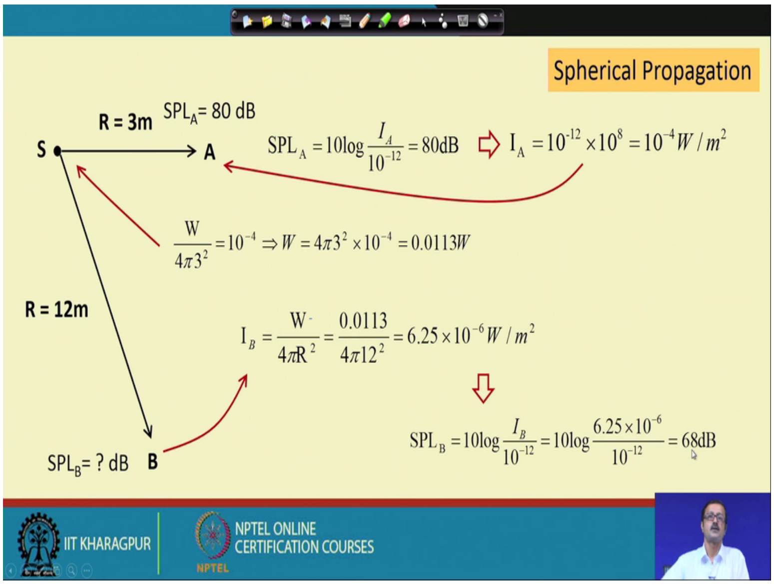

Let us see the this particular problem or another problem in a different way. Suppose this is a sound source and your with a dB meter at point a your at c bar act A of the that sound and your receiving eighty dB at A. The sound pressure sound pressure level at A or is 80 dB or the sound intensity level is eighty dB at A distance 3 meter.

The my question is what will this particular person get which is who is standing in B? What will be the SPL or the SIL at B? Who that is B is 12 meter from the sound source; I have I am going assume it is the spherical propagation it is the point source. So, first find out what is the SPL is 80 dB. So, first try to find out the what will be the intensity at this particular level by virtue of this formula.

So, by this it is 10 to the power minus 4, with the intensity at here. If this is 10 to the power minus 4 watt per meter square, which is on this particular sphere of radius of 3, then what is the wattage of the sound output at the source? Which I can find out from this equation because W by 4 pi 3 square is equal to this 10 to the power minus 4, and solving this I can get the watt output or the power output of this particular source is 0.0113 1. And if this is the wattage or the output wattage at the source, what could be the intensity at the B, which is at A distance of 12 meter 12 meter mix sphere.

So, that I can find out this W is now this and this 4 pi 12 square and this is the intensity level. We can compare the intensity is now very very low with compare to the intensity as A. So, I am expecting something less than 80 dB over here of definitely and as I got this intensity B I B, it is very easy to find out this particular level as your this old formula by log this by I reference at 68 dB.

So, this particular problem gives you how from intensity level to thus taking consideration of the spherical wave front propagation, how to find out the, what output? And from what output to again a intensity in some different distance and from that you convert that intensity to a intensity level or the sphere.

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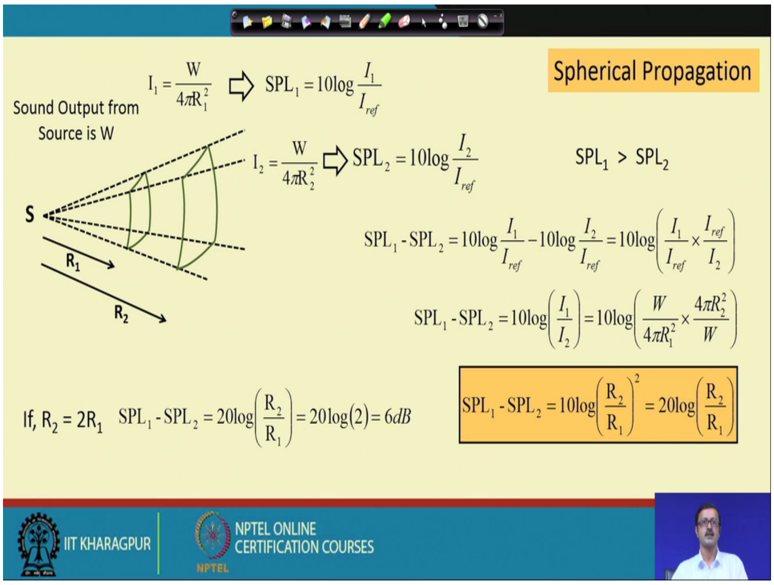

So, the sound output from a suppose a source is W is s and it at a distance R 1, which is nearer is the intensity is this and the SPL is suppose just I 1 by I reference. Now, you go further distance R 2, which is higher than R 1 and definitely you will be experiencing less amount of intensity, because the sphere is larger area is larger and your SPL 2 is your this.

And, then let us see this is going to be happened because your if your near to the source the intensity is high, your decibel is high SPL 1 will be higher than the SPL 2. So, what is the difference between them I am going to find out? So, difference is SPL 1 is this SPL 2 is this and if you just operate this mathematical operation is 10 log A by B.

So, I 1 by I reference by I 2 by I reference. So, we can get it like this I reference get cancelled. So, finally, I got 10 log I 1 by I 2 and now you replace the I 1 and I 2 from here and got SPL 1 minus SPL to the difference between this 2 is R 2 by R 1 squares this 2 goes here.

So, 20 log R 2 by R 1 and suppose if R 2 equal to twice of R 1, if the distance is doubled, R 2 and this ratio is 2 log 2 is 3 I am sorry log 2 is 0.3 0.3 into 26 dB.

So, in case of a spherical propagation, if the distance is double your decibel level is going to drop by 6 dB. This is the final outcome of this particular the slide; Now, spherical propagation and cylindrical propagation.

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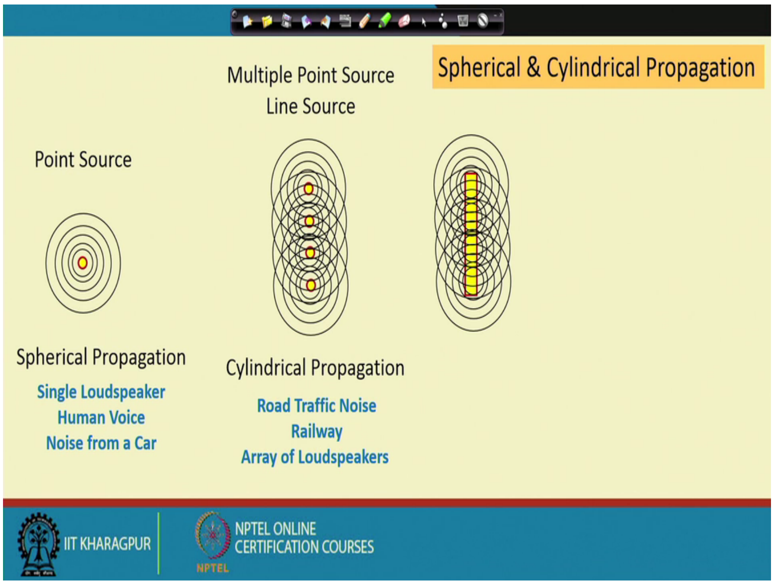

Suppose, this is the unit source and it is give me a spherical propagation and the examples of the spherical propagations are the some loudspeakers some human voice, some noise from and small car or something like that, but if suppose there are so, many point multiple point source in a very congested line or may be very close less are distance, linear format.

So, then you can superimpose those are the sphericals and it will you will get a the cylindrical propagation. So, the watt are the examples of that may be a noise from a moving rail, maybe a traffic noise, where there are lot of cars moving one after another which is the point source, but very closely separated point sources in a road or may be a array of loudspeaker in any theatre or any may be any public address gathering field.

So, those are the cylindrical propagation example of the cylindrical propagation. So, we can actually say it is not as point it is a cylinder.

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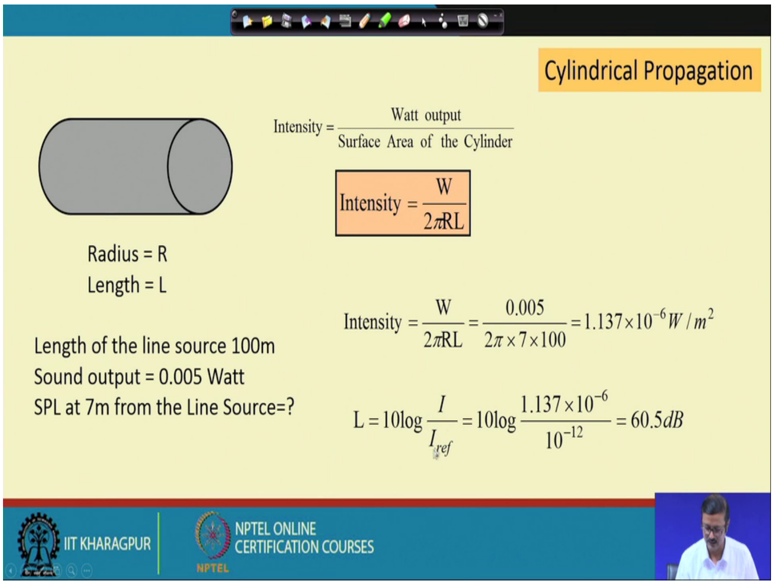

So, in case of a cylindrical propagation we will see the propagation is from a cylinder not from a point source so; that means, it is a line source. So, the length of the line or the length of the source is L and by virtue of it has in having a radius, because if you go further away from that line L your radius is increasing your surface area of the cylinder is increasing.

So, there I will take the same principal I will what output that is the power output, I have to divide that by the surface area of the cylinder. And surface area of the cylinder for virtue of this particular geometrical condition is 2 pi R, that is the perimeter into the L. And, now this will be the intensity. So, suppose a length of the source is 100 meter output is 0.005 watt what will be the SPL at 7 meter from the line source.

So, this we just convert with that I got this particle intensity level and again I will take the particular equation intensity or the intensity reference, I will get 60.5 dB as the decibel level.

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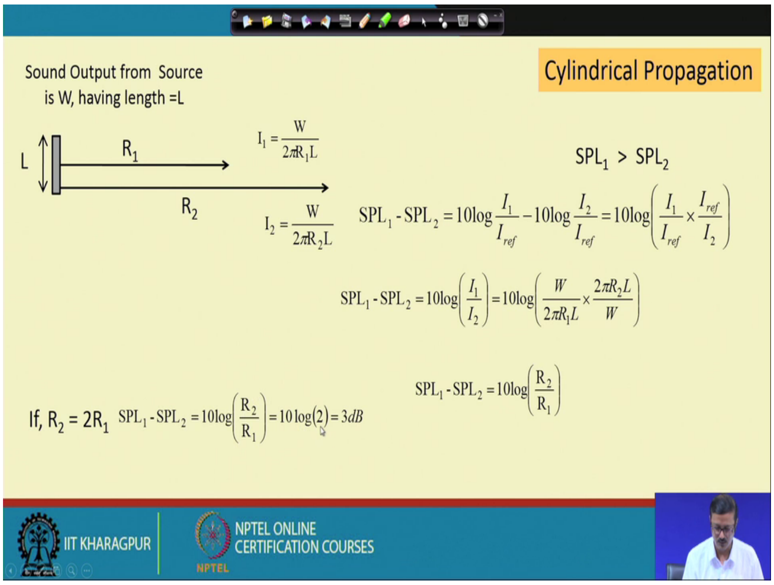

Now, from the line source If, I go R 1 distance from R 1 distance while get the intensity as the cylinder of the radius R 1 of length L, if I go to R 2 I get this value of I 2 and let us find out the what is the difference between the L the level at the at a distance R 1 and R 2. And I know this R 1 will be higher the level sound level at this is higher, because it is nearer to the source.

So, again I will take the operation of that and very similarly I can find out the what will be the values of I 1 and I 2 from here and what is the difference between the SPL a modern SPL 2 and this gives me a formula like SPL 1 and SPL 2 is 10 log or 2 by R 1. And, if the distance is doubled suppose R 2 is twice of R 1 then this is 10 log 2, which is 3 dB.

So, if it is a cylindrical propagation, if the distance is doubled, the dB level drop by 3 dB, but if you remember in the in the in the spherical propagation it was 6 dB. So, next let us go to the near and far field propagation.

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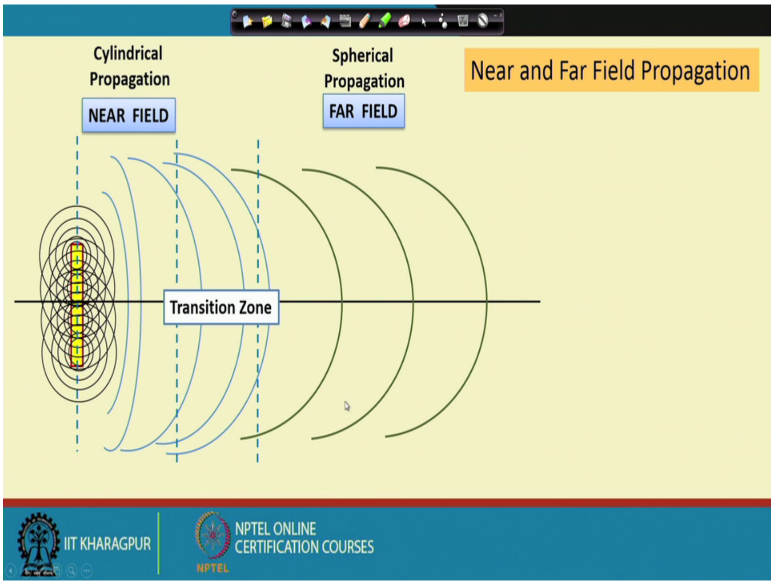

Suppose it is a it is a the BC road sections and that is gives me a cylindrical propagation.

But, why virtue of this propagation if you now go further in this away from the this line away from the road. This way front is again going to get a spherical of suppose, if you are very standing very far distance from the road since road noise will be act as a point source 1 ones again.

So, some point source gives you a line source and if you are very near to that particular line source this is a cylindrical propagation. And, now if you go further that particular line will act as a point and then it is trans form to a or to a thus spherical propagation.

So, there is a near field zone and there is a transition zone and there are the far field. So, what happened in the far field zone? In the far field zone sound is spherical propagation sound the sound propagation is spherical. What happened in the near field zone the propagation is cylindrical?

So, if in this near field zone I want to calculate something I have to assume that this source is a cylinder linear source propagation is cylindrical. Suppose I am here, if I want to find out the same effect of this particular road noise, then I have to assume this as a point source. And I have to assume this is as a spherical propagation.

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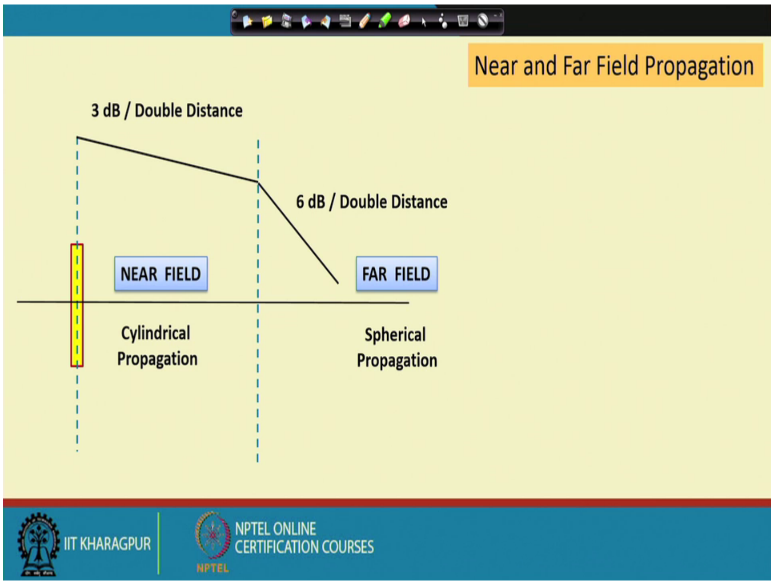

So, if the spherical and the cylindrical propagation or the near field and the far field has to be taken into account. So, in the near field zone it is drop by 3 dB by if the developed the distance and in the far field which is spherical is 6 GB as per the distance is doubled.

So, by virtue of this there are 2 type of sources in case of any kind of the analysis or any kind of the measurement, if you take for any kind of sound at in the environmental sound. Then you have to know that we were in a far field or your in a near field and you have to take the specific formula, and you to take the specific condition and then analyzed.

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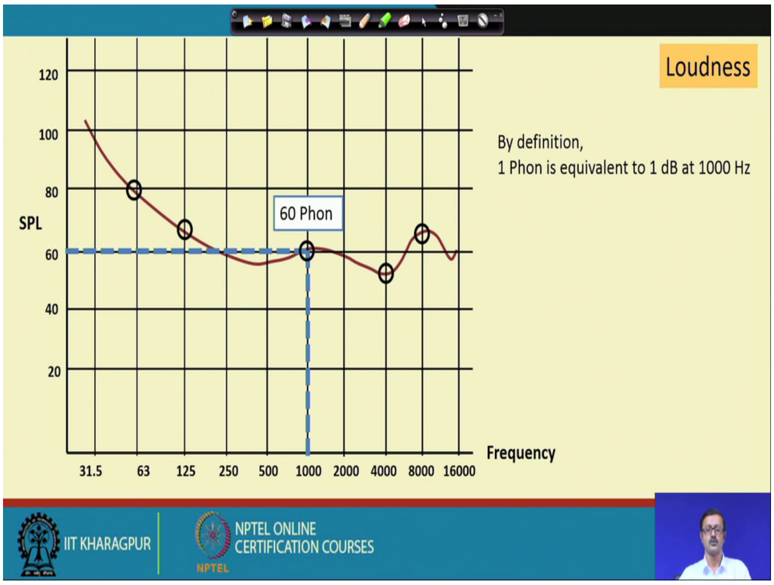

Now, next go to the loudness, loudness is a combination of the frequency and the SPL. Now, what happened if in the x axis I have marked the all the octave band frequencies, it is the starting from the 31.5 to the 16,000. And the SPL is actually written in the y axis that is in the dB.

Now, the human being perceive sound differently suppose I plot some points. The first point let us see this is the when 1000 hertz and 60 dB, it is gives me some kind of sensation, some kind of sensation. And the sensation is very similar, when the frequency of the sound is 125 dB and more or less 65 65 dB and 125 hertz.

Sorry 125 hertz sound with 65 dB for 63 hertz, the same sensation what I am experiencing here? I am getting the same sensation for 63 hertz at around 80 dB. So, if I just plot all those point, which gives me a same similar type of sensation, with respect to 1000 hertz and some amount of dB and I can actually create a contour line or a kind of a line.

And, this is a kind of a loudness it is a similar loudness or the same loudness. So, loudness of the sound is vary from with this 2 fundamental parameter of frequency and the SPL. So, this is the loudness and corresponding to this 1000 and 60, the loudness is this particular loudness graph is called 60 Phon. So, by definition 1 Phon is equal to 1 dB at 1000 hertz.

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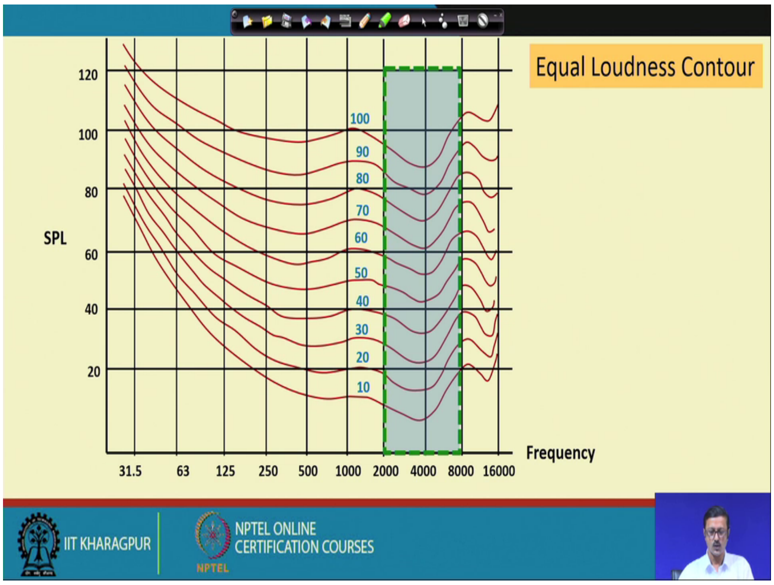

Similarly, can plot lot of such plots of in the frequency and the SPL level so, it is starts from 10, which is threshold of audibility and it is goes up to 100 may be 120 also, which is the threshold pen and those blue numbers are your Phons and this red lines are of your the equal or loudness path or the equal loudness contour.

So, you see in this I can say that this particular band, which is 2000 to 8000 hertz is very sensitive this frequency is very sensitive to our here, because you see this loudness contour curve dipping in dipping over here. So, even a smallest amount of smallest amount of loudness can here in this particular frequency zone.

So, suppose if you want to here is 6 of 30 dB sound of this 4000, you required this much of the sound level 22, but same with 63 you required almost about 60 dB you cannot here, you cannot here. So, 30 loudness sound this is the equal loudness contour also.

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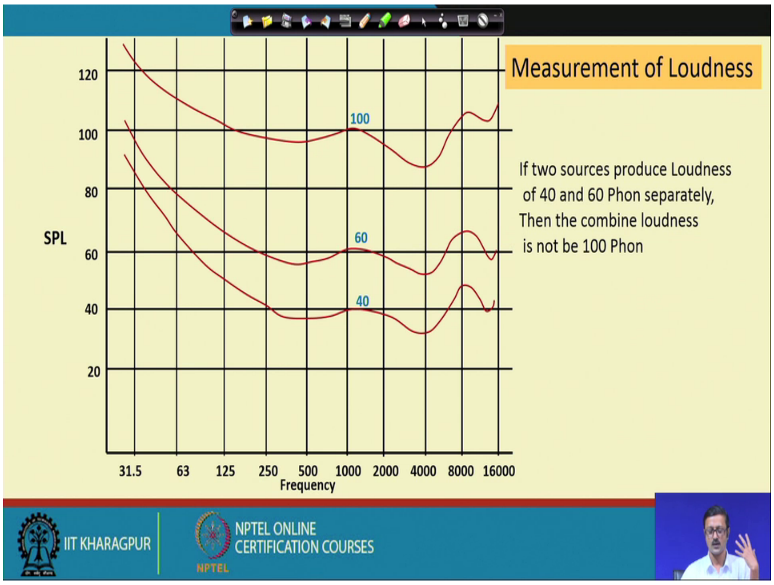

Now, how this loudness can be measured. So, suppose I say that I have a sound from a source which gives me 40 Phon. So, this is the curve and another source gives me 60 Phon. So, this is the curve. So, can I say if I though both the sound source if it is on switch on, the final sound which is combination of 60 and 40 the Phon is equal to 100 no it cannot be, it cannot be added like that be, because this phon is a is a not it is not a physical parameter. It is a kind of a psychological parameter, what a human being is receive?

Suppose this particular graph which we have shown you, this is equal loudness contour is for a young gentleman. Suppose, if you do the same experiment with a the old person of around age of 75 or so, this graph will be shrink a bit he or she will perceive a different way different type of sum graph some contour and maybe omitted.

He or she may not here that particular phon. So, it is fully psychologically or how the brain is going to map my the sound, that way it particular it is devised or it is actually analyzed and derived. And that is why this the unit of loudness this is phon cannot be added and it is not be justified to add like that. So, we need to add because there are 2 different loudness and why and this two different loudness has to be added to give a resultant count if the sound loudness.

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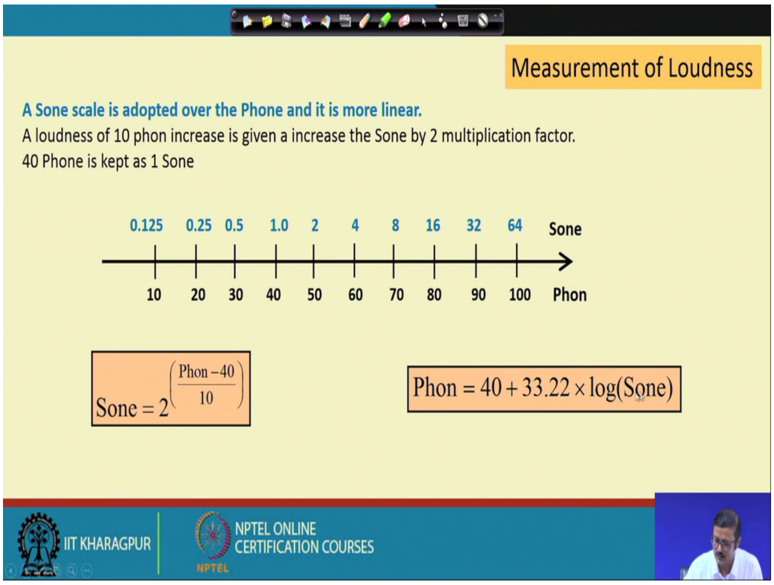

So, we have to take another scale and that scale should be little bit of a linear scale and that scale is called Sone scale. And in loudness 10 phon increase gives a increment of the twice of multiplication factor of the sone. So, if I see this is the loudness plot that is the from 10 to 100 phon, the corresponding and this cannot be added this phon cannot be added.

So, this corresponding phon can be translated to a linear format of sone, which is showing here in a blue numbers. So, the 40 phon is converted to 1 Sone and correspondingly, if you go to the next higher phon of 10 phon higher 50, it is multiplied by 2. If go to another 10 higher 60 this 2 is multiplied by 2 4 and then 8 16 like that.

So, the 100 phon is equivalent to 64 Sone and now if you go beyond b 1 in below 40 by 10 phon recruitment we have to divide this 1 by 2.5, another 10 decrease 20 from 30.5 divided by 2.25 like that. So, it can be, now mathematically express like Sone is 2 to the power phon minus 40 by 10 just put suppose 60, if you put 60 over here 60 minus 40 is 20, 20 by 10 is to 2 to the power 2 is 4.

Something like that you can with this particular formula we can find out. And in the reciprocal way a phon can be find out by just virtue of this particular equation. So, you just if you want to find out what is 16 Sone equivalent phon put 16 here log 16 multiplied by 33.2 2 and add 40 into it.

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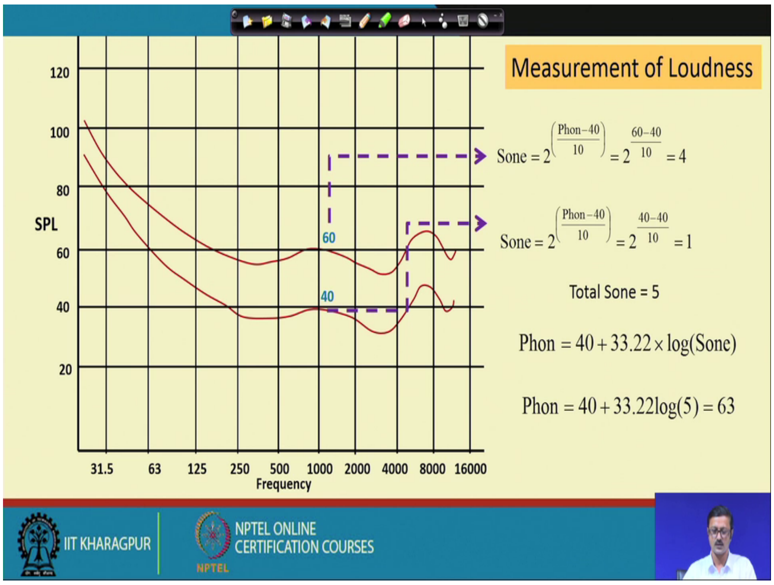

So, now we can actually go into this particular measurement. Now, 40 gives me 1, because I put 40 over here. So, this is 1 very similarly I convert this 60 phon to it is corresponding Sone level which is 4.

Now, I cannot add phon 60 plus 40 cannot be 100, but I can add this sone. So, 4 plus 1 is 5 total sone, because of this 2 is 5. And as I got this 5 Sone is the resultant Sone I can convert that Sone to the phon by that equation I put this Sone as 5 log of 5 into 33.2 2 and I add with that with 40, it is 63.

So, I can say it is not 100 phon, if you add 40 and 60 it is 63. So, that is ends this particular chapter this particular lecture number 5, which is about the near and far field propagation and also about the loudness and this 5th lecture also include the first week of our architectural acoustics course, online course.

And this total 5 lectures comprises of some historical development of the sound from the different era, which Dr. Suman Gupta has discussed in the very first day, and are very first lecture, and then the 4 consecutive lecture on the pure acoustical physics are the building physics.

So, at the end of this lecture let us have once again some homework and take away to your home let us try this.

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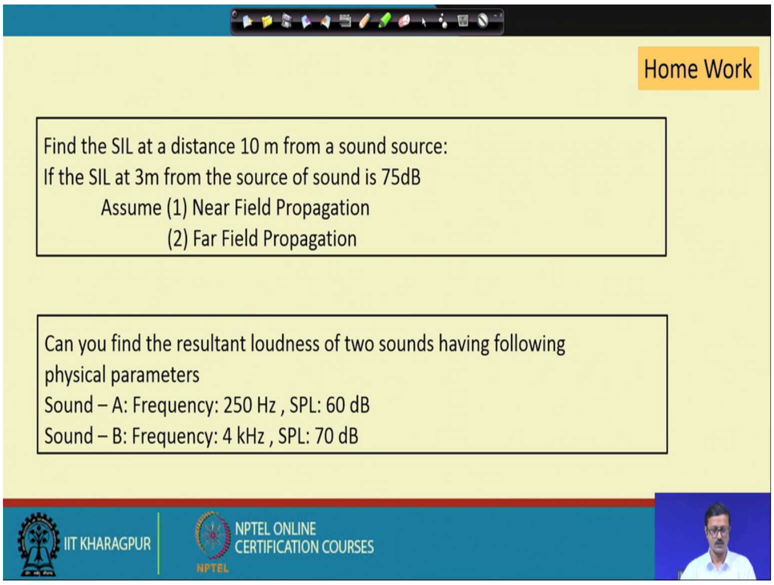

The try this particular the formula the sorry this particular problem because this will give you a kind of a understanding between the near field and far field, suppose a the sound intensity level SIL and is 10 meter from the sound source SIL at a distance 10 meter from the sound source, you have to find out what will be the SIL at the 10 meter from the sound source. If the SIL at 3 meter from the sound source is 75 GB and first of all you assume it is the near field propagation, where the sound propagate in a cylindrical form and in second case you assume that has a far field propagation.

So, that is a spherical wave. So, in this particular videos or in this particular PPT is sometimes you may sit is a SIL I have written sometimes it is SPL, a sound pressure level or sound intensity level, both are actually going to give in dB scale and these are related. So, do not be confused with that thus it is name suggest, it is sound intensity level and sometimes it is sound pressure level, but finally, by computation end result is dB is the same.

Take a second problem also for your homework, that is can you find out the loudness of 2 different sound parameter, sound source a gives you a frequency of 250 hertz and SPL of 60 dB, definitely this two combinations gives you some kind of a phon and a sound level a sound source be gives you a of a frequency of 4 kilo hertz and SPL of 70 dB, that also converted to a particular the phon in loudness contour and then you add this 2 together both the sound source A and sound source B.

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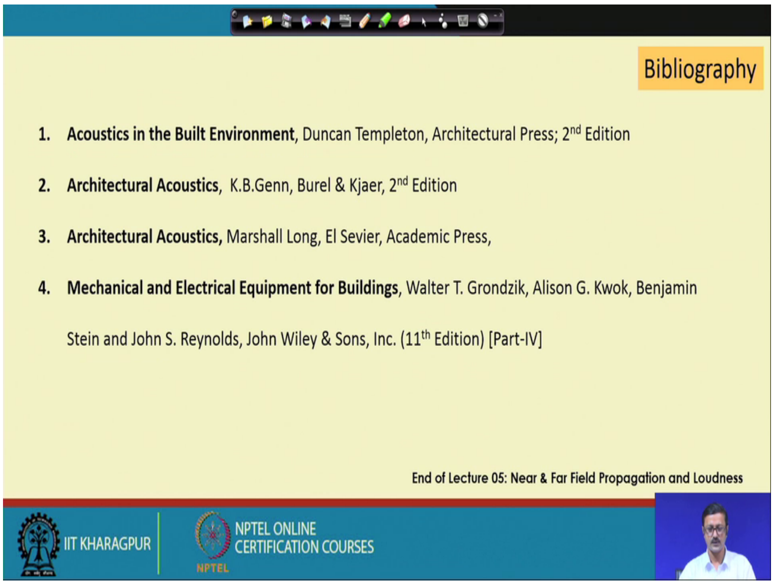

The effective or the resultant the loudness you have to find out. So, those are the references and that is the end of the lecture number 5, hope you understand the lecture well and if you not go through the lecture once more and you can also contact us and.

Thank you very much.