Energy Efficiency, Acoustics & Daylighting in building

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Lecture – 34
Noise Outdoors

So continuing from where we stopped actually.

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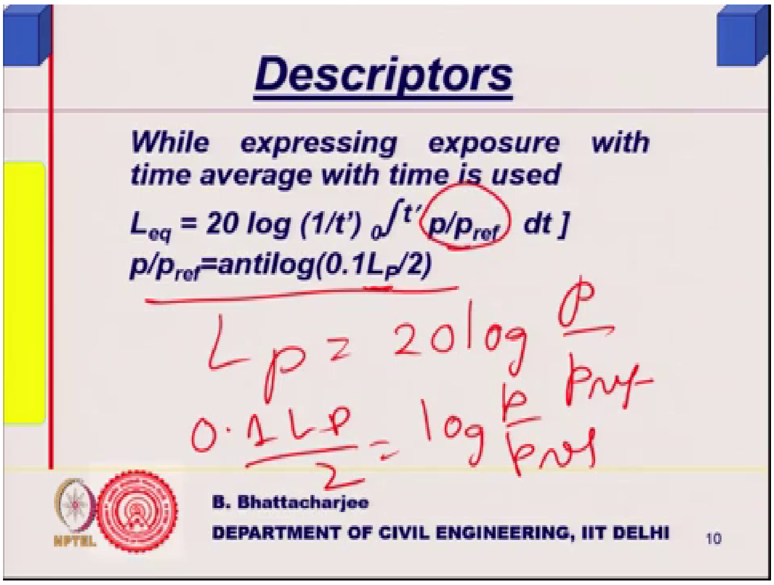

You know what we are saying is that L p is equals to 20 log p by p reference that is what it was. So, I can actually write this as 0.1 L p by 2 equals to log p by p reference. So, this follows you know p by p reference, because then I put it under integration sign these values, because L p is measurable, and then you write it like this.

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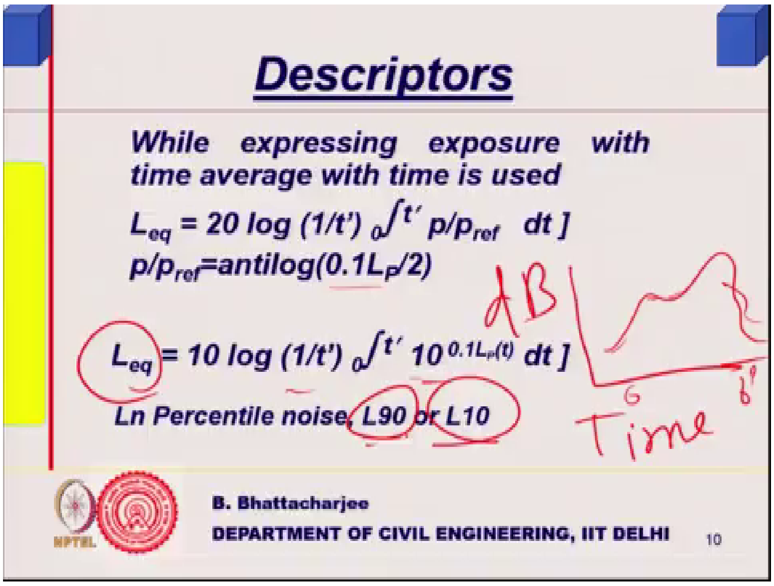

Therefore, L equivalent is written in this manner 10 log 1 by t dash this is t dash I mean during the period, and 10 to the power you know this is antilog this means 10 to the power 0.1 L p t dt.

So, you integrate this 1 and divide by 1 by t and then take 10 log again, then you get the L equivalent. So, L equivalent is nothing, but the averaging over the time and you cannot add the dBS just arithmetically, they are not in linear scale. So, what you do you take antilog of p by p reference 0.1 etcetera, integrate it that will sum it up divided by the time during which you have taken measurement that gives you the average. Now divide it by you know take 10 log of that and that that will give you the value.

So, this is how we find out L equivalent, then we have something called L n, which is percentile noise. Now as I said traffic noise for example, you know you will find that maybe 10 am 9 am is maximum, it reduces somewhat later on. So, if I plot it time versus dB level, close to some arterial road or highway, it might 6 am it might pick up 10 am it might pick up maybe somewhere there, then it goes down again maybe some sort of variation like this.

You know variation again to 6 pm or you know 24 hour dB variation and all that. Now then I should design for what, I should design for characteristics value, because you understand what is characteristic value is that noise, which will be exceeded only small percentile of time, design you know I cannot cover hundred percent that would mean that too much of a cost involvement.

Once in a while it will go beyond the value. So, my load if I want to find out, I find out the characteristic value that is 90 percentile value sorry 10 percentile value, the noise level which will be excited exceeded only 10 percent of the time. So, that I call as L 10 noise level that will be exceeded only 10 percent of the time, L 90 is what that is almost the ambient case, because you know it would asymptotically possibly go towards very small value like 0 no noise, but L 90 is that value which is that exceeded 90 percent of the time; that means, that is the prevailing noise at that particular situation.

Now, where does it come it comes background noise can come from anywhere, you know it will now it will may traffic another highway for example, you measure around IIT Delhi campus let us say block 6, you know around that place there is a traffic lane I mean traffic arterial road going by the side of it, besides that there are other roads. So, noise has actually d L t a there is a Delhi lawn tennis association or the deer park, you know that is green area permanent greenbelt that is there that it invades the noise significantly.

If you travel from you know places which are covered by green areas, even in highways and you follow it in the green areas around the green areas, you will find the noise level is somewhat different. The moment you come out of it, you will find a distinct difference in noise you can feel it actually. So, it comes from may not may not be nearby curve may become from somewhere else. So, background noise comes from many places, depends upon what is the surrounding the green, if there is a attenuator like trees it is you know trees causes some sort of attenuation reduction or there are barriers, or similar sort of thing which you will talk about, then there will be reduction.

So, background noise is always, there some background noise. So, that is L 90 corresponds to that noise which will be exceeded 90 percent of the time. So in fact, you go to get the distribution of noise plot the frequency diagram, average you have found out which will be exceeded 50 percent of the time. So, you can plot the frequency diagram, how much how many times supposing you have taken discrete measurements to find out the number of times relative number of times, your head between let us say 50 to

55 dB 55 to 60 dB and so on so, what. So, you can have what is called frequency diagram.

From that you can find out L 90, L 90 is that noise which will be exceeded 90 percent of the time, L 10 is that noise which will be exceeded only 10 percent of the time. In other words you need an insulation for L between L 10 and L 90, L 90 is ambient you can tolerate L 10 is access level. So, you would like to have as much reduction from there to close to L 10, and also your human ear adapts itself relatively. So, that is the idea. So, these are another kind, another descriptor percentile noise level.

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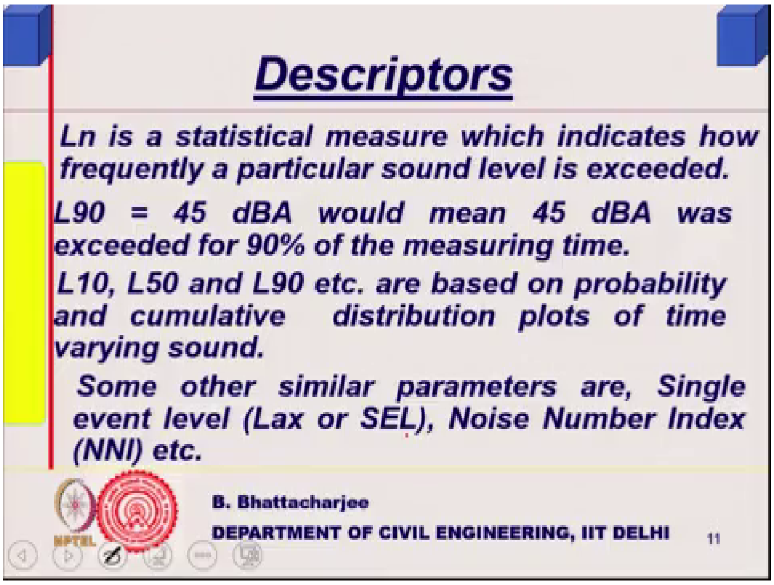

Then is statistical measure which indicates how frequently a particular sound, sound level is exceeded L 90 45 dBA would mean 45 dB was exceeded 90 percent of the time. So, somewhere it will specify that you know L 90 should not be more than this value or you know so, you have to cut it down here, to cut it down do some noise reduction measure L 10, L 50, L 90 etcetera it based on probability, and cumulative distribution plot of time varying sound.

So, that is what a percentage noise level some other similar parameters like, single event level, noise number index, there are many of them depending upon type of noise you deal with, I think you are not we need not go into all details, then we will have to spend a lot of time on the noise itself. So, that is what it is with that we can now look into outdoor noise. And come back to the physical thing that we are talking about.

We talked about first the basic fundamentals, what actually is noise or sound, you know as we perceive, then you looked into certain physical measures like, then converted them into measurable you know, what we can what one can how to describe them pressure level, power level etcetera etcetera, then we talked about the human ear response and so on and some of the descriptors. Now we can look into, how you know, what are the protective how do we control outdoor noise. Now if you remember it was very simple.

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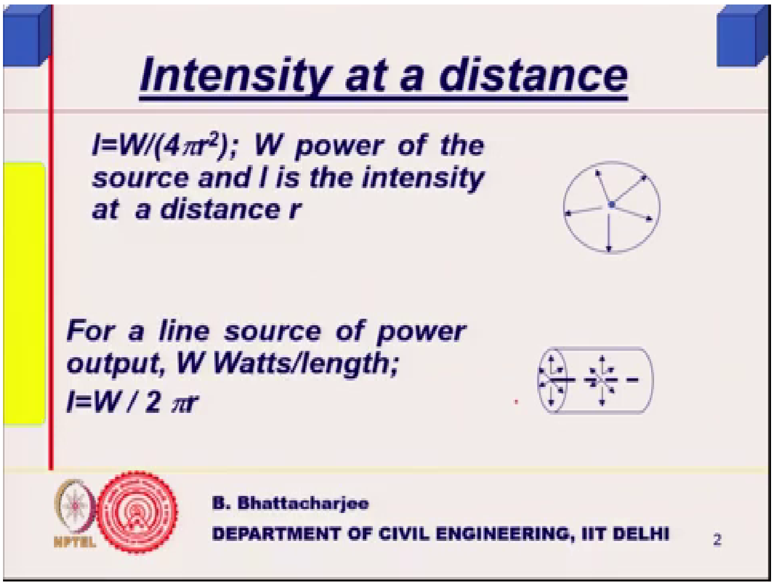

Supposing I have a point source like this. The pen should be here, and it is actually emitting sound equally in all direction, then at a distance r it will go spherically spherical wave front will move in all direction at sufficiently large distance of course, it will be plane waves. As you have talked about one dimension, if you go sufficiently large take its periphery of a sphere anyway it is a plane. So, what I you know if the r is large compared to the dimension of the sphere d a area. So, it will you can assume to a plane wave.

But anyway this power generated here, let us say its output is W watt. So, the at this distance will be W by 4 pi r square that sort will share the intensity and therefore, one thing you can see that intensity varies us inversely with.

Student: (Refer Time: 08:51).

Square of the distance.

Student: (Refer Time: 08:53).

But if it is a line source like a train, long train sufficiently long, then you can describe it in this manner long, and cylindrical waves. Let us say its making noise. So, it is something like this. So, you have a line source some there can be some line sources actually. So, then it will be what for a line source it is simply I is equals to W by twice per year, but then W here is per unit length, what you know power watts per unit length power in terms of watt per unit length. So, this is what it is and that then it follows supposing I have a plane source, plane source or very large source it may not be related to our at all, but I think I will not come to that now, while you do look at the lighting I mean you know skylight light from the sky volt. We will find that that is independent of the distance.

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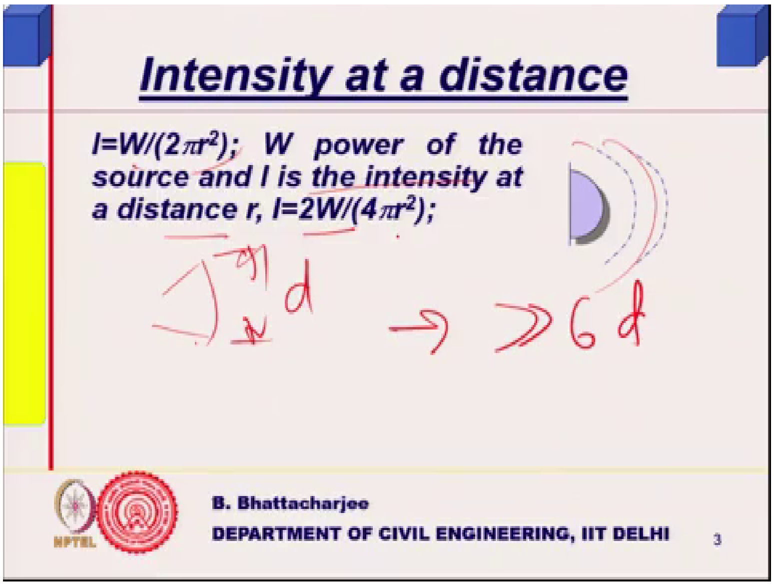

So, anyway for line source it is 2 pi, and if it is the source is in the wall. Supposing you know like something like a blackboard, I have a source there. Supposing I have put a very small. Now when it becomes point source, point source I can treat it as a point source is that if the distance of the receiver, is at least 6 times the largest dimension of the source itself. Supposing I have a speaker you know I have some sort of a speaker, such largest dimension is this much d if my distance is greater than 6 d, then I can say that I can treat this as a point. So, at least 6 d it should be more usually it is really more.

So, 6 d. Now, supposing I put a speaker on to the blackboard, I put the speaker on to the blackboard like this. Then all the sound wave is going over the hemisphere only. So, the this will be W divided by twice pi r square unlike earlier case a point source going in all direction, here is a point source, but because reflected sound from the wall will also go along the same direction, reflected sound will also go on the same direction. So, if I keep a speaker on the wall actually it will be going through the whole energy will be dissipated to twice pi r square, and W is the power of the source I is the intensity at a distance r. So, we will write it W 2 W divided by 4 pi r square, 2 W divided by you know twice pi r square 2 W divided by 4 pi r square.

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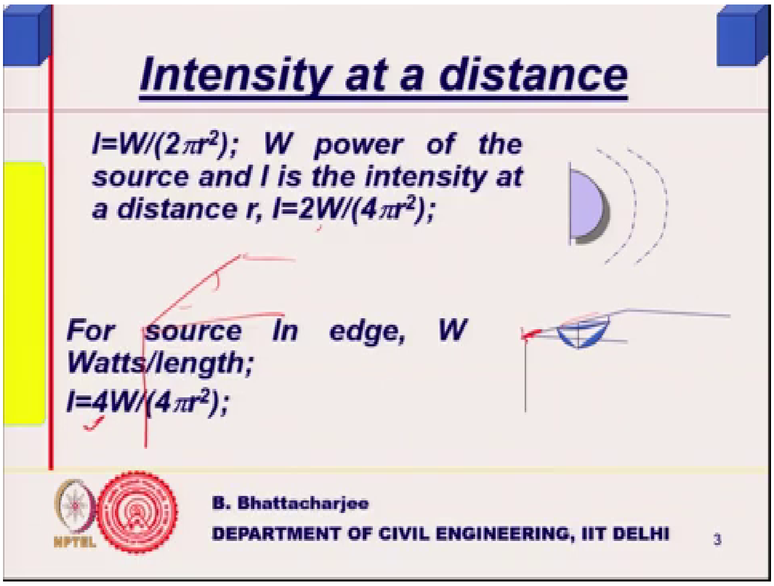

So, this is how we can write, and if it is in the corner, if it is in the corner, corner of the room, you know edge, it is in the edge, and then you know its somewhere here. So, it will go under what we call quadrant only. So, one quadrant only, if it is in you know this is your room that is what I have drawn. So, somewhere here I have placed it. So, it will go through the quadrant only because top is also block side is also block. So, it will go through the quadrant only, and I will have it for source in edge W is it was 2 now here I put in 4, because it will go through pi r square not 4 pi a 1 4th of it, and if I put it in this corner it will be.

Student: 1 8th.

1, 8th. So, if I put it in this corner.

Student: (Refer Time: 12:38).

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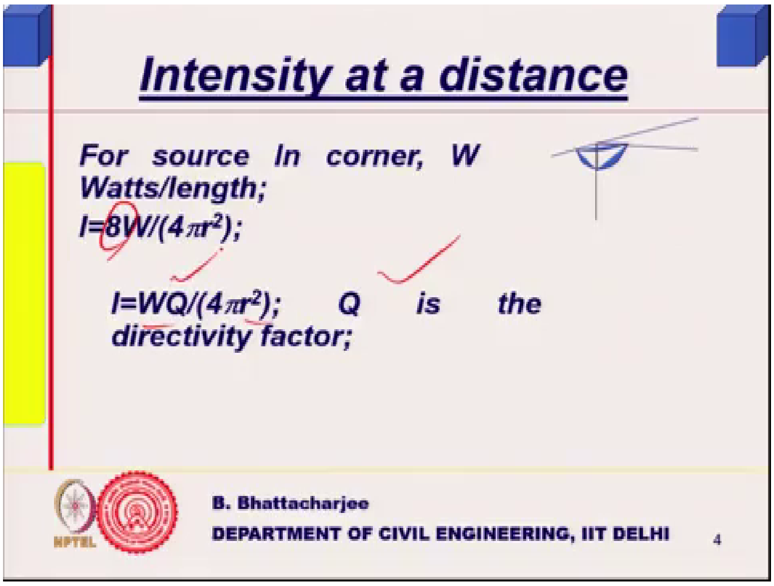

It will be 8 W divided by 4 pi r square. So, all I am saying is that I can multiply by a factor depending upon the nature of the source, whether it is also emitting the sound on the back side or reverse side, in all direction or only in specific direction. So, this is called this we define in general terms W Q. So, we write in general terms W Q divided by 4 pi r square. What is Q? Q is called directivity factor, because sources are directional, you know like you might have seen in dramatic sometimes, you know by deliberately a you know the actor or actress, you know talks with your face, along the back screen side no sometime I mean the demand the dramatics demand.

You hear actually less you will hear less. So, when somebody is speaking to you directly you hear much more, than if somebody's speaking so, actually human voice is also directive directional, I will say its directional the front side one is speaking then you hear better, but someone is speaking from the you know other side looking at other side, and speaking you do not hear of course, the vision has something to do, because your perception is also related to seeing also.

It is not seeing listening they got together. So, it is not just you know what I call independent of each other isolated ones. So, anyway what I am trying to point out is there is something called directivity factor. Sources can be directional machines are very much directional for example, you get the noise that you get behind a jet engine in an aircraft is much higher than, if you are on the side. So, that is the sort is it.

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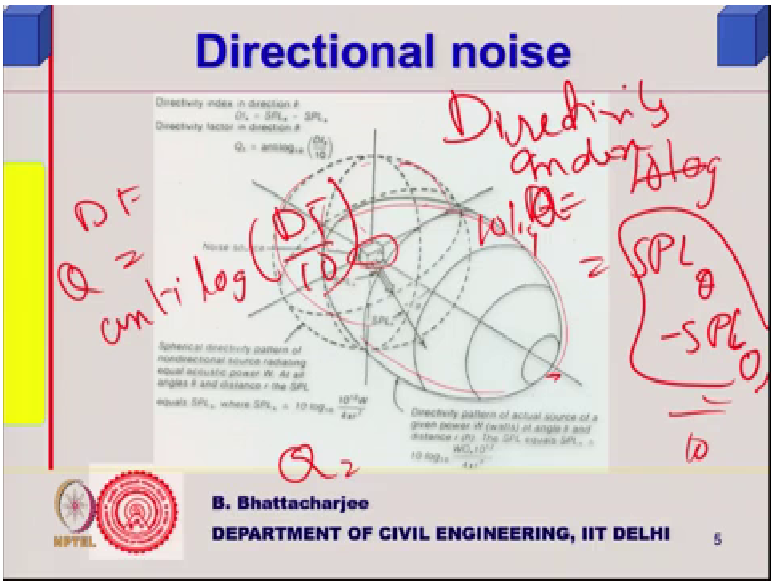

So, the Q is called directivity factor and noise sources are directional, and you define it something like this. This is my source speaker, if it was point source its point source because sufficiently large distance, if it was emitting sound equal in all direction I would have got, and you know this fear if I take a sphere everywhere I will get same intensity, but if it is directional like this along this direction it has got more, then I will get intensity here more, intensity you know it is a ellipsoid rather than a sphere and back side there is very little.

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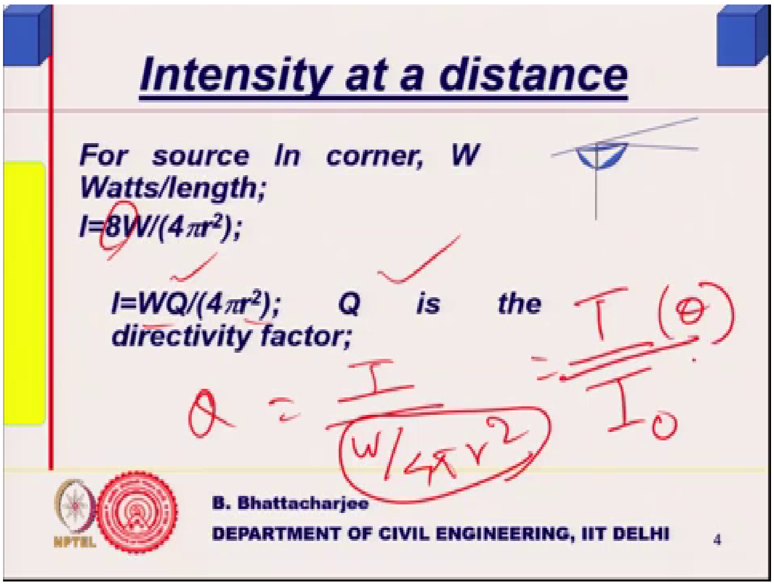

So, directivity factor Q if I go back to my previous slide, it would be defined like this Q is nothing, but I divided by W by 4 pi r square, and what is W by 4 pi r square it is the I for.

Student: (Refer Time: 15:46).

All direction and you know equal omnidirectional source, which goes equal in all direction. So, I call it I 0. So, I by I 0. So, directivity factor is defined by I along theta, I theta divided by I 0 or I theta may be subscript. So, measure the intensity along the direction concerned from a reference angle, if it is in 2 dimensional pretty easy, because you can define by only one angle. So, I theta divided by I 0, I 0 is what, the intensity that would have been there if the source was emitting equal in.

Student: All direction.

All direction equal in all direction. So, that is we call Q directivity factor that is directivity factor. So, directivity factor is defined like this. So, if I have this I will come back to this slide again later on. So, if I define like this Q is equals to I by I 0 take 10 log of both sides, take 10 log of both sides, followed from here.

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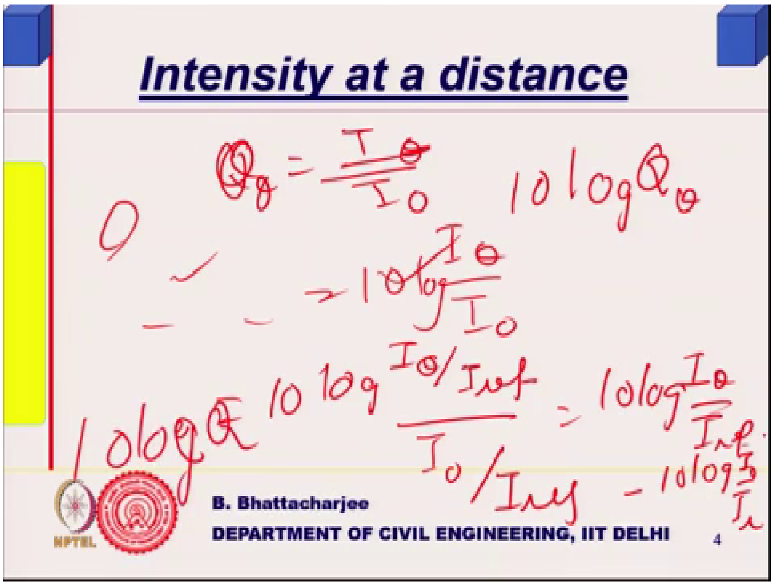

Take 10 log of both sides Q is equals to I by I 0, I theta by I 0. This is the I theta. So, Q theta let me call it directivity factor along any direction. So, this is Q theta take 10 log of Q 10 log of Q theta is equals to 10 log of I theta by I 0 log of sorry log I have missed, and this can be written as 10 log of how can I what can I write. I can write 10 log of 10 log of I theta divided by I reference, this I can write as 10 log of I theta by I ref divided by I 0 by I ref, which will mean that I can write it 10 log of I by I theta by I ref minus 10 log of.

Student: (Refer Time: 10:03).

I 0 by.

Student: I ref.

I ref and what is this, this is S I L 0, and this is S I L theta. So, sound intensity level. Similarly I can write for pressure level also, because it will be only rho c coming in which will cancel out. So, you can write this Q is equals to you know 10 log Q is equals to 10 log Q is equals to 10 log Q log of Q is equals to this, and this is what is written on top of this 1 this is what is written. So, directivity factor is written as 10 log it is written as 10 log, directivity factor is Q is antilog Q would be or 10 log Q is equals to first. Let us write this 10 log Q is equals to SPL Z theta minus SPL 0, SPL theta minus SPL 0.

So, Q would be written as you know this divided by this delta this difference divided by 10, an antilog of that. So, I can find out Q, Q is nothing, but difference in the levels along that direction, and that would have been there, if it was equally going in all direction divided by 10 antilog of that that will give you Q, and we defined that directivity index, what is directivity index this difference we call it directivity index. So, directivity index is nothing, but level along theta direction minus level along equally omitting for a source equal omitting in all direction that is called as directivity index. So, directivity index and, so how is directivity factor, and directivity index related Q that is directivity factor is antilog of directivity index divided by.

Student: 10.

10 directivity index divided by 10. So, that is what it is right. So, that is how we define directivity index.

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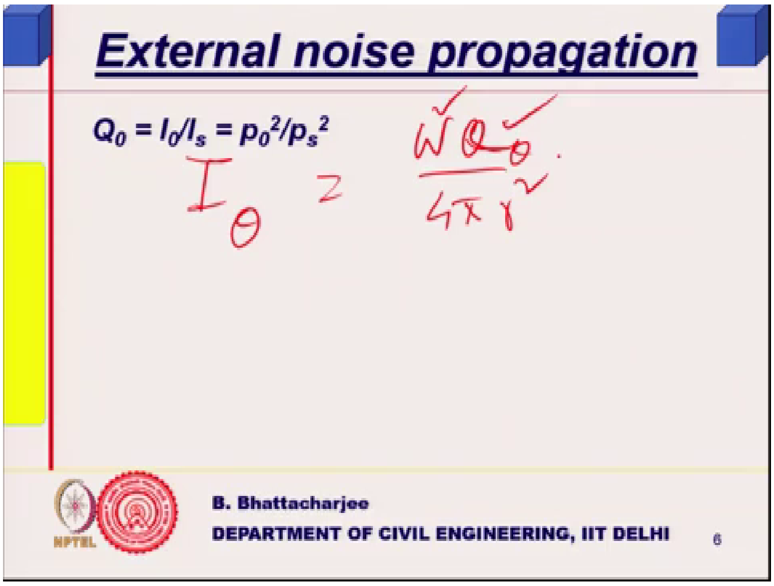

So, let us use make use of this sum what we said that intensity along any direction therefore, would be equals to W Q divided by 4 pi r square. So, if I know the power of the source, if I know the directivity for machines this is known. In fact, they test it in what are called anechoic chambers, the test the direction which direction how much is the intensity that can be tested.

So, one can test that, but noise just like you know, you can actually find out noise just like even from the for, let us say point, I am considering a point not a wall a point the noise coming from the highway side is more than that would come from the other side you know. So, you can actually measure. So, source should be directional going away from the highway as you know. So, you can find out Q for specific cases, and I theta will be given by Q theta divided by this. Now let me define that is what it is.

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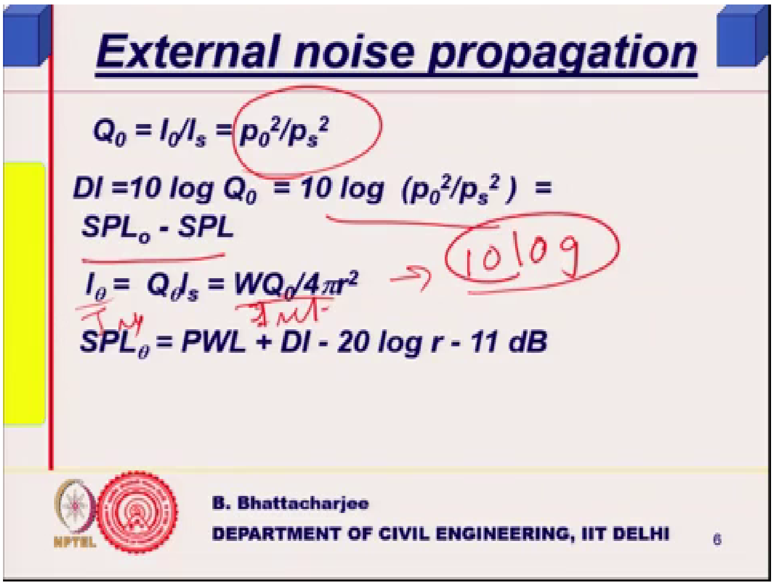

So, I have defined. In terms of pressure also pressure also. So, this is all that I am saying I have already explained this directivity index is SPL 0 minus SPL, and I theta is equals to Q theta I s. So, W Q 0 divided by you know W Q theta divided by 4 pi r square, already I have mentioned this, and SPL theta therefore, would be if I take 10 log of both sides, and first divide by I reference. So, divide this by I reference divide this by I reference, and then take 10 log of this. So, let me not put this now.

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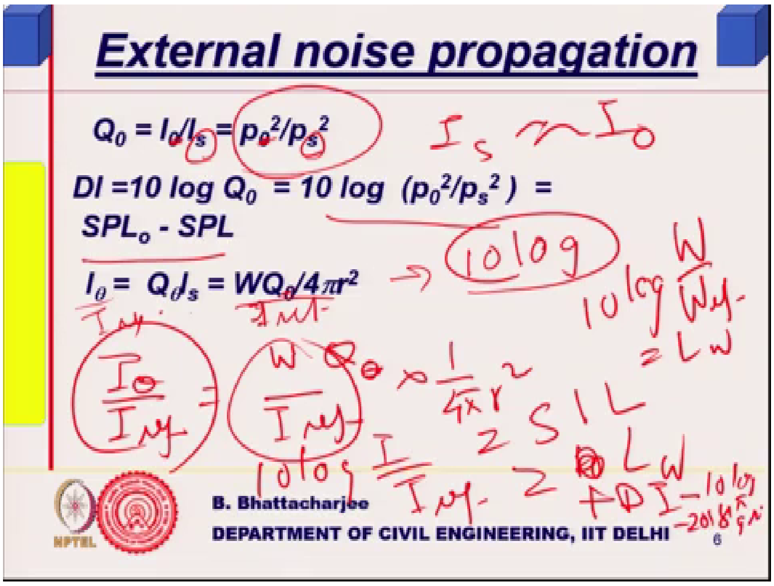

So, I theta divided by I ref would be equals to W Q theta Q 0, Q theta divided by I ref let me call it here, into 1 by 4 pi r square am I; I reference, if I divide both sides by I reference I get something like this. This is Q 0, Q theta, this Q theta, because this should be Q theta Q theta. So, general equation is Q theta into the 4 pi r square, I stands for the source going equally in all direction, I mean this should be theta naught p 0, this should be theta divided by I s, I s stands for what I was talking of I s is synonymously, I am using as I 0 equally in all direction. So, otherwise you might get confused. And this is theta p s, you know this is p s theta square, this is p theta square etcetera.

So, I can divide both side by I reference, I will get something like this, take 10 log of both sides, what will be this if you take 10 log of I by I ref that will be S I L intensity level at any direction at any distance theta, and right hand side W by I ref what is the value of W ref that is also taken as 10 to the power minus 12. So, numerically I ref and W ref are same.

Student: Same.

That is what I told you. So, this if I take 10 log of this S I L will be equals to 10 log you know W by W ref, which I will call as L W 10 log W by W ref remember we call them L W power level of the source. So, this I call as L W, then 10 log Q, 10 log Q is what.

Student: Directive index.

Directivity index I define it like this. So, I will have L W plus directivity index, and what about this minus 10 log 4 pi minus 20 log r. Do I can I write like this, r square 1 by r square. So, 1 by r square will be you know, if I take 10 log 1 by r square, because these are all product. So, I can separate them out. So, if I separate them out I get this expression, which I just try to derive for you, actually just now let me just erase this out.

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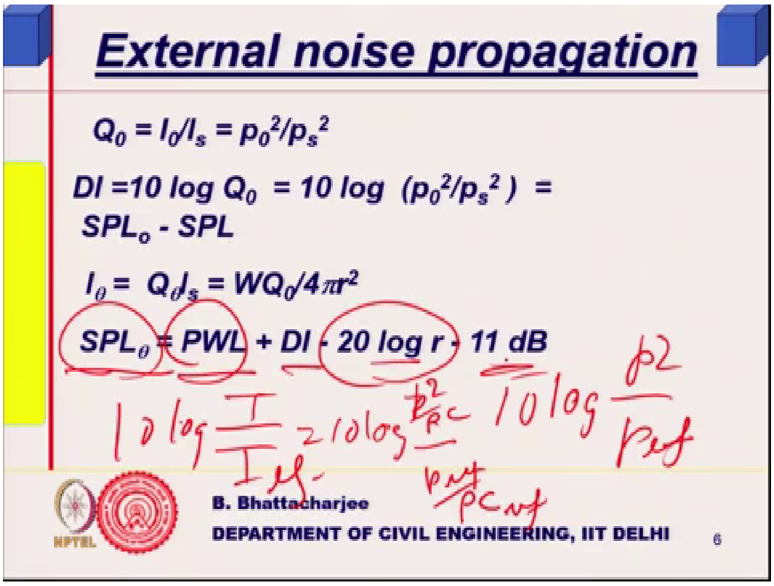

So, this is what I was trying to come back. So, SP you know it can be written as 20 log r and this is related to 10 log.

Student: 4 pi.

Yeah 4 pi. So, 4 pi is if you take 4 pi how much does it come to 4 pi would be 4 into about 12 1 point something, 11 10 log of you know 10 so, 10 multiplied gives you approximately 11. So, it something like this. So, this is power level, and there is a slight difference of intensity level, and pressure level, what is the difference because you remember intensity level was intensity level was I by I reference, 10 log of that and in case of pressure level it will be 10 log of.

Student: (Refer Time: 26:34).

P reference square, and if I write it further, I will write it 10 log I you know p square by rho C, and this will be p reference square divided by rho C standard rho C reference. So, if I rho C reference, and rho C is more or less similar or same, because it is a function of temperature rho is a function of temperature, and velocity of sound in air. So, if they are more or less same, then they will be SPL, and SIL will be same, there is a small difference we generally tend to neglect that and therefore, we are writing straight away SPL is equals to PWL, DI 20 log r minus 11 dB.

So, this is an expression which you would like to use, one thing it shows whatever may be the power level of the source.

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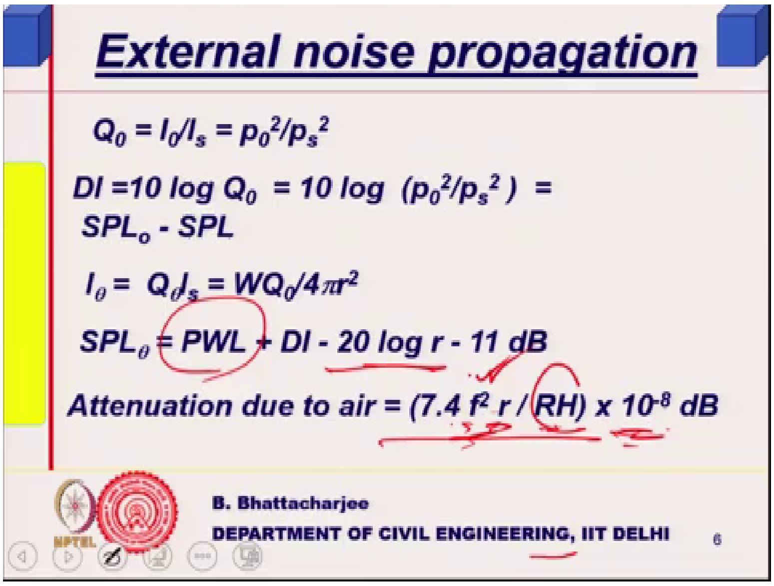

If I increase the distance, my noise level will be less. So, keep your receiver noise sensitive areas, or noise sensitive spaces, as much as far as away from the source. So, external level (Refer Time: 27:49), and this is exactly what to use in town planning as well we will come to that. So, attenuation due to this is one thing, and we have not assumed anything, we have assumed that simply it is attenuating, because it is passing through larger area, from the source there is no absorption by the there is no absorption by the atmospheric absorption we have not taken into account, all that we are saying is that it would be you know dispersing over a larger area now.

So, but there is some amount of attenuation due to air, because this is vibrating the molecules are vibrating about their mean position of equilibrium so; obviously, there will be from frictional losses, there is moisture present in the air. So, depending upon the frequency, higher the frequency air will absorbed more, some energy will be converted into you know other sort of thermal and so on.

And it also depends upon inversely, depends upon relative humidity, higher the relative humidity multiplied by some 10 to the power 8 dB. So, it is a function of r frequency relative humidity into 10 to the power minus 8 dB. So, attenuation due to air is very small, we can neglect it, but if the frequency is high, then it comes into you know it might be 1 2 dB for example, if the frequency is something like 10 k.

So, this this will get nullified 10 k square 10000 means 10 to the power.

Student: 4.

10 to the power 4, and square of it is 10 to the power 8 this will so, and relative humidity in percentile percentage, and you express that and r distance depending upon the distance. So, it might be some value which is comparable to otherwise talking in terms of 50 dB, 60 dB etcetera etcetera, and small frequencies this is not there. So, it is a minor absorption, in totality never the effect is not more than 2 3 percent, you know in totality rural 5 percent. So, we tend to neglect it, but you want to calculate out you can calculate out depending upon the frequencies all right.

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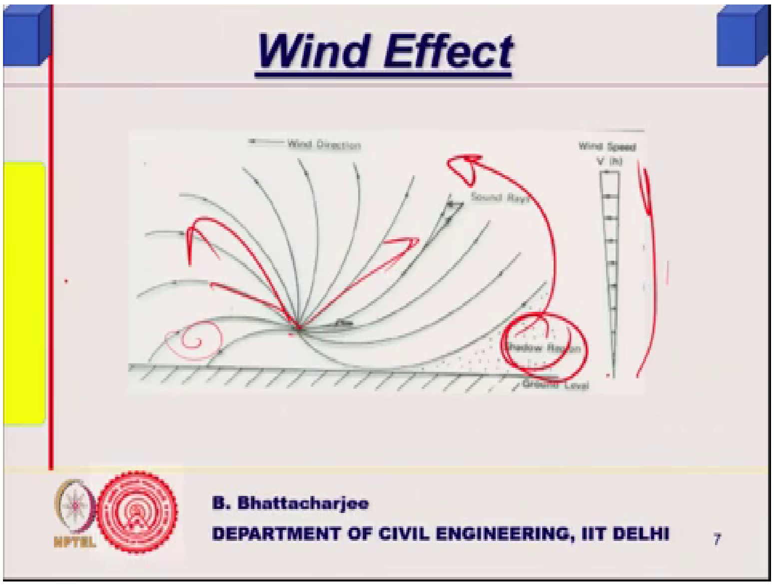

One more issue it is related to effect of wind, you know the velocity gradient is like this, remember velocity gradient we talked about velocity is higher. So, what will tend to do it, will tend to actually bend the spherical wave front in open space.

It should have gone equally in all direction, but since the velocity here is higher here it is less it will have a tendency to.

Student: (Refer Time: 30:34).

Cause a rotation of this. This causes a shadow region here. So, in the window outside of the source and kinds of a excess noise on the leeward side. So, when you are doing town planning or something like that the 1 can keep that in mind. So, the source here the effect will be much less, if the wind direction is like this. So, it will affect will be much less where here it would be higher. So, if ever of course, these days there is no steam engine, but steam engine making that whistle? So, what similar sort of thing you know you keep those sources in leeward direction of the city, industries should be on the leeward direction of the you know residential areas. So, that you get much less.

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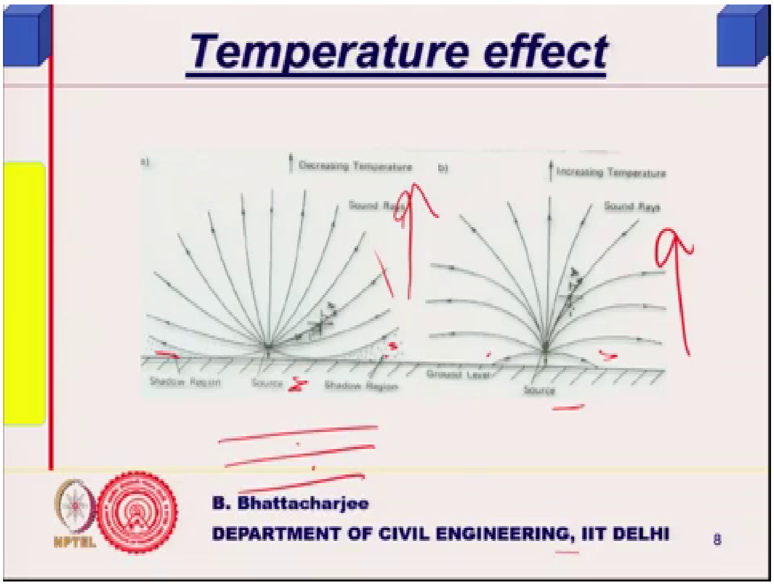

The second effect is related to temperature effect is what happens is as the temperature daytime for example, you know daytime and nighttime. Now, daytime temperature will be high here, near the ground daytime temperature will be high near the ground. And nighttime what will happen temperature will be less near the ground, because it will radiate it out.

So, if the temperature is in decreasing along this direction, density is a function of temperature, you will have higher density at lower temperature as a result the refraction occurs each layer behaves like a you know there are layer of airs then, with different densities. So, refraction of sound would from higher density to lower density, it has a tendency to bent away from the, you know normal. So, what happens is this side my density is higher, it will have a tendency to bent towards the normal, bent towards the normal. So, it will bent towards the normal whereas, if the temperature is increasing along this direction it will have a tendency to bent away from the normal.

So, you find that there is a sound shadow region here, excess sound, sound region here. This might be 1 might keep that in mind for tall buildings very tall buildings, because you might find that in the daytime you know the noise level same source is close to it might be less at the lower floor, might be somewhat higher seeing not brought very large, but somewhat higher in the so, this is other temperature effect. So, we will again take 1 or 2 questions, and then will close for the day. So, look into next what is called barrier. So, one thing before we close essentially distance is a good way to.

Student: (Refer Time: 33:32).

Reduce the noise, but you must keep this kind of a effect must be in mind, must take this affects the direction of wind, if it is a tall building with temperature effect temperature inversion effect, and then of course, directivity of the sound, directivity of the source, itself source itself might be directional. So, distance is a good way, and that is what is used in urban planning, and when within building also you can take that kind of situation into account. So, questions I will take.