Architectural Acoustics
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Lecture – 04
Sound Pressure and Intensity Levels

Good morning everybody. So, today we will going to start the lecture number 4 and the module number 1; in the first week module. So, today we will going to discuss about the Sound Pressure and the Intensity Level. If you remember in the last two lecture what we have discuss is that is the propagation of the sound, we also discuss the frequency and the octave band.

So, now let us proceed further and let us know what is the sound pressure and how it can be measure and how that particular sound pressure and the sound intensity can be mathematically converted to the sound levels.

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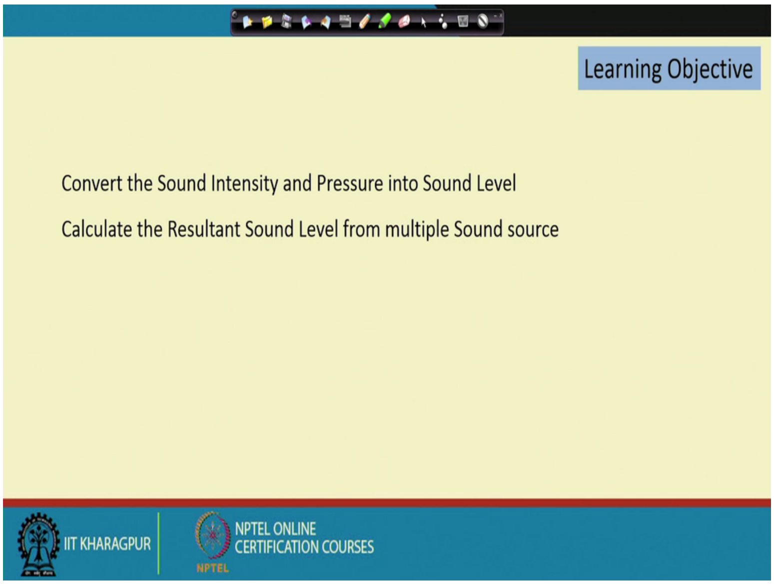

So, in this lecture we have again two objective as a learning objective. So, what you will want to do in this particular half an hour lecture is that, we need to convert or we need to know how to convert the intensity and the pressure to a particular sound level.

And also we will like to know that how can this particular sound levels of from the multiple sources can be added and what will be the result and sound level for that the for the additional all.

So, here we need some kind of operation, some kind of a mathematical operation to know about. And this mathematical operations are well known to you, but that for the starting point of view, let us brush up those mathematical operations and we need here some logarithmic operation.

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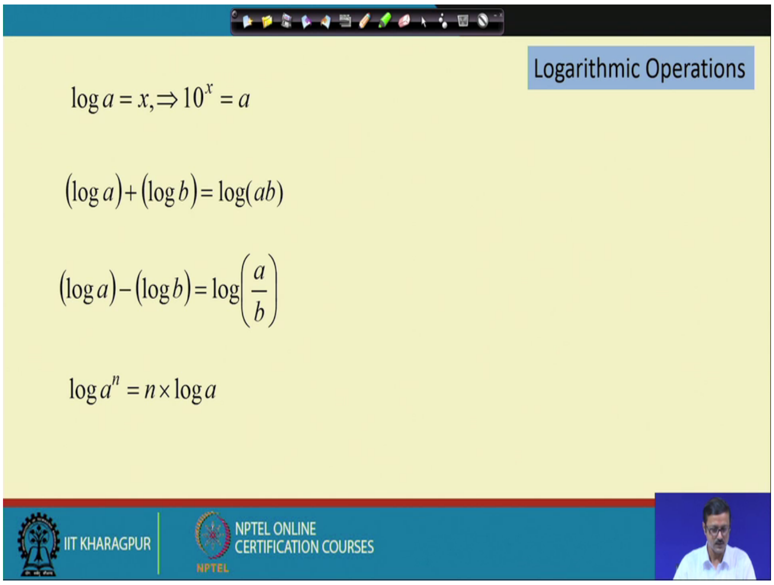

In the logarithmic operation the first operation is something like this, which is also you know that is log a if it is x, then 10 to the power x it is equal to a. The next operation what we also need is that if though 2 log terms are added.

Suppose log a plus log b, it will be log a b. The third operation what we need is that is the subtraction from one to another log; that means, log a minus log b will be reciprocal that is the log a by will b log a by b; and the third or the fourth one and the last one what we need is that if log a to the power n is always equal to n into log a.

So, this four basic operation of log will be required to understand the basic principles of the sound pressure level and the sound intensity level.

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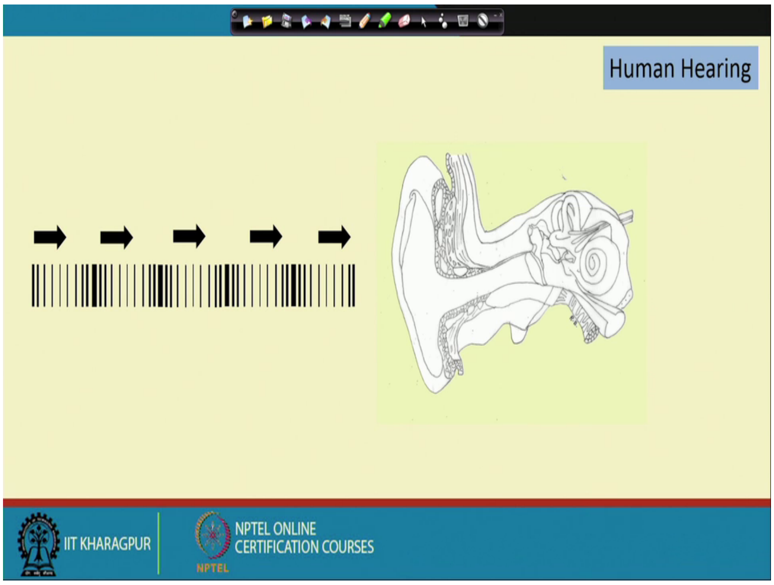

Now, let us know how we actually here human hearing.

So, what we see in this particular board is that the cross section of human ear. You must have seen this particular cross section of the human ear in your school days in your biology book. So, here as we understand from the first lecture is the sound is a wave transmission, and that wave transmission gives in the ear in a multiple layer, which will some layer will be compressed and the next layer will be radar fact or the extend and it will move from one point to the other.

So, when it moves from one point to the other, the wave propagation towards the if it is towards the ear it will enter into our ear and how it will actually sense the brain, let us discuss that.

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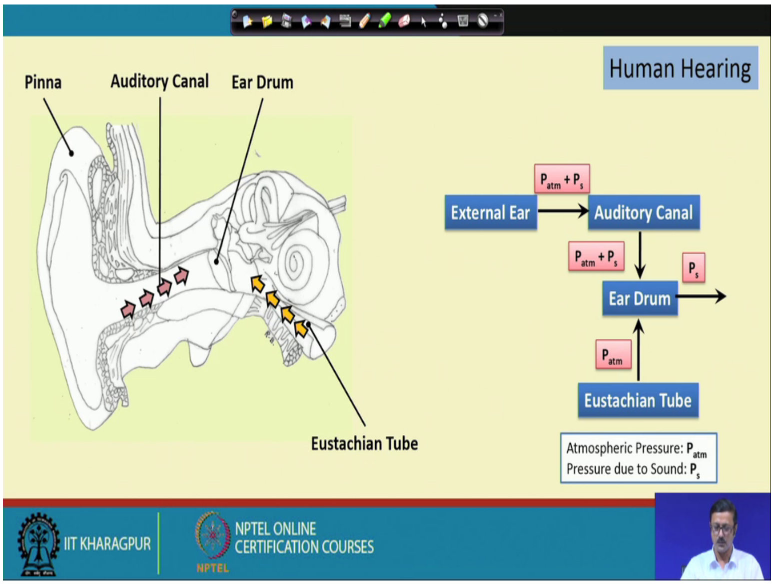

Suppose this is the ear cross section, the similar ear cross section and it has some part. So, these four parts are may be the first three parts are called as a the outer ear part, which is has a pinna which is like this and then there is a auditory canal over there and then auditory canal is actually terminated to the eardrum.

And if there is a particular propagation and if I am showing it in a flow chart diagram, the external ear that is from here, the pressure which followed by a follow the path of the auditory canal and it will strike to the eardrum. And the total pressure of the particular channel or the canal auditory canal is equal to the atmospheric pressure plus the sound pressure.

The P atmospheric plus P s and it will strikes to the ear drum. And there is a another cannel or another tube that is there in through our mouth to the to the cannel. So, that is called as a the eustachian tube and this eustachian tube will only take care of the atmospheric pressure, and it will also proceed to the ear drum. If you see I have animated a bit, this particular this the red arrows or the pressure from the air pressure that is the atmospheric pressure and the sound pressure and another the yellow arrows from the eeustachian is the only atmospheric pressure.

So, the ear drum basically under two different pressure scenario, one is P atmospheric and plus P sound and from other side it is P atmospheric. So, finally, the ear drum will vibrate because of the resultant pressure of that, that is two the P sound pressure that is the two mutually perpendicular and opposite directional not perpendicular, mutually in a in a in a linear and a opposite indirection. So, the sound pressure, will the P s will actually vibrate the eardrum. What happened in the next operation is that.

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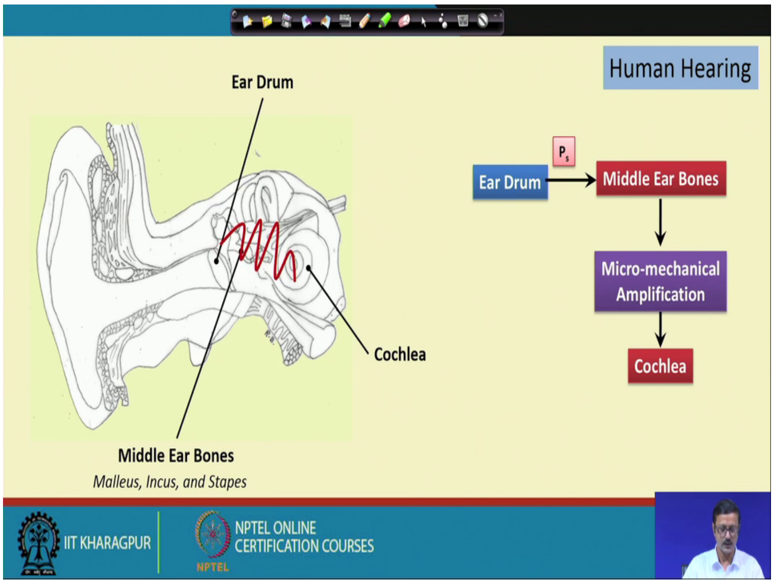

So, this ear drum is connected by the three is middle ears very small bones and there are three bones malleus incus and stapes is linked one after another, and that is actually transmitting the transmitting the particular the three ear bones to the cochlea.

And cochlea is full of some liquid or so. So what happened is that, when this ear drum is vibrate by the sound pressure it will going to vibrate the middle ear bones this three bones and there is a micro amplification, micromechanical amplification I must say, because this is a three bones are a hinge together and it will be the amplify the thing and it will be actually impulse has been provided to the cochlea.

And this three are the bones and the cochlea are called the in interior part of the ear and then finally, cochlea sense that, cochlea sense that and then it is the behind the cochlea there are auditory nerves.

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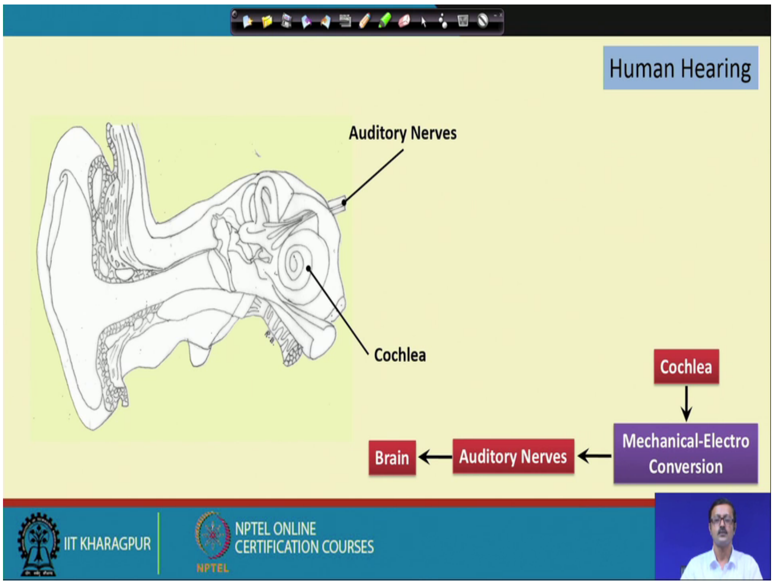

So, there the cochlea sense that particular vibration from the three middle ear bone and it provide the some mechanico electrico kind of a conversion, the mechanical to the electrical conversion and this electrical sensor pulses through the nerve it will sense in our bend.

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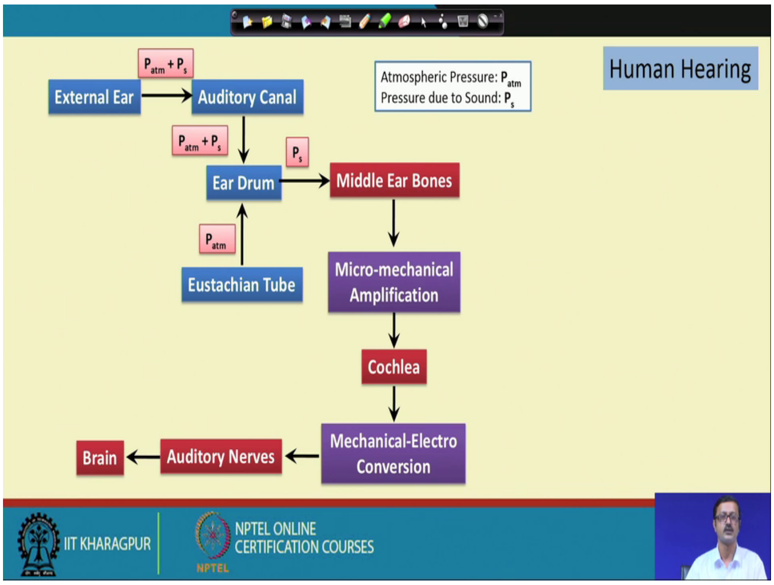

So, this is at a go, we can actually again see that particular flow chart. So, this is the ear drum vibrate by P s that is the pressure from the sound, sound pressure than middle ear vibrate micromechanical amplification gives to the cochlea, from the cochlea a mechanico electrico conversion and then it is going through the auditory nerve to the brain.

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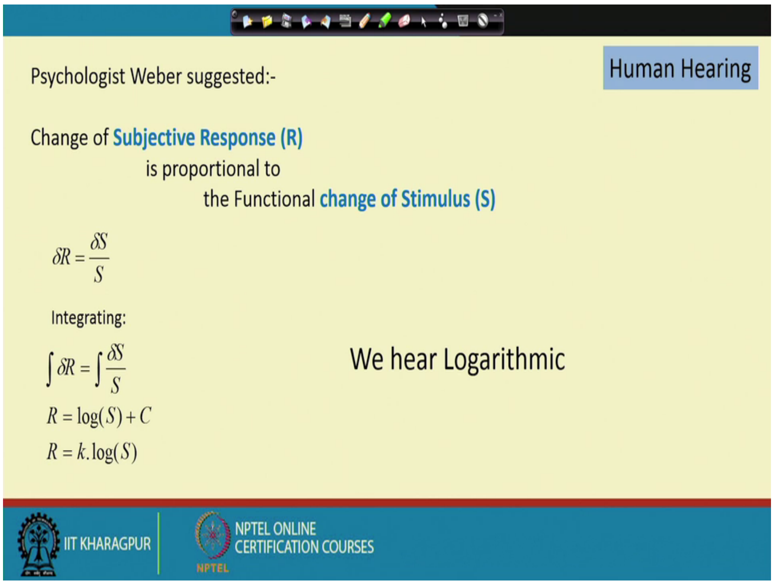

Now, next is let us see the how the brain and our sensation of the sound is perceive by the brain. A psychologist Weber suggested this particular phenomena or this particular proposition, that is the subjective response is the function of change of stimulate is proportional. So, if it is proportional.

So, if it is something like a the change of responses R, this response may be the weight, this response may be the light, there is a slight change in the light whether I can identify that particular change or not. If there is a weight in my hand I just increase a bit of extra weight can I sense that one that is the stimuli the change of the stimuli and the R is the sense.

So, mathematically it can be expressed as the change of R is equal to change of stimuli by the act the initial stimuli that is the cap S. If I integrate then this two side, then I will get a mathematical expression like the R is equal to log of S and there is a integration constant are C and then further, this integration constant C can be clubbed into this logarithmic part also, and then we can write that R is equal to k times log of S.

So, this is a particular way the human being sense for weight for any scenario like a light or may be temperature or maybe the sound.

And we see that in the sound in case of a the auditory case auditory sensation, we can sense the very minute change not in a specific way, but if there is a change in a bigger order then it may be sense in a better way. And this particular change is very much adopted or very much sensible if the frequency or the level of the sound is in the lower order.

This particular change the same change if it is in a higher order, we may not sense that one. So, that is why we can say finally, that a human being or a we here logarithmic. So, the expression of the sensation that is the sound pressure or the sound intensity finally, translated to a logarithmic scale and that will give us the sensation, what we have just now discussed or the see from this particular Weber's proposition.

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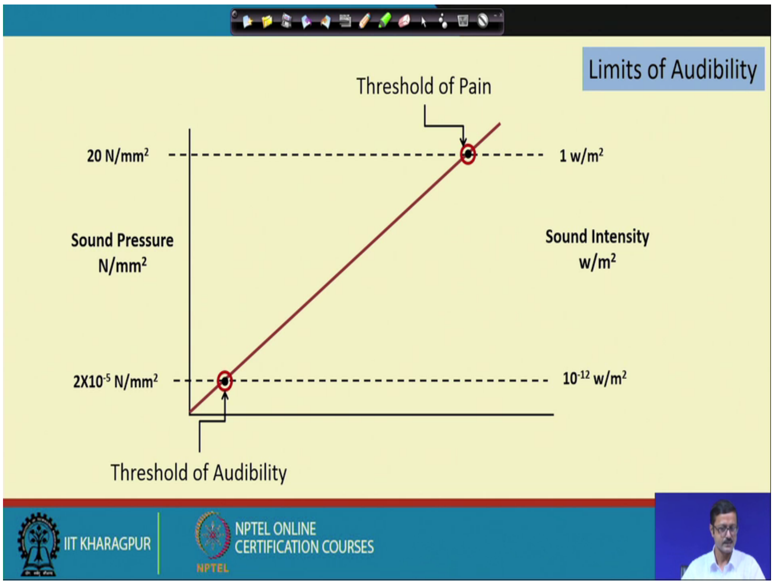

So, let us take a graph and in the y axis let us have the sound pressure starting from 2 to 2 into 10 to the power minus 5 megapascal 220. So, it is a huge range huge range. So, (Refer Time: 10:35) almost 10 to the power 7 a 6 times of the sound pressure changes and in a another side let us write down the sound intensity and as you know the intensity is the watt per meter square or the power per particular square print of the foot print of the area.

So, they are also it is equivalent to 10 to the power minus 12 watt per meter square to 1 watt per meter square. It is almost about 10 to the power 12 times higher from the lower to the higher level. And if the sensation or the sound pressure which is actually followed and to enter to our the enter to our ear is at around 2 into 10 to the power minus 5 Newton per mm square or in the intensity terms 10 to the power minus 12 watt per meter square.

We start hearing that is the minimum amount of the intensity level or the minimum amount of pressure sound pressure is needed to the human being to hear some sound and that is why it is called the threshold of audibility. So, if the sound pressure level is below that, we cannot response that the to that particular sound. And if it is higher than 2 to the power 10 to 2 into 10 to the power minus 5 yes we hear better, and further better if the intensity and the sound pressure is further up, but there is the limit.

If the particular pressure is 20 Newton per mm square or the intensity is 1 watt per meter square, then it is start paining to our eye paining to our ear and that is very very comfortable, and that particular point or that particular intensity is called the threshold of pain it is the discount foster.

Sometimes it is also referred as the threshold of this discomfort and further it may go further, it may go further 10 to 12, 12 to 15 percent further, but it will start giving lot of problem to our ear and finally, the ear drum may rapture and that is going to be a serious concern.

So, we will try to limit our the hearing pressure level, this 2 into 10 to the power minus 5 to 2 20 and the intensity level 10 to the power minus 12 to 1 watt per meter square. Now, this are the some physical factor or the physical parameter, we have to translate this physical parameter to a sound pressure level or the sound intensity level.

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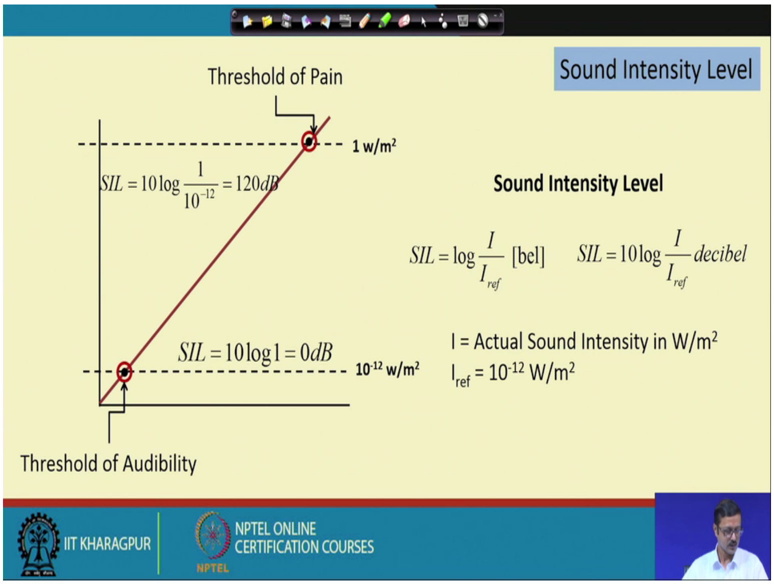

So, let us see the what is the sound intensity level. So, this graph and in this graph what happened is that, the sound intensity level which is called as a SIL is defined as logarithmic of I by I reference and if it is so, it is called bell and if it is 10 into logarithmic of I by I reference it is called disable.

Now, what is I and what is I reference let me see. The I reference is the minimum level of the pressure or the intensity, that we required for the threshold of audibility. So, this is that particular 10 to the power minus 12 watt per meter square and what is I? The actual intensity of that of the sound; so, suppose I am going to calculate some intensity which is in between 1 and 10 to the power minus 12. So, that suppose 10 to the power minus 5.

So, the I value of I will be 10 to the power minus 5 also. So, here from here let us see if the if the if the sound pressure is 10 to the power minus 12. So, then it is 1 this logarithmic value is 1 the log 1 is 0. So, the it is 0 decibel almost no sound just starting of the audibility. And if it is the higher suppose it is 1.

So, I put 1 over 10 to the power minus 12 over here, I may say take the logarithmic and multiply with 10 this is 120 disable. So, it is painful its threshold of pain is 120 almost we may go up 240 also and this is very much painful and very much not that much that the hygienic and the peak going to rapture the ear drum or so.

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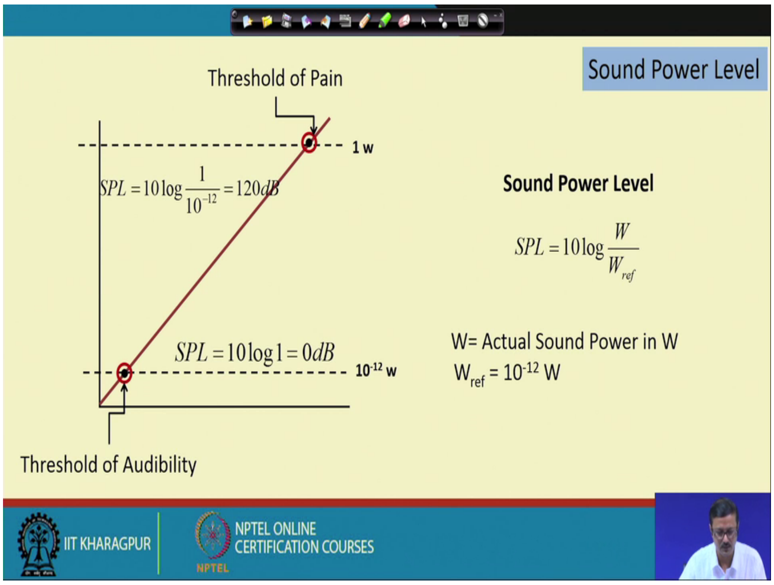

Very similarly we can find out the sound power level also. Sound power level is also define in a same way in a decibel scale log of W by W reference into 10.

And this W reference is 10 to the power minus 12 watt because power the unit of power is watt, and it goes up to 10 the 1 watt or so, where there is a (Refer Time: 15:36) and if you convert the same way it is 0 and 120.

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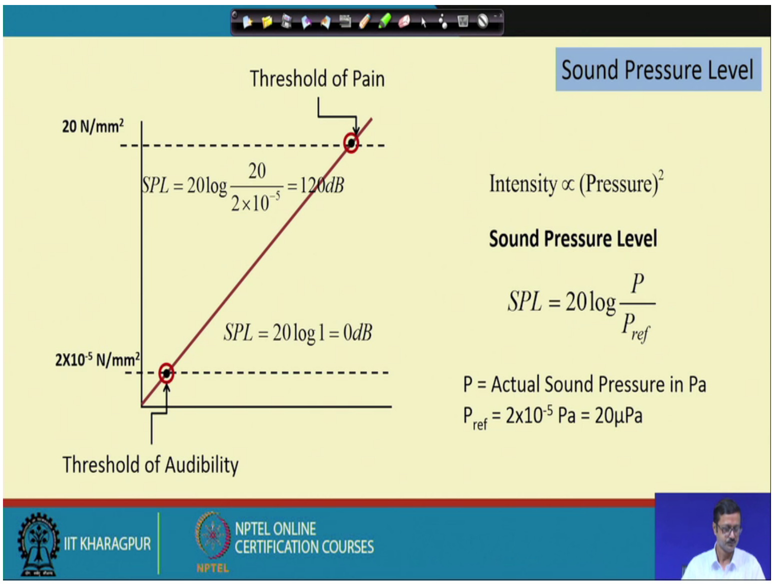

Now, let us see the sound pressure level which we have just discussed in the first graph. The sound pressure is again fluctuating from 2 into 10 to the power minus 10 to 20, and sound pressure level is defined as not 10, but 20 into logarithmic of P by P reference as the intensity and pressure is related with the proportionally is pressure square the intensity is proportional to the square of the pressure.

So, how it is we will discuss in the fifth lecture and how it is actually the proportional to the pressure square. So, here also the similar manner we can find out the our P reference is that the minimum, which is the threshold of audibility which is 2 into 10 to the power minus 5.

The P the whatever may be the value of the pressure that I will put over here, and if it is 20 that is the highest level if I put 20 by 2 into 10 to the power minus 10 log and multiply by 20 its gives me 120 disable. So, by virtue of this if I go back and then we have derived the intensity level, we have derived the power level, we have derived the sound pressure level and all are in decibels.

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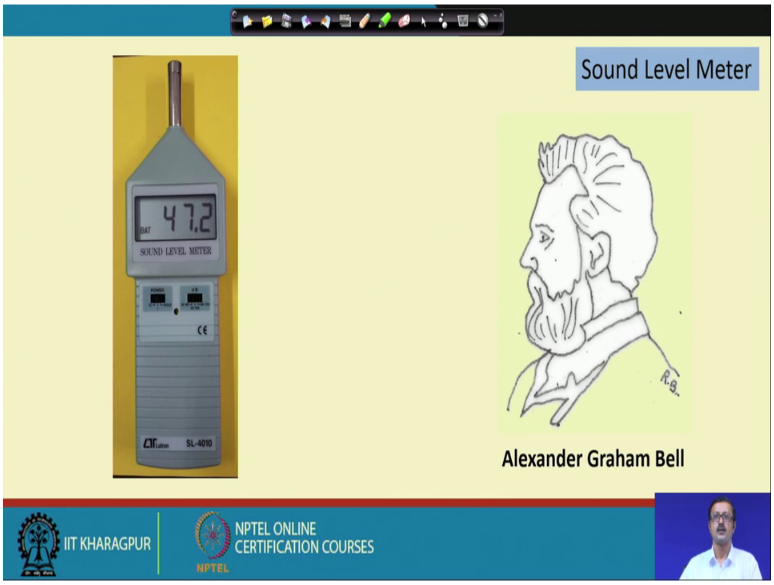

So, the y decibel y decibel because the we everybody knows the Alexander Graham Bell on the honor to his name honor to his scientific development in our the world community we have or the scientific community has proposed the unit of the sound pressure level as bell or decibel.

And in the left hand side you will see that from instrument, which is the sound level meter and the sound level meter is used for the measuring the sound level that is in decibel or so.

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So I have a sound level meter with me and if you see this sound level meter it has a power button. So, you have to switch on the power button and then there is a the range you can said the range, we can said the range from the minimum to the medium to the maximum and there is a microphone attach to this particular the arm on the top and as you see I am speaking. So, this is going to be some kind of the sound pressure level.

Now, it is 65 70 68 68 62 like that. So, some sound it will catch and then it will going to give you the sound pressure level directly.

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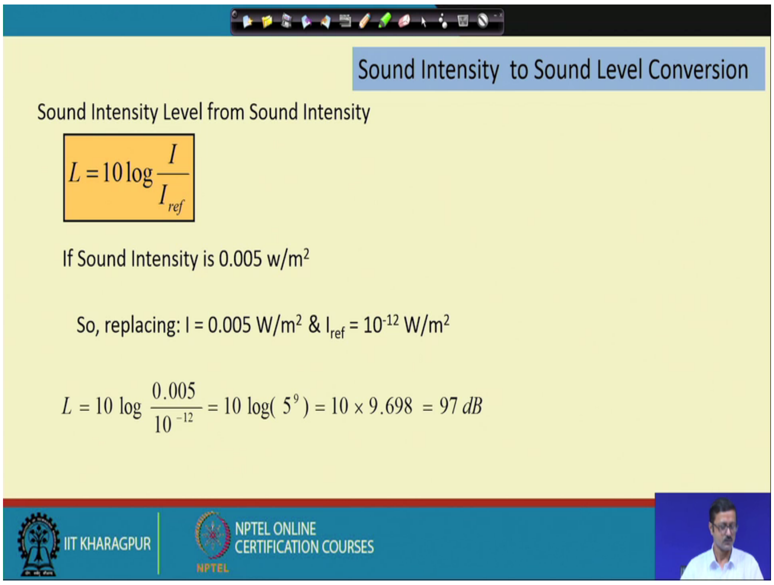

So, the sound intensity to the sound level conversion; So, now, let us play with those formula and see how the sound intensity and the sound pressure and the sound pressure to the intensity or those levels can be taken into consideration. So, here in this slide we will discuss the sound intensity.

So, the sound level conversion so, as we know this is the formula the level L is equal to 10 into the logarithmic of I by I reference. So, I have a small small very small problem that suppose the intensity is 0.005 watt per meter square what would be the intensity.

So, as you put it everything in the value, everything in this particular every value in the particular formula and the get the ratio and multiply with the 10 log and multiply with the 10 and you get 97 dB which is pretty high.

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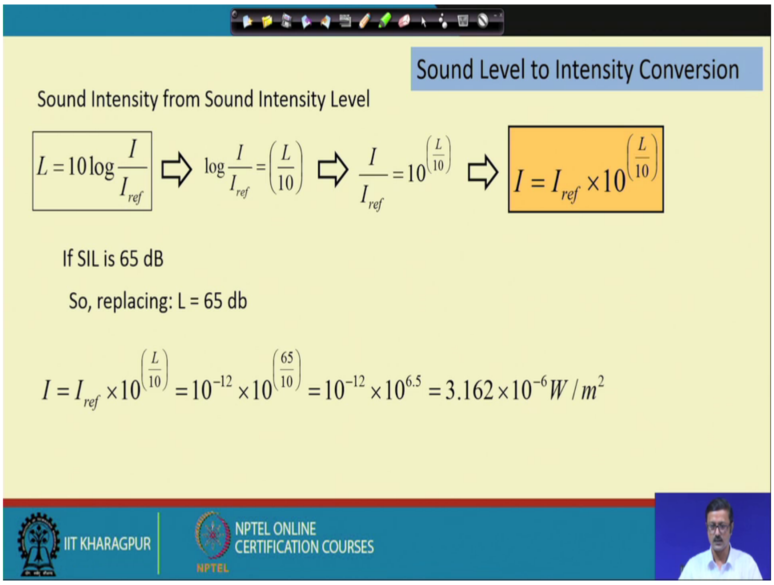

Then the reverse order the sound level to sound intensity conversion. So, the sound level to sound intensity conversion you have the same formula and from the formula, you derive like the then the log of I by I reference will be by 10, because you see the if you just go with this formula and then if it is I by I reference will be 10 to the power L by 10 and finally, I am interested to find out the I. So, the I will be equal to I reference into 10 to the power L by 10.

I reference we all know that is 10 to the power minus 12 and l is the sound level that is dB how much is the decibel that you can put and finally, we can find out what is the value of I. So, suppose a SIL of the sound intensity level is 65. So, I will put 65 over here. So, finally, it is 10 to the power 6.5 and the I reference is your 10 to the power minus 12. So, finally, this is the watt per meter square that is the intensity.

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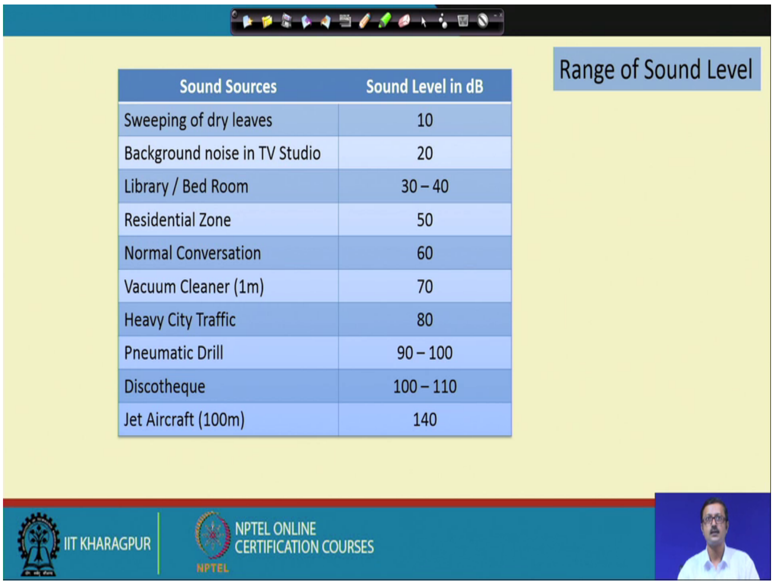

So, I have listed down some intensity or the sound level in fact, in the dB just to give you a kind of a idea that what is the dB that exist in our day to day life. You sweeping of the dry lips is very very low level of or the sound which is around 10 15 or so, background noise in the television studio where there is kind of a broadcasting or may be telecasting is of a happening over there, we required very low amount of sound level which is prescribed as 20 decibel.

Library, very quit area, bedroom very quit area 30 to 40 is recommended, residential zone recommended as 50, now normal conversation which we are doing now it is more or less 60 we have seen in this sound level meter 60 to 70 it is fluctuating. Vacuum cleaner, vacuum cleaner is a sound produce producing the equipment which is if you in front of 1 meter of that particular vacuum cleaner gives you around 70.

Heavy city traffic is 80; the pneumatic drill is very bothering sometimes it is the 90 to 100. The discotheque it is the noise area very noise area in fact, and it is almost touching to the threshold of pain sometimes it is 100 to 110 and if it you if it is very near to jet aircraft, around 100 meter net to jet aircraft it is really painful 140.

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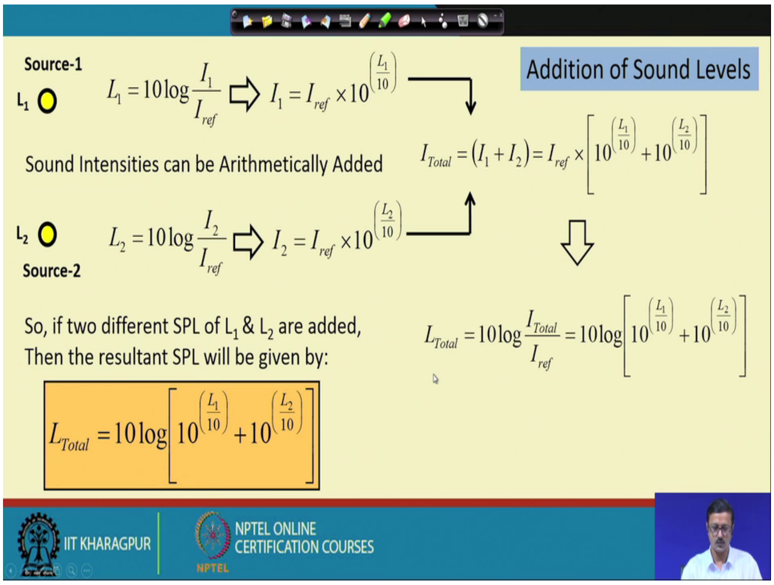

Now, let us see the how the addition of sound levels can be done. So, I actually have to encounter or in a in a in a any kind of a sound physicist has to encounter different sound level multiple sound level. So, here we will discuss the how this two sound level can be added together and in a logarithmic way.

So, sound level 1 is having a level 1 L 1 dB. So, that can be translated to the I 1 as you know there I reference by 10 to the power L 1 by 10, and there is a sound level 21 or sound source 2, which is available L 2 and that is also give you a I mean very similarly I 2 equal to I reference into 10 to the power L by 10. L 2 by 10 and this sound intensity can be added arithmetically, not the sound levels that is the decibel cannot be added the arithmetically.

So, suppose there is a 60 decibel and there is a 40 decibel you cannot add and say it is a 100 decibel. You have to actually transferred the 60 decibel to the intensity its the respective intensity and the 42 its respective and then you add the intensity arithmetically and convert that intensity to the decibel.

So, here also I have to now add this arithmetically I 1 and I 2 and then this I 1 and I 2 gives me the a new I total the new intensity, and then I will put it into that and finally, the value will be like L the total intensity is this and the total level. Now, you will be or the final level will be now will be the this comes from the first part intensity 1 and this is comes from the second part intensity 2 and if you provide in the I total by I reference you will get the total intensity.

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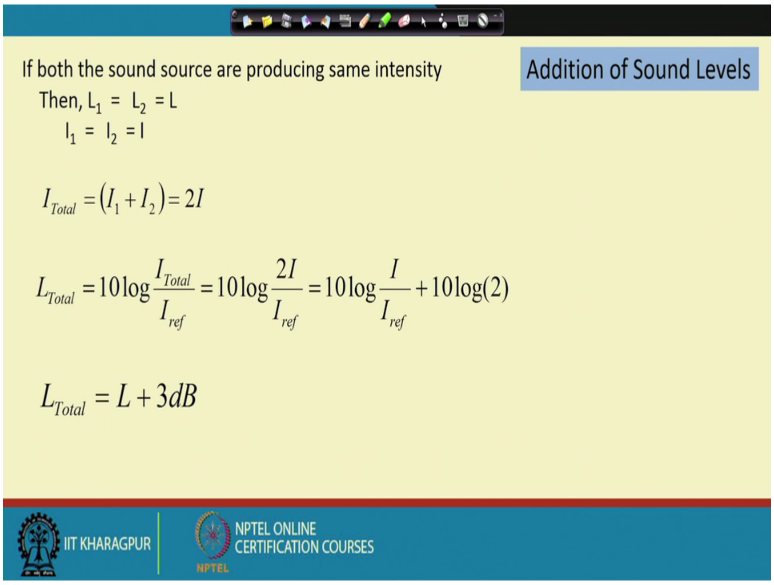

Now, addition of the sound level again let us further say that if this two levels L 1 and L 2 which we have just now discussed is similar. So, there are two sound source give the similar output. So, L 1 is equal to L 2 and that is equal to L; so, definitely that the intensity of I 1 and I 2 also will be similar.

So, the total intensity of the 2 y twice of I and finally, it will give instead of in place of the total intensity is now 2 I by I reference; now we can separate it out, one is the 10 log of I by I reference plus 10 log of 2. So, what is this? What is this 10 log of I by I reference it is nothing, but the anyone of the level.

So, this is the level which I am going to add plus 10 log 2 is log 2 is 0.3m and 10 log 2 is 3. So, if two sound source of equal in nature equal output equal decibel level is added, suppose 30 and 30 is added. So, the resultant will be 30 plus 3 33. So, that its what tells about.

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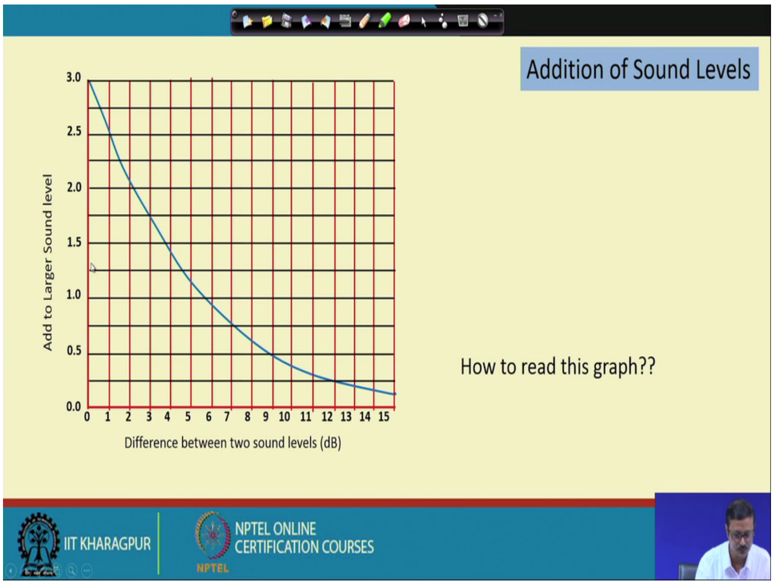

So, next we will see the sound the addition of the sound, addition of the sound also can be infer from this particular graph, but how to read the graph. This in the x axis it is the difference between the sound level is given and the y axis the addition will the at to the sound sources it is also given.

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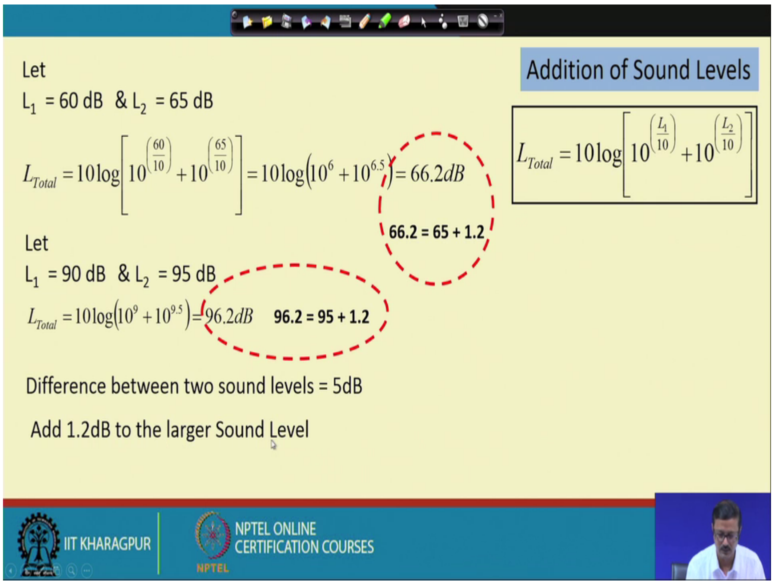

So, let us go to the a small problem, where I am adding a 60 decibel sound to the 65. So, by virtue of this particular expression, I got 66.2. Another example I get 90 and 95 and I express that in the mathematical form and I am getting 96.2 I am getting taking the help of the previous equation. Now, what I see is that in the both the case it is a similarity what is this similarity? 62.2 66.2 is nothing, but 65 plus 1.2 what is 65? 65 is the out of this is the higher one 60 and 65 the higher one is 65.

So, 65 plus 1.2 and what is this? 96.2 is 95 plus 1.2. 95 is what the higher of this two. So, if the difference between the two level of sound is 5 dB add 1.2 dB for the largest sound that is actually translated over here.

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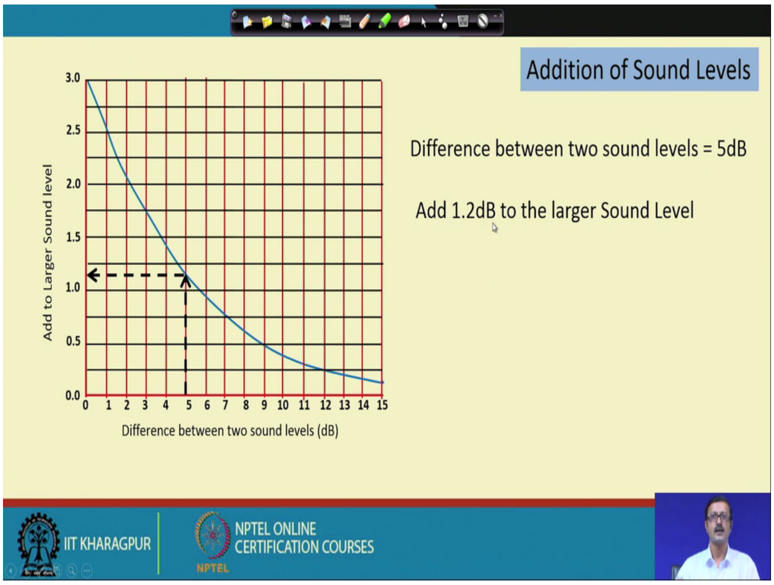

Suppose the difference between the two level of sound is 5 dB of my I mean previous example, you go from the x axis to here and then you go here. So, add 1.2 1.0 this is 1, this is 1.25 so, 1.2 to the larger sound.

So, if there are two sound which are equal in nature. So, there is no difference. So, the higher and lower there is no difference. So, difference is 0.

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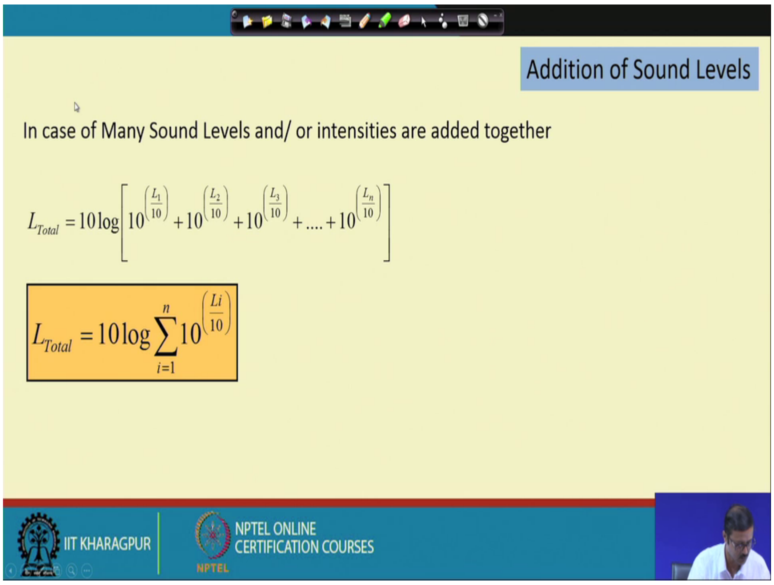

So, you have to add sorry you have to add 3 dB 3dB with that that we have already discussed in the previous to previous slide.

And if there are n number of sound sources suppose it is not to two there are more more L 1 2 3 4 more, then we can just rewrite this particular equation in a this way and finally, which is summation sin, we can find out the what is the total logarithmic or total logarithmic and finally, multiply by the that into 10 to the L total or the level total level.

So, at the end of this particular lecture number 4, let us have some homework for you.

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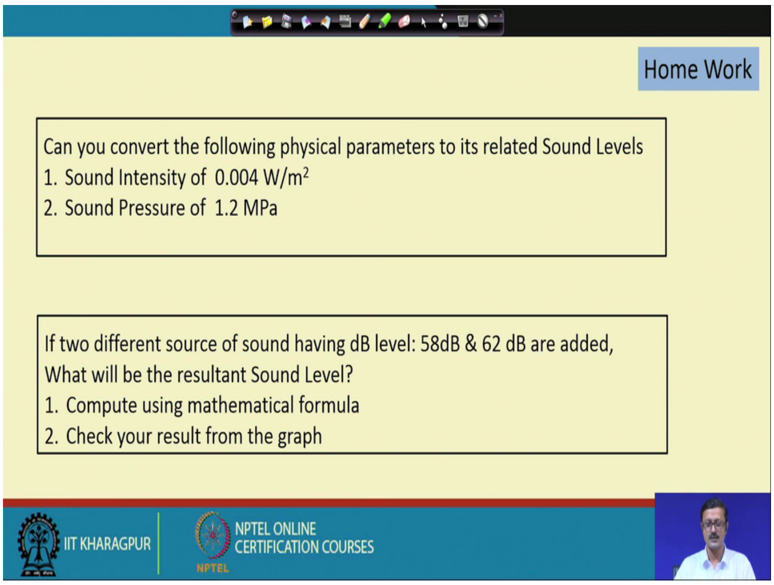

The first one is that the intensity of the sound if it is 0.004 watt per meter square and suppose another sound is of the sound pressure of 1.2 megapascal, can you can you find out the related sound levels. These two are not equal, but we have to find out for one also, we have to find out for the second one also. So, just go to the previous slides find out the how to convert and while converting in have to remember one thing, that is when it is intensity and when it is power.

So, it is 10 log and when it is pressure it is 20 log and it is the intensity, which I am going to take for finding the level divided by the threshold that is for pressure it is 2 into 10 to the power minus 5, for intensity it is or the this thing it is 10 to the minus 12.

There is a second homework also, suppose I have two different sound levels from two different source one is 58 dB and one is 62 dB. So, if they are added. So, what could be the resultant sound level? So, you have to do the this thing by mathematical computation with the mathematical the formula, do it by mathematically and then check your result from the graph, that the graph we have discussed from the graph and finally, match your result.

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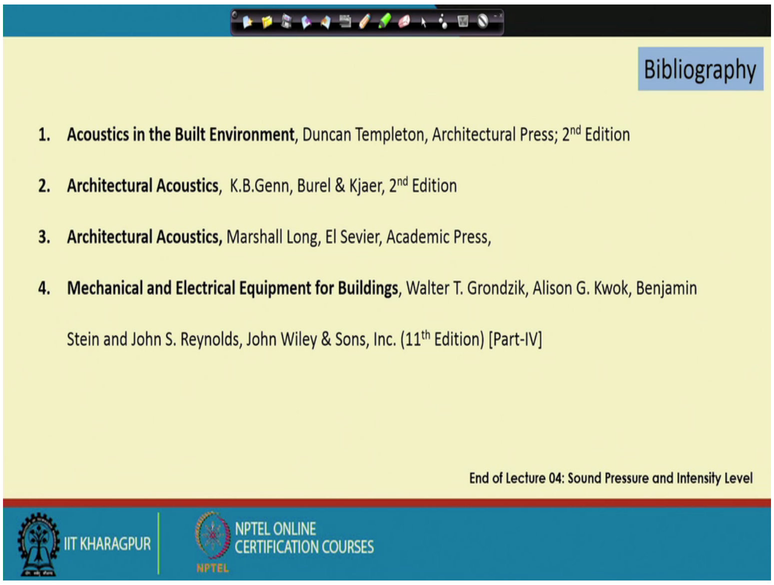

There are some bibliography, there are some books has to be referred for this particular lecture and those are the books you can find it in the library or maybe we can go to the some library and get some books are available in E format also.

So, thank you for joining in this lecture number 4, in the next lecture we will go to the that will be thus the last part of our acoustical physics and we will discuss something and on the near and far field propagation and also the loudness.

Thank you.