Basics of Noise and Its measurements
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Lecture – 06
Adding Decibels

Hello again, welcome to this module on Basics of Noise and its Measurements.

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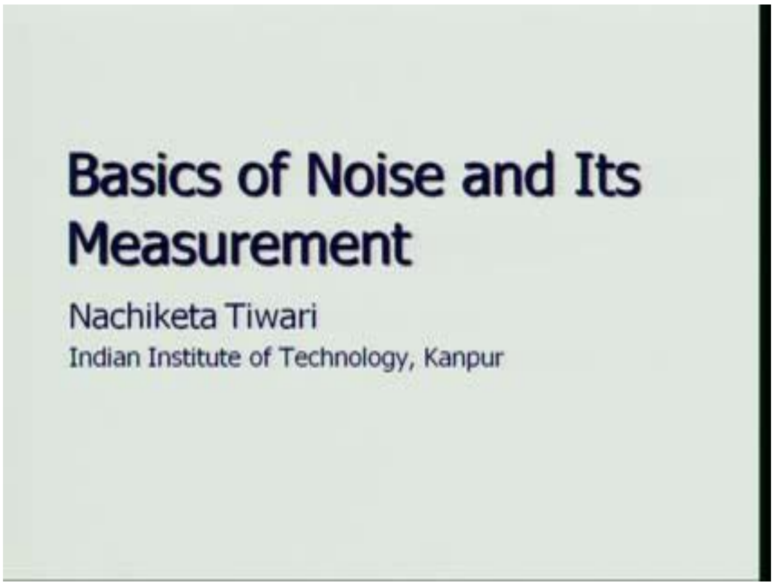

In the last module, we had discussed about the decibel scale, octaves and important terminology related to acoustics and noise. So, what we are going to do today is, figure out how do we add decibels? What is that mean?

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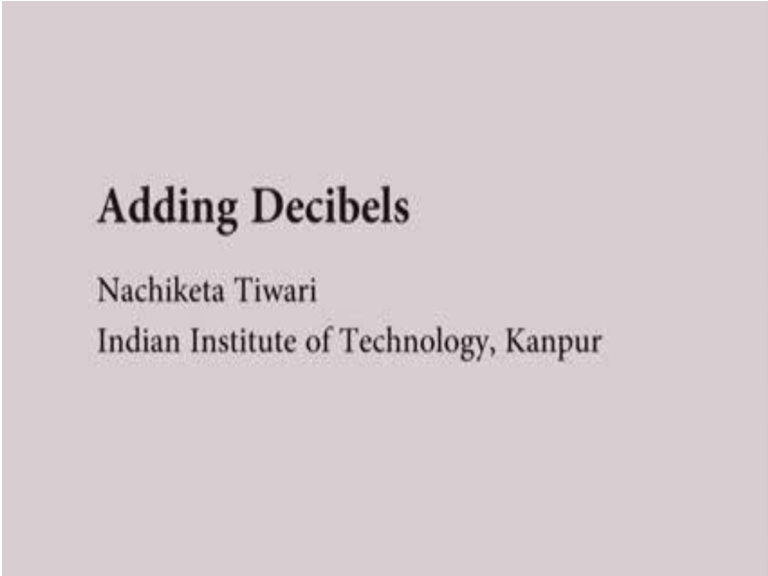

Suppose, I have 1 particular source of noise and I have another particular source of noise, and let us say the decibel level from 1 source is L 1 and another source is L 2 and then if I play both these sources together, what will be the overall sound pressure level in the room? This what the question is going to be, and quite things related to that. So, that is what we are going to discuss in today's lecture.

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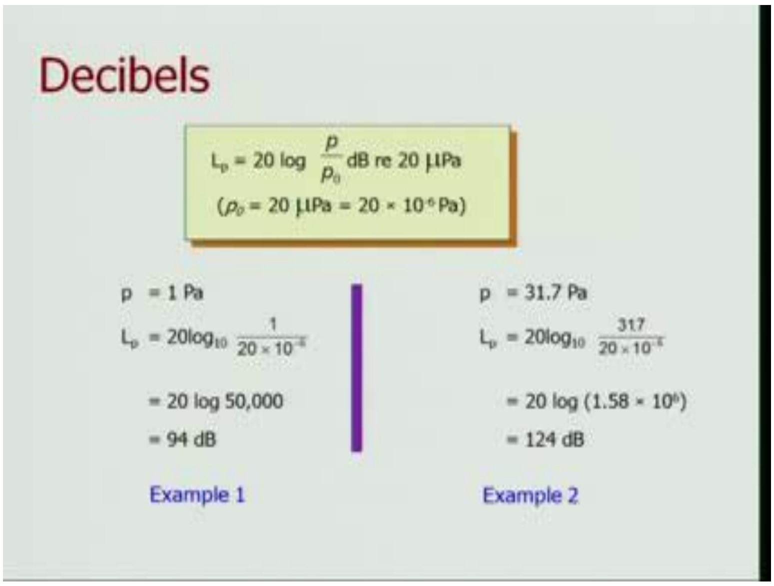

So, let us look at the definition of decibel once again. So, if we are talking about the sound pressure level, that is Lp then is defined as 20 log and when I say log its log on base 10, 20 log of p which is the pressure, RMS pressure divided by p naught which is the reference pressure then in decibels and the reference pressure if the medium is air is 20 micro pascals. Now, at this stage I wanted to make one important clarification. That this p here which we are talking about is the value of RMS pressure, what does that mean?

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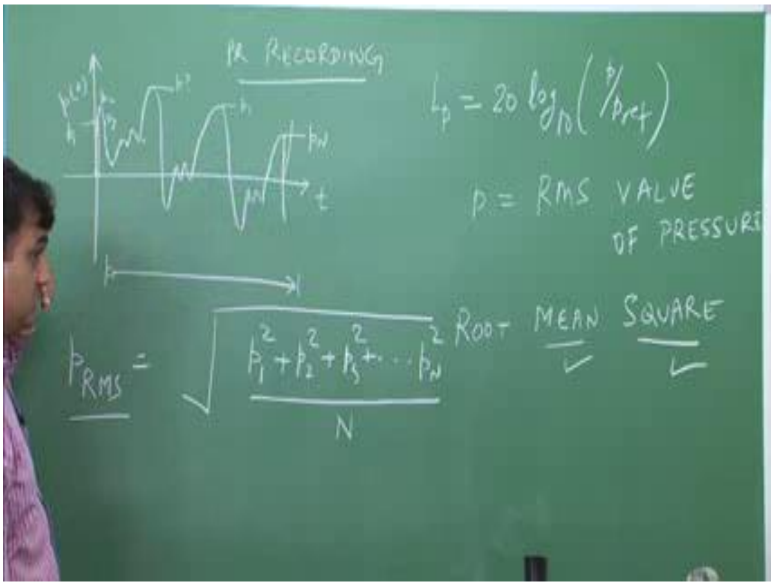

Suppose, this is my pressure level and let us say I am measuring, and let us say this is my pressure recording. So, when I am going compute decibels or Lp, the question is. So, this is the formula p over p ref. I take the log of it on base 10 and then multiplied by 20, I will get pressure. So, the question is. Is this the value of pressure? Or is this the value of pressure? So, which pressure I am going to putting in, in this formula?

The answer to that question is that this pressure is actually RMS value of the pressure. So, that is the RMS value of pressure. How do I calculate its RMS? Well, what I do is, that I discretise, I break this data into small points. So, this is p1 this is p2 this is p3 and so on and so forth. I break it up into a very large number of points. Suppose I want to calculate the decibels corresponding to this whole time period. So, I break it up till I get to this time period, and say let say this is pN. So, RMS is stands for Root Mean Square and that is how I am going to calculate, the value of RMS.

What I will do is first I will take square. So, p RMS, first I am going to square up all the pressures p1 through pN. So, I have done the square thing, then I am going to take the mean or their average. So, I will divide it by n. So, then I have done, taken the mean also and then I am going to take the square root of this entire thing and that is the value of p RMS.

It is important to understand that if I have data like this, and I have to calculate decibels I have to calculate RMS value of the pressure. That RMS goes into this formula. I divide that p RMS value by reference pressure, which is 20 micro pascals and then I use this formula to calculate the sound pressure level. For and this is only for sinusoidal waves.

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For sinusoidal waves, p RMS is equal to p max over square root of 2. So, it is important to understand that only for sinusoidal wave the RMS value of pressure is maximum pressure divided by square root of 2 this factor changes based on the shape of the wave. For this wave it may be something totally different we do not know we have to actually calculate it for the square wave it will be a different value. For a sinusoidal wave or a cosine wave the RMS value is p max divided by square root over 2. So, with that understanding we will do these 2 examples.

Suppose, p is 1 pascal what that means here is that we have, we are assuming that the value of RMS pressure is 1 pascal not the maximum pressure. So, its RMS pressure is 1 pascal then, if I have to calculate the decibel level, then that is what I do, 20 log 10 p which is 1 divided by 20 micro pascals. So, I get 20 log 50,000 and I do the calculation I get 94 decibels of sound. In another case p is 31.7 pascals.

So, again I calculate 20 log 10 31.7 over 20 into 10 to the power of minus 6 and I do all the math and I get 124 decibels of sound. Now, it is important to understand at this stage is that in this case the pressure was, 1 pascals and we got 94 decibels of sound. In the other case, pressure was 31.7 pascals. So, pressure went up by a factor of 31.7, but on the decibel level the pressure went up only by 30 decibels. What these 2 example show is, that the, on that if the pressure is getting doubled on the linear scale, that does not mean that the pressure will also get doubled on the decibel scale.

On the decibel scale the pressures change a little slowly, but on the linear scale they can change very rapidly. I mean that is the whole point. Why we are using logarithmic scales. So, once again when we multiply pressures of if the ratio pressure goes up by a factor of x on the linear scale it does not necessarily mean that pressure will also go up on the decibel scale by the same factor. So, that is a very important point to understand.

The next question is that; suppose, I have 2 motors or suppose there are 2 machines in a room, and 1 machine is generating let say L 1 decibels another machine is generating L 2 decibels and then I want to figure out that what if both the machines are running in the room together. What will be the overall decibel level of the sound? So, how do we add it up?

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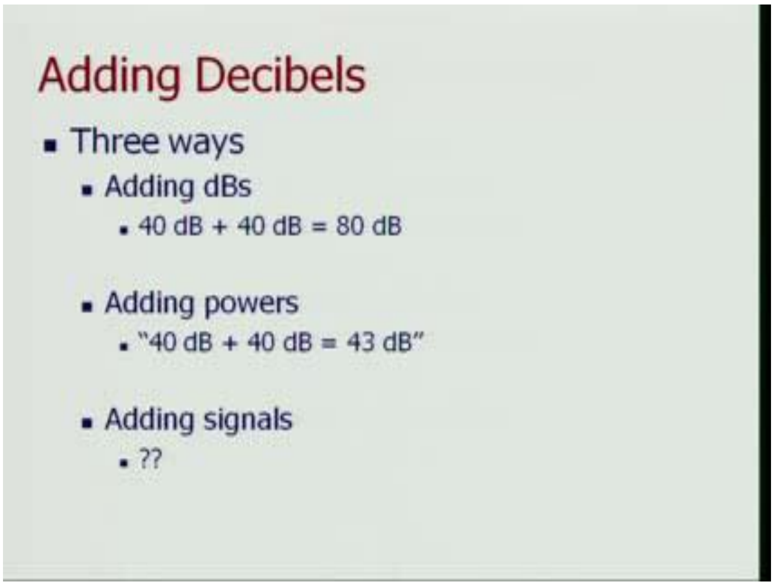

Now, they could be 3 ways or 3 several ways and 3 possible ways I have shown here, 1 is we add up dB's. So, suppose there is L 1 is 40 dB, L 2 is 40 dB can I argue that it is 80 decibels? The second way is adding a powers and then that gives me the 43 decibels and how do we get 43 dB will see it later or do we add up a signals or pressures. So, there are several ways to add dB, but only 1 of the ways is correct and that is what we are going to learn that which, what is the right way to add up decibels.

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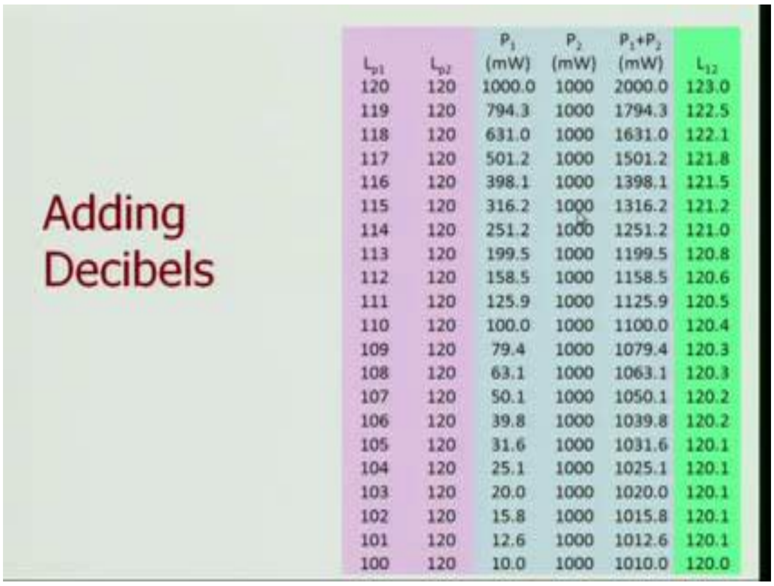
Adding Decibels

L_{p1}	L_{p2}	P_1 (mW)	P_2 (mW)	P_1+P_2 (mW)	L_{12}
120	120	1000.0	1000	2000.0	123.0
119	120	794.3	1000	1794.3	122.5
118	120	631.0	1000	1631.0	122.1
117	120	501.2	1000	1501.2	121.8
116	120	398.1	1000	1398.1	121.5
115	120	316.2	1000	1316.2	121.2
114	120	251.2	1000	1251.2	121.0
113	120	199.5	1000	1199.5	120.8
112	120	158.5	1000	1158.5	120.6
111	120	125.9	1000	1125.9	120.5
110	120	100.0	1000	1100.0	120.4
109	120	79.4	1000	1079.4	120.3
108	120	63.1	1000	1063.1	120.3
107	120	50.1	1000	1050.1	120.2
106	120	39.8	1000	1039.8	120.2
105	120	31.6	1000	1031.6	120.1
104	120	25.1	1000	1025.1	120.1
103	120	20.0	1000	1020.0	120.1
102	120	15.8	1000	1015.8	120.1
101	120	12.6	1000	1012.6	120.1
100	120	10.0	1000	1010.0	120.0

So, this is a chart and how do we get this chart we will see it later, but what this chart shows is, that you have 2 sources; source 1 and source 2. And let say in first case you have source 1 at 120 decibels, source 2 at 120 decibels. Then what we do if we have to add these two up is, you calculate you know in terms of milliwatts.

Let say wattages and how much each sources is emitting and that is 1000 watts, 1000 milliwatts the second 1 is 1000 milliwatts. So, the total energy or the power which is flowing into the system is 2000 milliwatts, which make sense it is physically consistent. So, then you use that 2000 number, this number to calculate the overall decibel level in the room and that gives you 123 decibels.

Let us take another example, first source is 115 decibels, second source is 120 decibels, the watt is corresponding to the first source is 316.2 you can calculate it using the formula and the watt is corresponding to the second source is a still 1000. Total wattage is 1316 and from that you calculate that its 121.2 decibels. So, even though the wattage went up by 30 percent and decibel scale, the wattage went up by about 5 dBs. So, this is something very important to understand. And what this chart shows us that is there are 2 sources this is how they add up.

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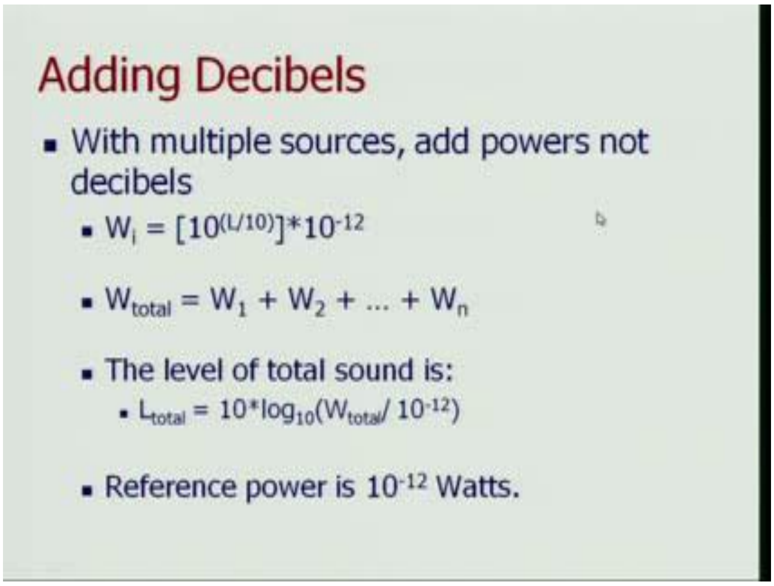

Now, we will actually do an example. So, adding decibels with multiple sources add powers and do not add decibels. What does that mean? Suppose there are n sources, the power emitted by i'th source W I is 10 to the power of L. L is the decibel level divided by 10 times 10 to the power of minus 12. So, total wattage is, so this is how you calculate the wattage of i'th source and then you add up all the wattages and then once you have done this then, you compute the total sound level a sound power level using this and that is how it is done.

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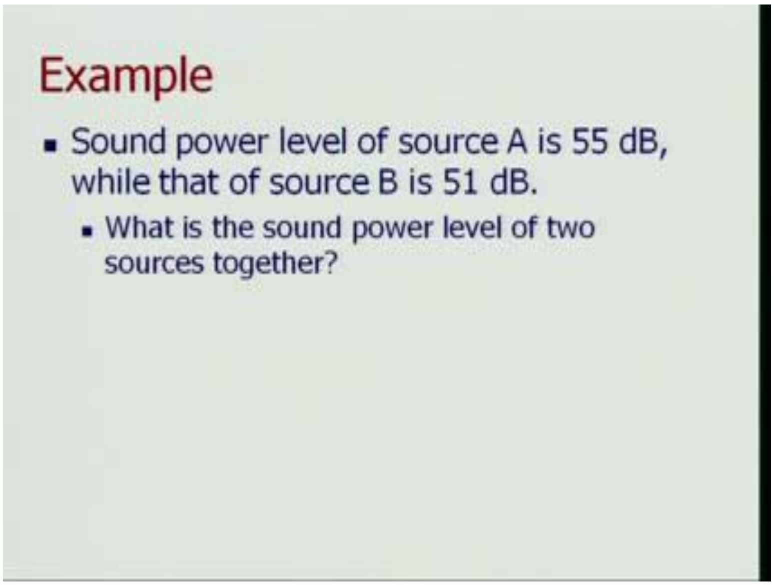

Example: suppose, you have a sound power level of source 55 dB, and another source is 51 decibels then what is the total sound power level, of 2 sources together. We will do that here. That is over.

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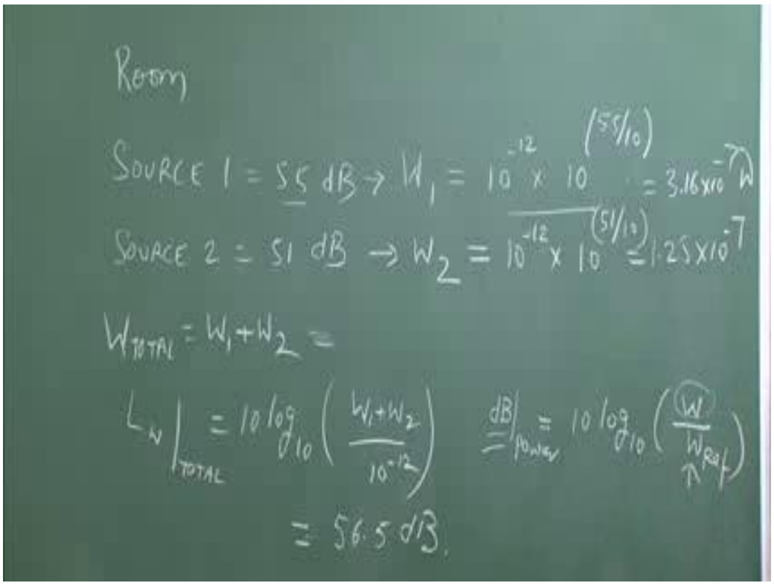

So, you have let us say you have a room; source 1: 55 dB is 51 dB. Then from here, you calculate how many; what is the power flowing out of this source. So, W1 is equal to 10 to the power of minus 12 times, 10 to the power of 55 over 10. How did I get this? I got this because I know that dB for power. This method is for power, but if you have pressure you can do it in the same way. So, dB power is equal to 10 log of 10 RMS power divided by reference power.

I am using this relation, I know this is 55, I know W ref is 10 to the power of minus 12. So, I am calculating W using this formula. So, it comes out to be 3.16 times 10 to the power of minus 7 watts. Similarly, for the second source, W2 equals 10 to the power of minus 12 times 10 to the power of 51 divided by 10 equals 1.25 into 10 to the power of minus 7 watts. So, the total power which is been emitted, if both the machines are running is W total.

W1 plus W2, this is there. So, LW total is equal to 10 log divided by 10 to the power of minus 12 I put in the values of W1 and W2 from here and what I get is my final answer which is 56.5 decibels. So, this is how I add up 2 powers. So, the answer is 56.5 dB and the method as we shown here. So, if I have 2 sources I can use this method and if we are talking about powers or intensities I can add them up in such a way then get the answer.

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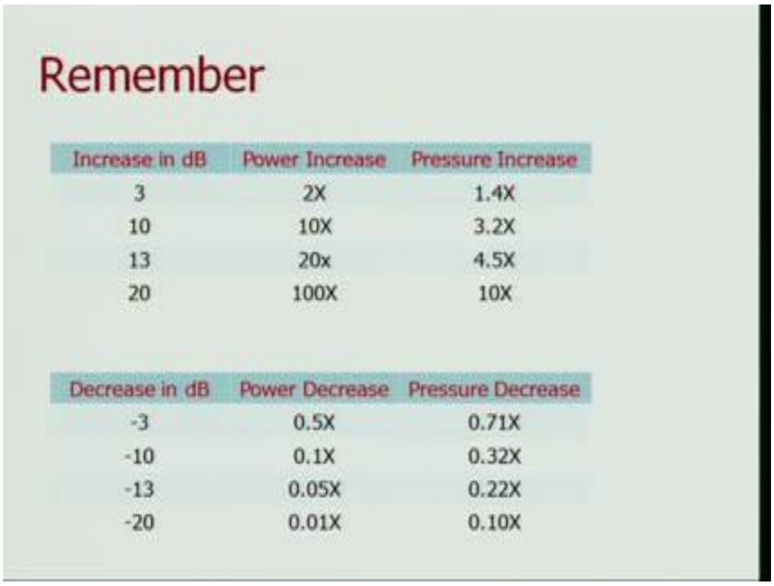

Remember

Increase in dB	Power Increase	Pressure Increase
3	2X	1.4X
10	10X	3.2X
13	20x	4.5X
20	100X	10X

Decrease in dB	Power Decrease	Pressure Decrease
-3	0.5X	0.71X
-10	0.1X	0.32X
-13	0.05X	0.22X
-20	0.01X	0.10X

Remember and this is based on all the calculations you can verify it yourself. If there is an increase in decibels by of 3 power increases 2 times, and the pressure increases 1.414 times. If there is an increase in pressure of 10 decibels power increases by factor 10 pressure goes up by 3.2. If increases 20, power increases by 100 and pressure goes up by 10x. And similarly, you have on the negative side. If I decrease by power by 3 decibels power becomes half pressure goes down by 0.717 and it will be worthwhile for you all to do this exercise and prove it to yourself, how is this happening.

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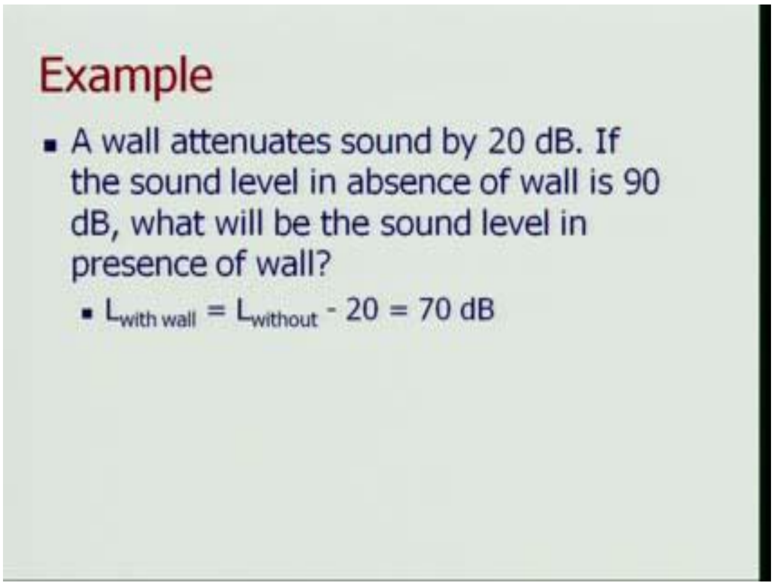

Another example, there is a wall which attenuates sound by 20 decibels. There is a wall, there is a sound coming from here, initially there is no wall and once I and I measures sound pressure level here, let us say sound pressure level here is, 180 and no 90 decibels if there is no wall, then I put the wall and then the sound pressure level is going down by 20 decibels. So, we say that the wall is attenuating sound by 20 decibels that is the language. So, if a wall attenuate sound by 20 decibels, and in absence of the wall, we can here sound at 90 decibel level. What will be the sound level in presence of wall? So, the answer is Lwith wall is equal to Lwithout minus 20, Lwithout is 90; 90 minus 20 is 70 decibels.

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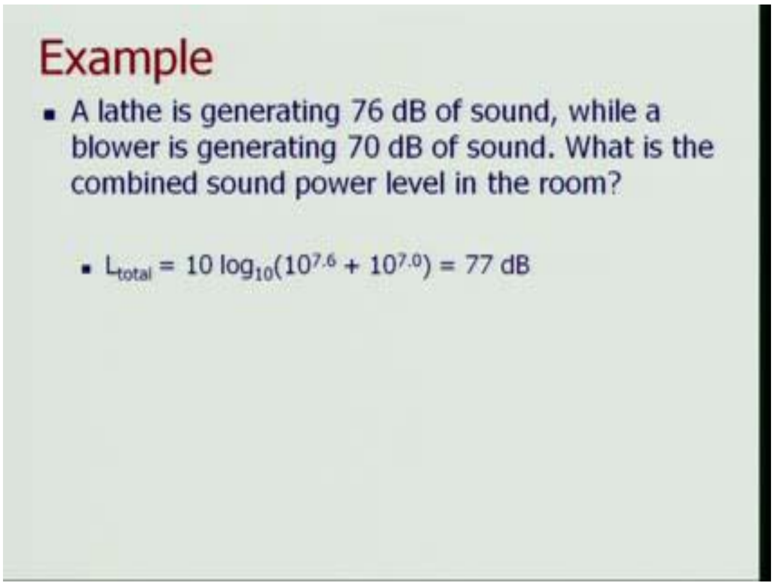

Another example, a lathe is generating 76 decibels of sound, while a blower is generating 70 decibels of sound. What is the combined sound power level in the room? So, this question is exactly same. As this particular question, there is the numbers are different. I Instead of ah 55 decibels, you have 76 decibels instead of 51 decibels you have 70 and you do all the math using the exactly the same approach. What the answer you get is Ltotal equals 10 log 10. 10 to the power 7.6 times plus 10 to the power 7 is equal to 77 decibels.

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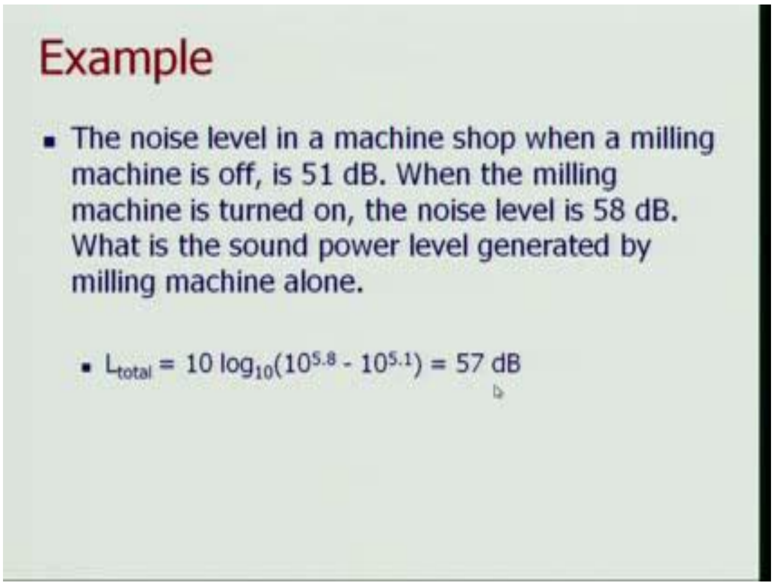

So, this is the other one. This is another question. The noise level in a machine shop, so you have a machine shop, with lots of machines are running and there is also one special machine a milling machine. So, when you turn off the milling machine, the noise level is 51 dB and when you turn it on the noise level is 58 decibels. The question is, what is the sound pressure power level generated by the milling machine?

The answer to that is; so, again it is this wall may also be an exercise for you at home today and that the answer is 57 decibel. How do you calculate it? You find the power level the overall power level when everything is learning, which is 10 to the power of 5.8 and then you subtract it from 10 to the power of 5.1. So, you get the difference in power levels and that is the power generated by the milling machine alone. So, then you take the 10 log of that number and you get 57 decibels. So, this is important.

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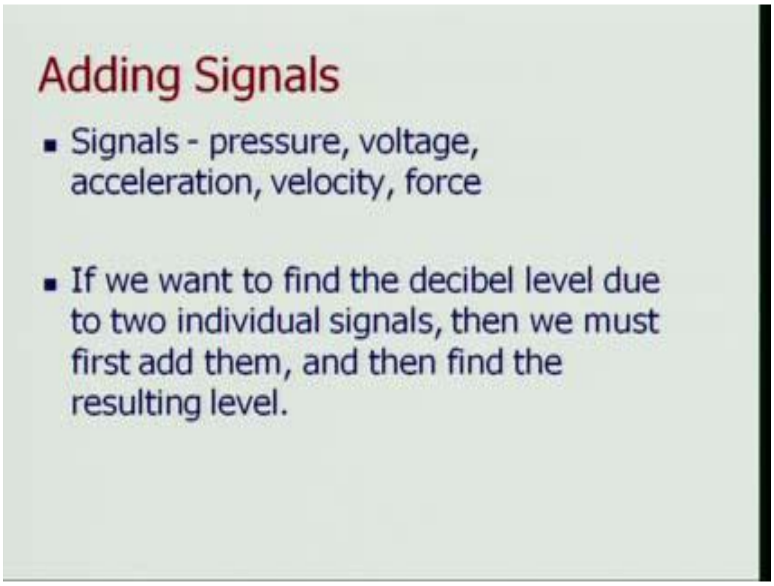

Lastly I wanted to explain that if there are signals. So, we are not talking about wattage's, But suppose, there is a pressure signal or velocity signal or acceleration. Now in case of sound we are not talking about acceleration or voltage or velocity or force, but primarily pressure. So, suppose there is a pressure signal and then if we have to add them, how do we add them?

So, if we want to find the decibel level due to two individual signals, then we must first add them. So, this is about signals, this not about wattage's. Then we must first add them and then find the resulting level. What does this mean, suppose there is a speaker which is generating one pascal pressure and there is another speaker which is generating another say 1.5 pascals. Then in certain situations we can add them up and when do we add them up? This is what it says.

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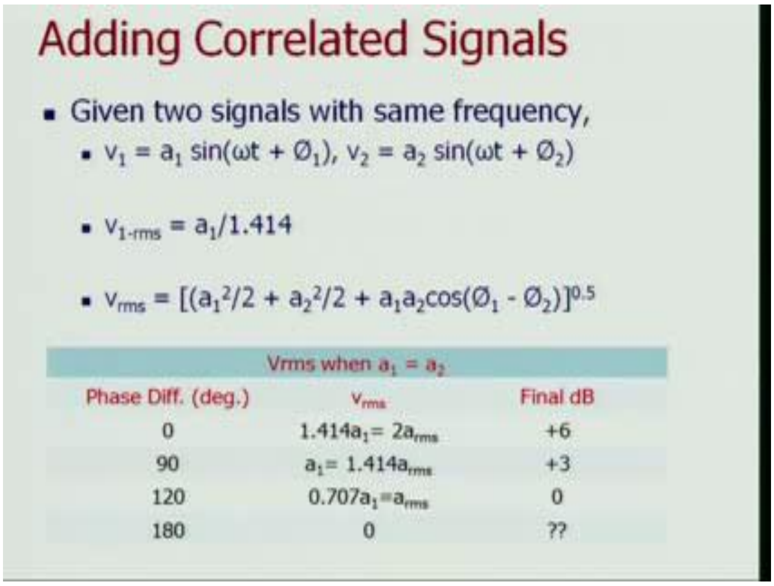

So, what it means is. Suppose I have one pressure signal.

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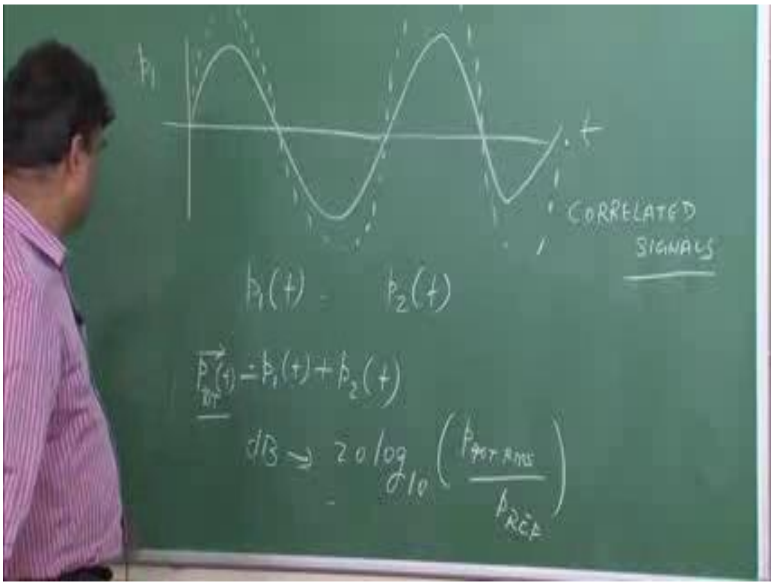

So, Let us say this is p1 and then I have another pressure signal and I will plot it in dotted line. These two signals are known as correlated signals. What does that mean? What means is that there is a strong degree of correlation between each of these signals. In other words, when the dotted signal is becoming maximum, the solid line also become maximum, when the dotted signal becomes minimum the solid line also becomes minimum. So, there is a correlation between both the signals, both the signals are dancing together, they are moving together. These are correlated signals if there are 2 correlated signals.

If the pressure due to 1 is p1 t and the pressure due to the other 1 is p2 (t) then the overall pressure I can calculate by adding up individual pressures p1 (t) plus p2 (t) that is by total pressure and then I can take the RMS value of this signal p total and calculate decibels using formula 20 log 10 p rm p total RMS divided p ref. So, this is for correlated signals. Now, I will do another example, if the signals are not correlated.

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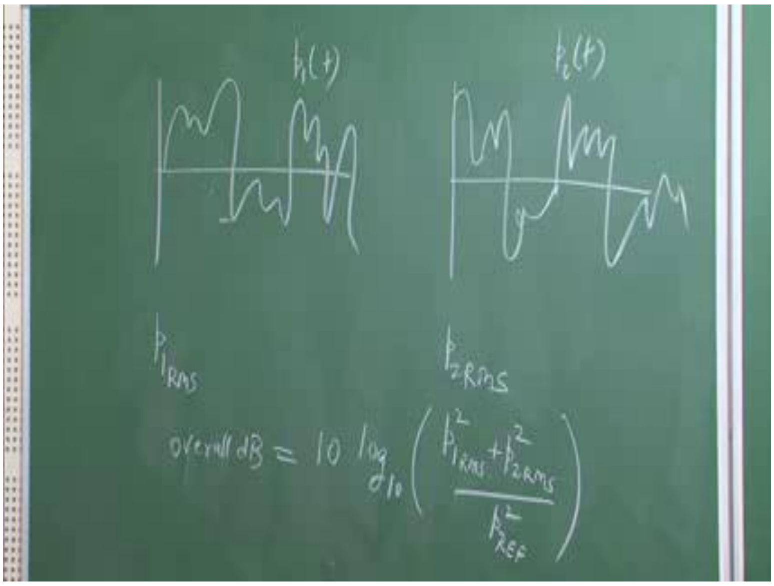

So, suppose there is 1 signal and then there is another signal. So, this is signal 1 this is signal 2 and both of these are not correlated. In this case if we have to combine the effect of these 2 signals, what we do is you add up energies, when I say energies, we can do that in equivalences by adding up the square of the RMS.

So, what we do is, we calculate p1 RMS and we calculate p2 RMS and then overall dB is equal to we use the original formula, 10 log 10 and this formula is going to give us the overall sound pressure level. So, when we are talking about signals, we have to figure out whether the signal is correlated or not. If we have correlation then we can add the signals by themselves. If the signals are not correlated then we have to square of the RMS values of those 2 signals.

Add them up divided by reference pressure square take the log multiply it by 10 and then we get the overall sound pressure level. So, if it was wattages or intensities we just add up wattages or intensities, if it is pressure then that is what we do to calculate the answer. So, that is what it says adding and correlated signals, this is what it says and decibels add like power.

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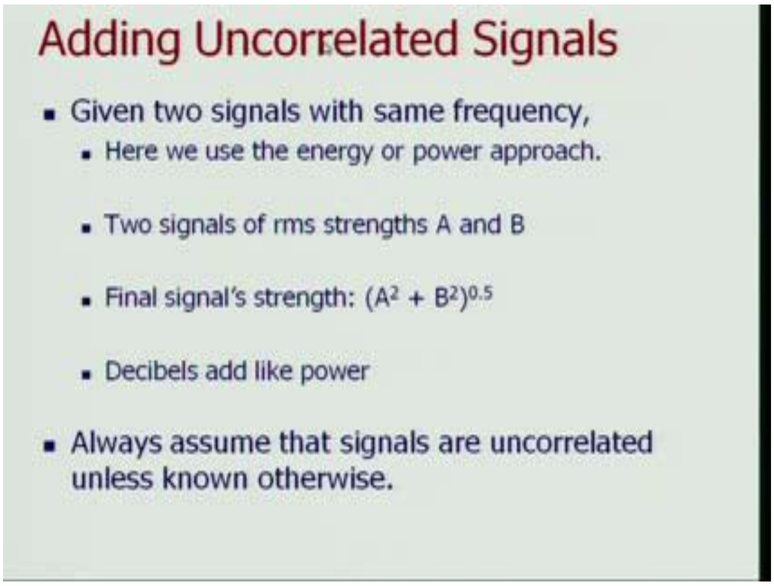

So, with this we conclude this last module of the first week. I hope this has been a very predictive week for you, and please review all the concepts which we did today and look forward to see you in the next week.

Thank you.