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

Lecture – 04
The Decibel Scale

Hello. Welcome to Fundamental of Acoustics. As I mentioned earlier this is the 12 week course, this is the first week of this particular course and specifically this is the fourth day in the first week. What we will be discussing today is the Decibel Scale. In the last lecture I had explained that the range of pressure while we are doing measurements on sound pressure level can be very large; it can be as low as 20 micro pascals at one end and it can be on the higher end as high as few hundred pascals, so the range is extremely large.

And because it is partially difficult to depict this entire range on a single piece of paper effectively if we had to use a linear scale, we resort to the decibel or a logarithmic scale. And in this particular case in context of sound that particular logarithmic scale is known as the decibel scale.

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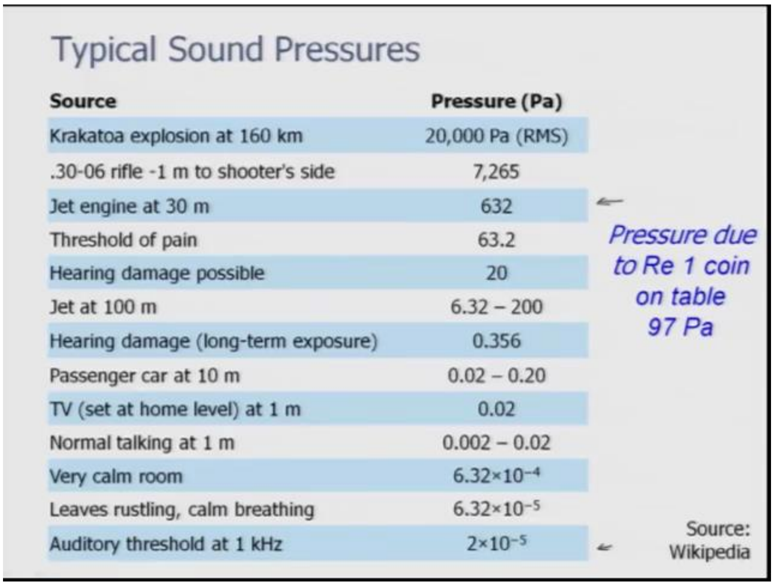
Typical Sound Pressures

Source	Pressure (Pa)
Krakatoa explosion at 160 km	20,000 Pa (RMS)
.30-06 rifle -1 m to shooter's side	7,265
Jet engine at 30 m	632
Threshold of pain	63.2
Hearing damage possible	20
Jet at 100 m	6.32 – 200
Hearing damage (long-term exposure)	0.356
Passenger car at 10 m	0.02 – 0.20
TV (set at home level) at 1 m	0.02
Normal talking at 1 m	0.002 – 0.02
Very calm room	6.32×10^{-4}
Leaves rustling, calm breathing	6.32×10^{-5}
Auditory threshold at 1 kHz	2×10^{-5}

So, what this chart once again shows is that at the low end the pressures could be as low as 20 micro pascals, and we may be interested in also measuring pressures as high as a few hundred pascals. So, it is an extremely large pressure range.

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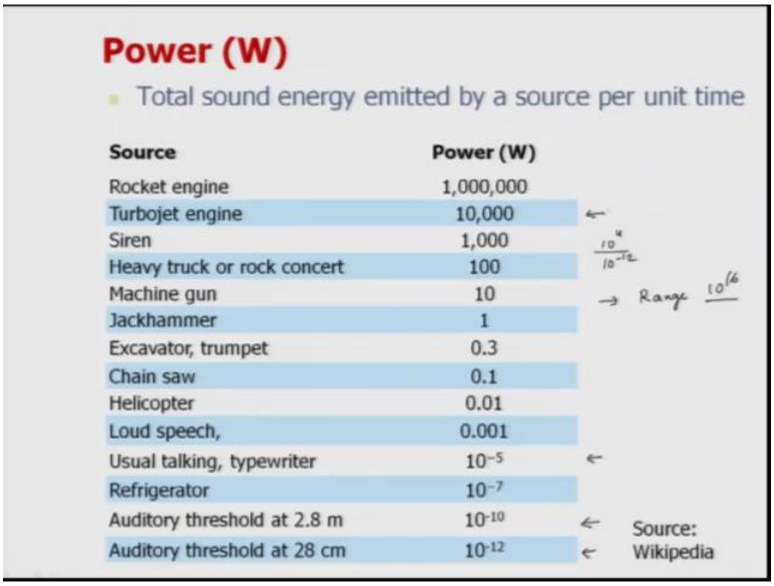

Let us look at powers. So, in the last lecture we had also discussed that we can measure sound in three ways. We can measure the pressure, it generates at the receiver end which is near the micro phone or near the ear or we can measure it in terms of power that is the acoustical power generated by the sound source which could be a loud speaker or an engine or a human voice or an animal or an aircraft, or whatever or it could be in the third case it could be intensity that it is watts per square meter.

Once again if there is a sound source which is barely audible and it is let say producing frequencies somewhere close to 1000 hertz and the sound source is about 28 meter 28 centimeters away, then it will have to produce power as low as 10 to the power of minus 12 watts so that it is barely or it is just audible. So, that is the minimum amount of power our ears can sense when the sound sources 28 centimeters away.

If we bring that or we take that sound source further down or further away and we protect may be about 2.8 meters away then the power it has to generate, so that it is just audible is 10 to the power of minus 12 watts. So, this is at the low end of the power scale. And then when we are talking it is about 10 to the power of minus 5 watts loud speech is about few milliwatts. And then for turbojet engine it is as high as 10,000 watts.

Once again we see that the range of power is also extremely large. So, at one end it is 10 to the power of 4 watts in this case and at the low end it is 10 to the power of minus 12 watts. So, the range is something close to 10 to the power of 16. Once again this entire range cannot be depicted on a linear scale. So, we once again see that in case of pressures the range is very large, in case of wattages the range is very large, and in the case of intensity is also the range is very large. So, we have to have a log scale to depict some pressure levels.

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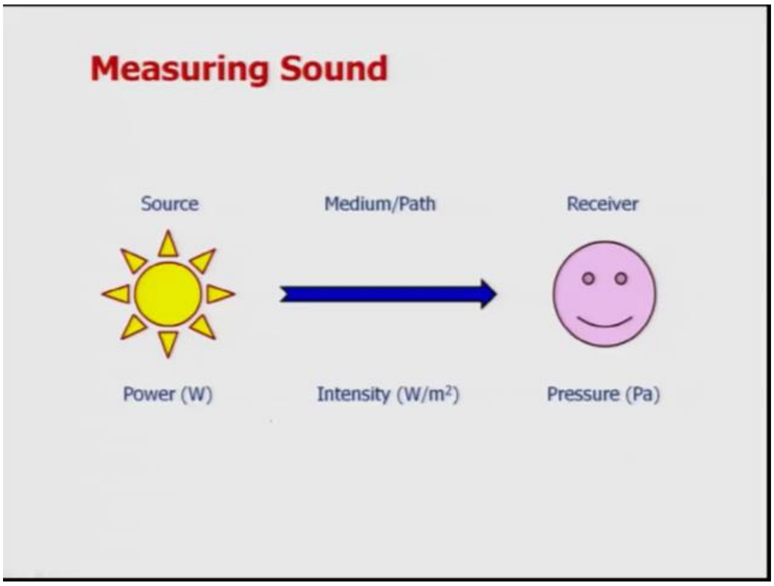

As I mentioned that there are three ways to measure sound either in terms of power or intensity or pressures.

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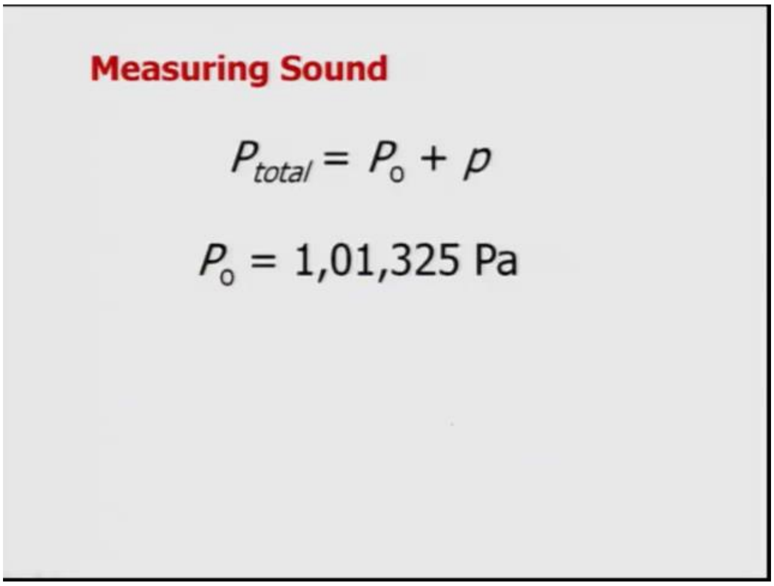

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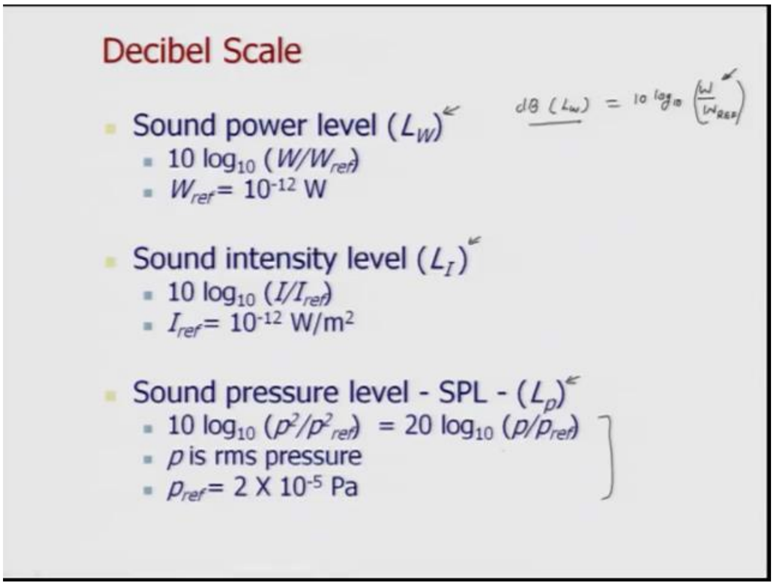

So accordingly, we have three on the decibel scale we can measure either the sound power level that is SPL or the sound intensity level that is L I, the sound power level is L W or the sound pressure level which is L p. So, these are more or less industries standards L W, L I and L p.

Now let us look at how they are defined, and so this is a log scale on which these powers intensities and pressures are defined. So, decibel in L for L W is defined through this formula is equal to 10 log of 10 W over W ref, so I will explain that. Suppose there is a device producing W watts of power and I have to compute how much decibels of sound it is generating then I can compute that decibel value by using this relation where W is the power of the sound producing device. W ref is the RMS power level of a reference device which in this case is 10 to the power of minus 12 watts. Once again, W is the amount of power or acoustical power that is it is RMS value, so that is W. W ref is the reference value, and if I take the log 10 scale and then multiply it by 10 I get decibels.

Similarly, if I have to compute sound intensity then sound intensity level L I equals 10 log 10 I divided by reference intensity. And the reference intensity is again 10 to the power of minus 12 watts per square meter. Please note that in both these relations W and I are the RMS values of power and intensity respectfully. Similarly, if I have to compute sound pressure level; L p, then L p is defined as 10 log 10, but instead of having the ratio of p and p ref we take the squares of the ratios; so it is p square where p corresponds to the pressure generated by the device and p square ref where p ref is the RMS is the reference pressure which is 20 micro pascals.

So, if I take the two out in this relation then L p equals 20 log 10 p divided by p ref, where p is once again the RMS value of the pressure.

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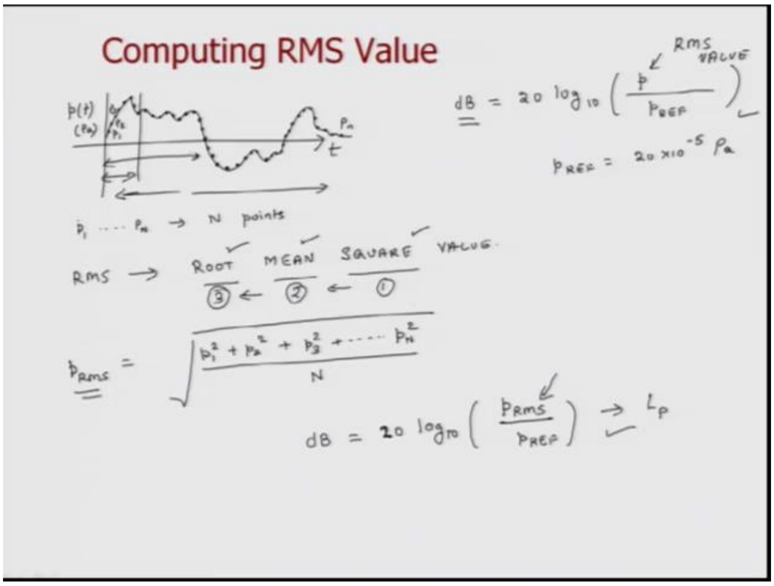

Now, we will spend the few minutes on understanding how do we go around computing the RMS value of pressure or RMS value of wattage or whatever. So, before we start doing that please understand that how is sound being recorded. So, you have a micro phone, sound is coming and hitting it and the micro phone is sensing that pressure and it is recording the data. Essentially what we get from a micro phone is a graph like this; on the x axis we have time and on the y axis we have pressure, as a variation of or as a function of time. So, this pressure could be some graph like this.

So, if I have to compute how many decibels we this pressure corresponds to then we have to this relation decibel equals 20 log of 10 p, and then this p is the RMS value divided by p ref and p ref equals 20 into 10 to the power of minus 5 pascals. So, when we are recording pressure we have to first thing we have to make sure is that this is in paschal. If a micro phone is giving you in voltages then we have to somehow convert that voltage using the calibration factor of the micro phone into pascals, because for computing the decibels we have to record pressure and a unit of pressure is pascals.

And then the other thing is that we have to compute its RMS value. So how we do that? The first thing we do it is that we identify several points on the graph. So, that is what we do, we discretize this graph into several points and typically and we will discuss this also later in detail in this course this is done by an analog to digital convertor. So, analog signal is continuous in time and that they should convert term break setup into small discrete points.

So, let say this point is P 1, P 2, P 3 and let say this is P n. So, P 1, P n are n points on our axis. So, what is the RMS? RMS it corresponds to root mean square value. And how we do compute the root mean square or these end data points? So, the first thing we do is, we take the square then we go in this direction then we take the mean and then we take the square root; this is how we do it. So p RMS is what, first we take all the square of individual pressures, so it is P 1 square plus P 2 square plus P 3 square P n square. So, we have done the squaring and we have added this up. And then we take the mean. So, there end points, so we take the squares add them up and then divided them by n; so we have taken the mean. And finally, we take the square root. So, we take the square root and that is how we get the RMS value.

Once we calculate the RMS value we can calculate the decibels, and the decibel is computed as 20 log of 10 for p RMS by p ref; now this is for L p. Similarly if we are interested in calculating the sound power level, we will record the value of power as the function of time and then calculate the RMS, but in this case instead of multiplying by 20 we will just multiply it by 10. And likewise we can also compute the pressure intensity decibel in a similar way, but it is important to understand that in this relation or in this relation it is the RMS we are interested in.

Now, having said that another question will be how long, how many point should I include. So, that is what is the range of this time; Should I record my data for half a second, should I record it for 1 second, should I record it for 1 millisecond, should I record it for 20 seconds and because based on how many data points we have the RMS may change. If I recorded only this much portion of data then the RMS would have been larger. If I record for a little longer time at list in this case then the RMS would come down.

So, how long should I record so that I get a good value of p RMS? And the answer to that question is; that it depends if your data is repeatable if it is or in mathematically lot of times people call it stationary. So, suppose you have tyre which is rolling on the road if you record it; you have make an assessment that how long should you take the data for so that the data is somewhat repeatable, once it is repeatable then you do not have to record it for a longer period of time. So, that is one part of the answer; that it depends and in based on your understanding that you have to get a feel of how long you have to do the recording so that the data becomes repeatable.

The second part of the answer is that it also depends on what kind of a frequency resolution you need. So, if you take data for longer period of time then later, and we will discuss this later in this course somewhere close to the end of this course when we talk about a FFT; if you take a longer time period then when you convert this time domain data into frequency domain data you get a final resolution on frequency. So, it depends on that parameter as well. But in either of those cases you have to compute the RMS value, so that is important to understand.

So, we have seen that there are three important on the decibel scales; there are three important sound levels power level L W, intensity level L I, and pressure level L p; and these are the definitions.

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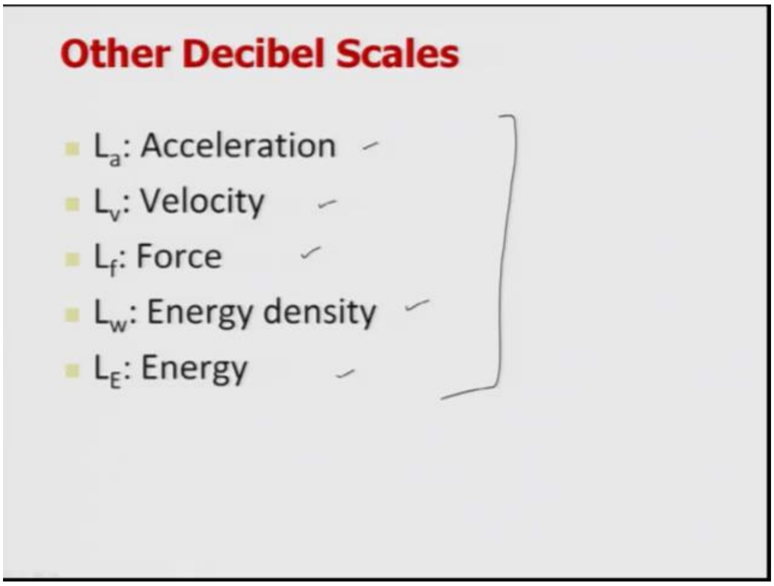

So, these are the most popular definitions of decibels, but there are several other decibel scales also. So, you should understand that the sound is not only that the decibel scale is only use for sound; it can also be used for acceleration, velocity, force, energy density, and energy. Now these may or may not be related to sound, but in literature when we do you will find the decibel is used in several context. So, when you use this time decibel you have to be careful.

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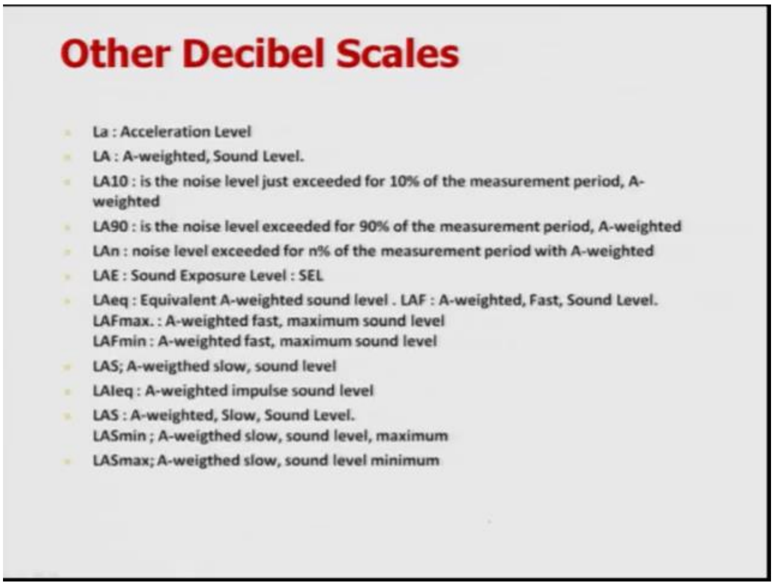

And then in context of noise and sound also there are a very large number of L's or sound levels. And a lot of these levels are based on how long you take the duration that overall time period. But, regardless of the multicity of these scales the most important scales at least in context of this course are L W, L I, and L p which we have to understand and interlines because this is what we will be using very frequently in this course.

So, this concludes my fourth lecture for this week, and tomorrow we will further continue this discussion. Have a great day and see you tomorrow. Bye.