**Noise Management & Its Control**
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**Lecture – 05**
**Introduction**
**The Decibel Scale**

Hello, welcome again to noise management and its control today is the fifth day of this week and we will continue our discussion on acoustics some of the important terms and terminologies associate with the science of sound and noise.

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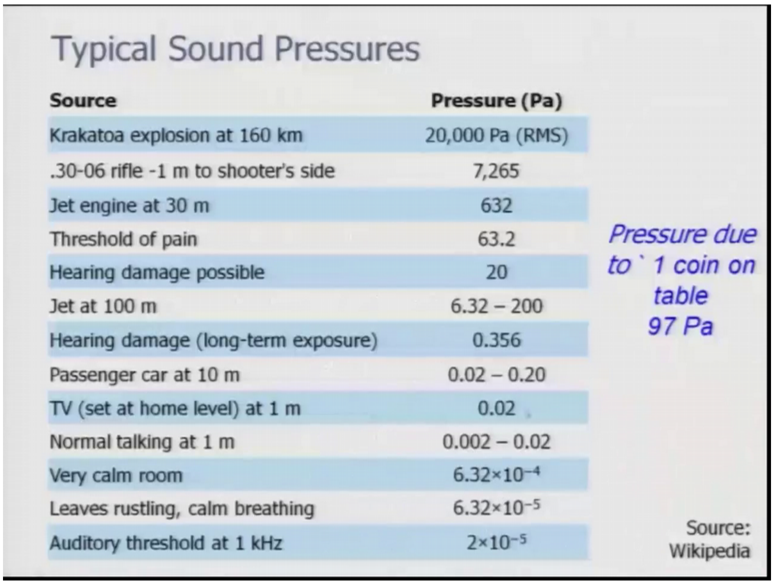

Typical Sound Pressures

| 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 | $6.32\times10^{-4}$ |
| Leaves rustling, calm breathing | $6.32\times10^{-5}$ |
| Auditory threshold at 1 kHz | $2\times10^{-5}$ |



So, what we plan to do today is introduce to you the decibel scale before that I just wanted you to again have a very quick view of the range of pressures. So, when we am in the business of measuring sound we could be measuring sound pressure levels as low as 20 micro Pascals in some cases we are actually interested in measuring even smaller sound pressure levels even though we may not be listening to them. So, so we may be interested in measuring sound pressures as high as 20 Pascals and as low as 20 micro Pascals.

So, when I look at order of magnitudes involved in this, it is 6 orders of magnitude 20 divided by 2 times 10 to the power of minus 5 its 6 orders of magnitude. So, here is the problem.

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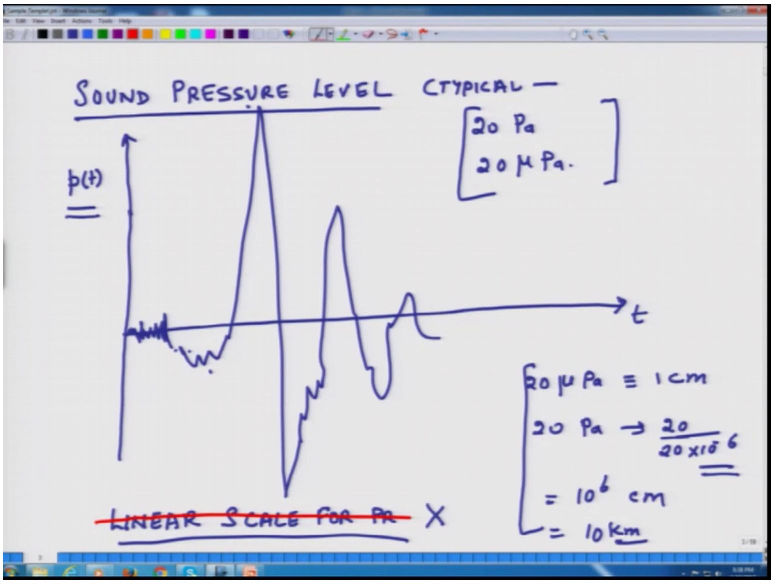


So, sound pressure level typically I mean this does not mean that in all the cases it will be like that it can be between 20 Pascals to 20 micro Pascals. Now what does that mean if I have to plot let us say on the time scale. So, x axis is time and y axis is let us say pressure P ha. So, this is P as a function of time. So, at some location I have a microphones access fixed and I am measuring how pressure is changing. So, at some points the pressure may be very small may be this is 20 micro Pascal and then at some points it may be very less large it could be 20 Pascals.

Now, let us say 20 micro Pascals corresponds to one centimeter on the y axis in that case if I also have on the same axis if I also have to plot 20 Pascals, then how many centimeters do I need it will be 20 divided by 20 into 10 to the power of minus 5 centimeters, right. So, that is 10 to the power of 5 centimeters which means that my axis should be how much it will be something like 1 kilometer long. So, my y axis has to be. So, paper has to be one kilometer long. So, because the range of pressures I am interested in is such large because the range of pressures involved is such a large thing what; that means, is that I need very large pieces of paper. So, I physically I cannot represent this entire range of pressures using this linear scale.

Student: 10 to the power of 6.

10 to the power of minus 6 I am sorry you are right. So, then it becomes 10 kilometers, it becomes 10 kilometers. So, it becomes even worse power of 6 yeah.

So, the message still remains same that this range is extremely large. So, a linear scale for pressure, it does not work a linear scale for pressure it does not work. So, for this reason we go for a decibel scale which is a logarithmic scale for reasons related to practicality actually that is one reason the other reasons also.

And that is why we use a decibel scale where instead of plotting the actual pressure we plot logs of the pressure. So, then I can cover a very large range of pressures on a same scale on a small piece of paper. So, that is the importance of a decibel scale and we will actually see; how those scales are defined.

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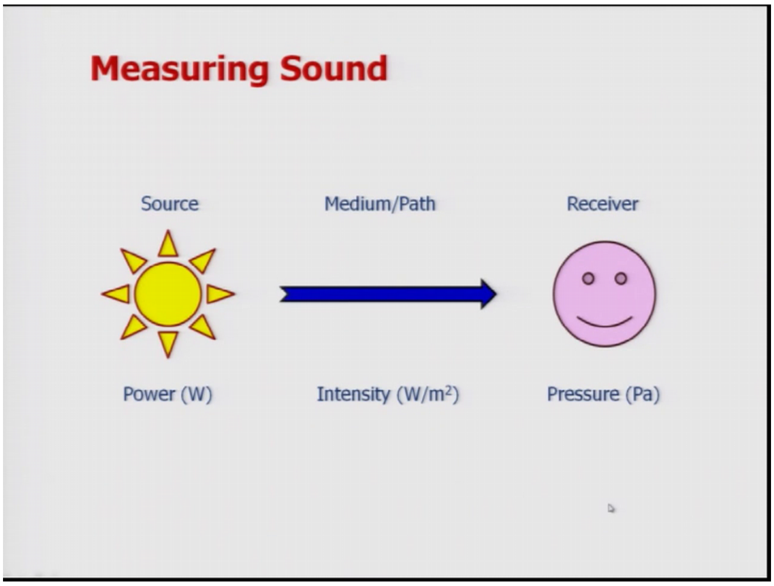


But before we see the actual relation or relations associated with decibel scale we should look at this picture and this is in context of what are the different things, we are interested when we measure sound.

So, these are 3 important things we measure when we are interested in the business of measuring sound one is how much. So, suppose there is a sound source. So, this is a sound source it generates some sound this sound travels from its origin and it reaches its destination or may be the destination is a person who is listening to sound or it could be a microphone or some whatever.

So, there is a source and this is the destination sound gets generated at the source it travels through a medium it could be air water human body metal whatever and it is received by an instrument on animal a human being or whatever. So, there is a source there is a medium and there is a receiver in general lot of times we are interested in figuring out how much sound energy is being emitted by the source per unit time or what is the power of sound source for example, if I buy a loudspeaker I may be interested in trying to figure out how many watts of sound energy that source is generating per unit time or what is the power of that sound source.

So, that is one parameter we are interested in measuring then we come to the medium. So, I may be at some point in between the source and the receiver and as sound is travelling away from the source I may be interested in knowing how much power is being transmitted per unit area, if I am in the in somewhere away from the source. So, suppose there is a window open in a sealed room and there is a speaker in the room I may be interested in and trying to understand how much sound is being transmitted through that window which means how much watts is being transmitted per unit area through that thing. So, that is known as intensity. So, we may be interested in measuring watts we may be interested in measuring intensity and the third parameter we may be interested in is what is the pressure fluctuation which we talked about earlier when sound gets generated when it is received by the speaker because that is what our ears are sensitive to.

So, we may be interested in finding the sound power level that is the first important parameter we may be interested in finding out sound intensity level that is the second parameter and the third parameter which is often used is sound pressure level sound power level sound intensity level sound pressure level in regular units sound power level could be expressed in watts sound intensity level is watts per square meter and sound pressure level is Pascals, but this is for a linear scale, but linear scale, we have seen we cannot fit it on a small piece of paper. So, to express power level intensity level and pressure level we have a decibel scale.

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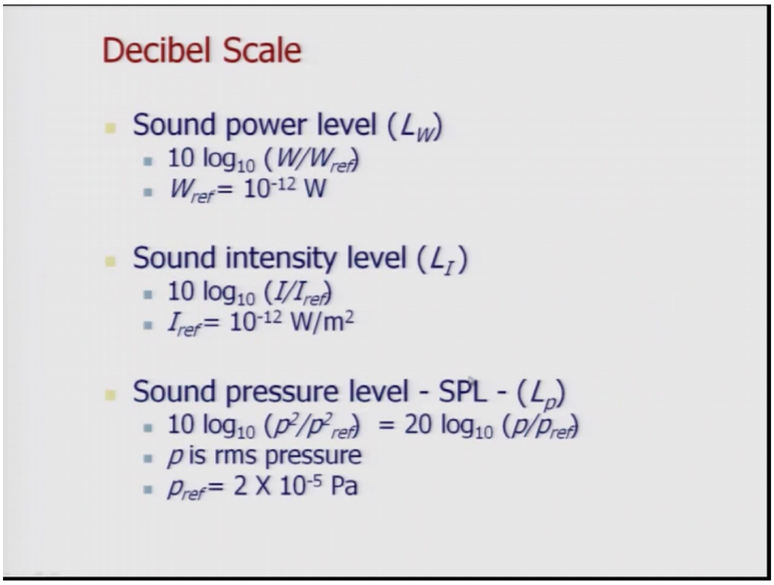


And this is what that decibel level decibel scale is all about. So, if we are interested in sound power level, it is designated as L W this is the symbol for L; L is level W is watts. So, LW. So, what is L W; it is equal to 10 log W divided by reference W.

So, what is W? So, suppose there is a sound source and it is emitting 5 watts of power. So, W will be 5 and then we divide it by a reference value that reference number is the minimum power which generates minimum pressure which is sensed by our ears right. So, that is about 10 to the power of minus twelve watts. So, that is my reference power. So, sound power level LW equals 10 log 10 W divided by W ref that is the definition of sound power level if I am interested in figuring out what is the intensity on the decibel scale then I express it in terms of sound intensity level L; I is intensity L is level intensity level and that is 10 log 10 I divided by I ref reference intensity and the value of reference number is. So, these reference values are for ear the reference value for water may be different these are the reference values for air.

So, reference value for ear for intensity is 10 to the power of minus twelve watts per square meters and then the third parameter is sound pressure level lot of times it is also written as SPL P may be power or pressure, but in general SPL means sound pressure level it is not sound power level SPL typically we say its means sound pressure level and more precisely, it is expressed as LP; here P is the pressure L is level and here the relation is slightly different here it is 10 log 10 P square not t it is square of P divided by reference pressure squared and if I take the square thing out it becomes 20 log 10 of P divided by P ref . So, we will explain this further.

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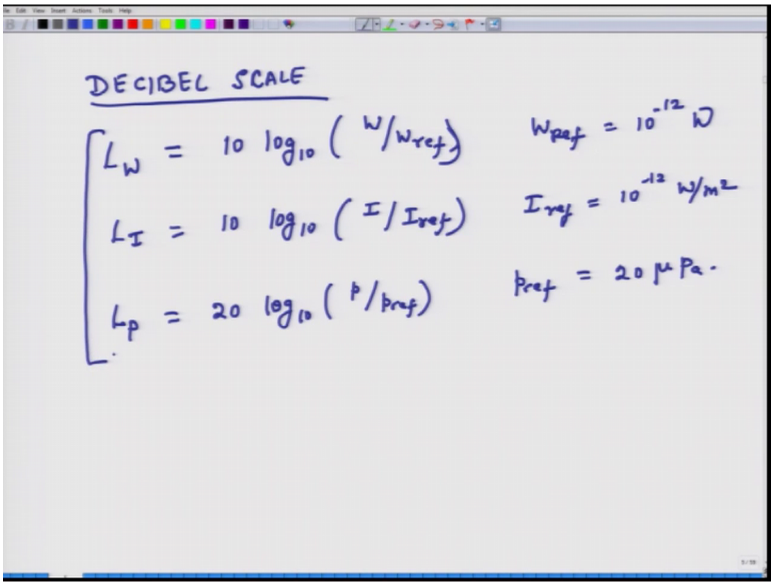


So, we have LP is 10 log 10 power by reference power and reference power is what 10 to the power of minus 12 watts.

Student: LW.

LW; I am sorry;

LW then we have L I is 10 log 10 I divided by I ref and I ref equals 10 to the power of minus twelve watts per square meters and then we have sound pressure level is 20 log again on a 10 scale P P ref and this P ref is our threshold minimum auditory threshold pressure and that we saw in that slide earlier is 20 micro Pascals; 20 micro Pascals.

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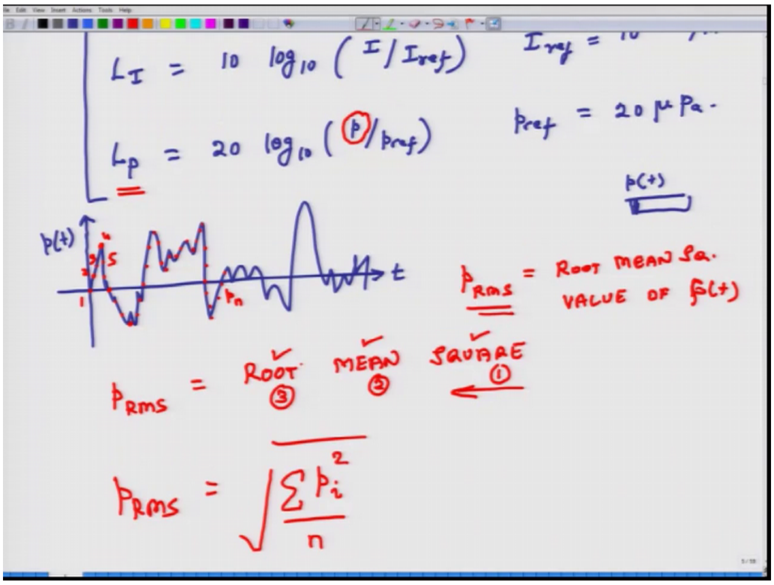


Now, here is a question. So, suppose this is time and there is a microphone and the microphone is measuring pressure and the position is fixed. So, it is measuring pressure as a function of time. So, here I am plotting pt and when I measure the pressure this is what the graph looks like. So, then how do I calculate LP because P is changing with time P is changing with time. So, what is the value of P is this the value of P is this the value of P or should I use it as 0 or this which value of P should I use that is the important question. So, when we use P in this relation it is actually P RMS that is root mean square value of pt.

So, we take the entire signal and then take the RMS value of that entire signal and that number we plug in. So, we do not put individual values, but we take the entire signal for which we are trying to figure out the sound pressure level take its RMS value and then put the RMS value in this formula LP equals 20 log 10 P divided by P ref now the question will be how do you calculate this RMS value . So, some of you may be already knowing it I am sure that you have learned this, but for purposes of completeness we will explain this. So, how do you find this RMS value first thing is you mark a lot of points on the signal at equal intervals of time. So, you mark these points. So, that it accurately captures the signal. So, you should takes sufficient number of points. So, that the signal is accurately captured.

So, let us say this is 0.1, 0.2, 0.3, 4, 5 and so on and so forth. So, let us say this is pn. So, you take n points and what is P it is actually P is PRMS is what it is root mean square . So, what do you do you actually go in this direction you first square it take the mean and take the root. So, PRMS is what you first take the squares of all the signals. So, for the ith point it will be P I square then you take the mean of it. So, how do you take the mean you sum all the values of P I square and you divide it by number of points and then. So, so this is. So, you have done square you have done mean and then you take the square root. So, this is the process first you square it then you mean it then you take the square root you get the RMS.

And this number you plug in this relation for LP and you will able to calculate the sound power level sound pressure level. So, this is important to understand that is what it means. So, the next couple of slides I wanted to show you were related to what kind of decibel pressure relationship between decibels and pressures.

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**Pressure & Decibel**

| Source | Pressure (Pa) | dB |
|---|---|---|
| Krakatoa explosion at 160 km | 20,000 Pa (RMS) | 180 |
| .30-06 rifle -1 m to shooter's side | 7,265 | 171 |
| Jet engine at 30 m | 632 | 150 |
| Threshold of pain | 63.2 | 130 |
| Hearing damage possible | 20 | 120 |
| Jet at 100 m | 6.32 – 200 | 110-140 |
| Hearing damage (long-term exposure) | 0.356 | 85 |
| Passenger car at 10 m | 0.02 – 0.20 | 60-80 |
| TV (set at home level) at 1 m | 0.02 | 60 |
| Normal talking at 1 m | 0.002 – 0.02 | 40-60 |
| Very calm room | $6.32 \times 10^{-4}$ | 30 |
| Leaves rustling, calm breathing | $6.32 \times 10^{-5}$ | 10 |
| Auditory threshold at 1 kHz | $2 \times 10^{-5}$ | 0 |

Source: Wikipedia

So, at auditory threshold what is the pressure 20 micro Pascals and that corresponds to 0 decibels because PRMS is 20 micro Pascals divided by P ref is 20 micro Pascals log of one is 0. So, you get 0 decibels let us look at the next number 6.32. So, roughly compared to auditory threshold this is 3 times higher right this pressure 6.32 divided by 2 is about 3.15, right. So, pressure has gone up by a factor of 3.15 or 3.16, but on the decibel scale you have gone up by 10 dB.

So, what; that means, it does not mean that if you double the pressure decibel also doubles the decibel is a different scale pressure scale is different. So, if I am in a very calm room not a lot of sound the pressure level may be something like thirty decibels right now I am talking and people are recording my voice it is quite likely my pressure will be somewhere between 40 to 60 decibels.

If I am playing in a TV or playing a TC in my room; not too louder level then it may be somewhere between 65, 70, 75 decibels in that range a loud car about 10 meters away is about 80 decibels and we may have damage to our ears; if we get exposure to sound on a long term basis if the decibel level exceeds 85 and immediate damage can occur if the decibel level exceeds 120 and the pain starts happening at 130 decibels , but once again the pressure range is linear the decibel range is non-linear. So, small changes in decibel level means large changes in pressures. So, this is important to understand.

So, we have on the decibel scale we have learnt about LW sound intensity level Li and sound pressure level LP; there are several other decibel levels also.

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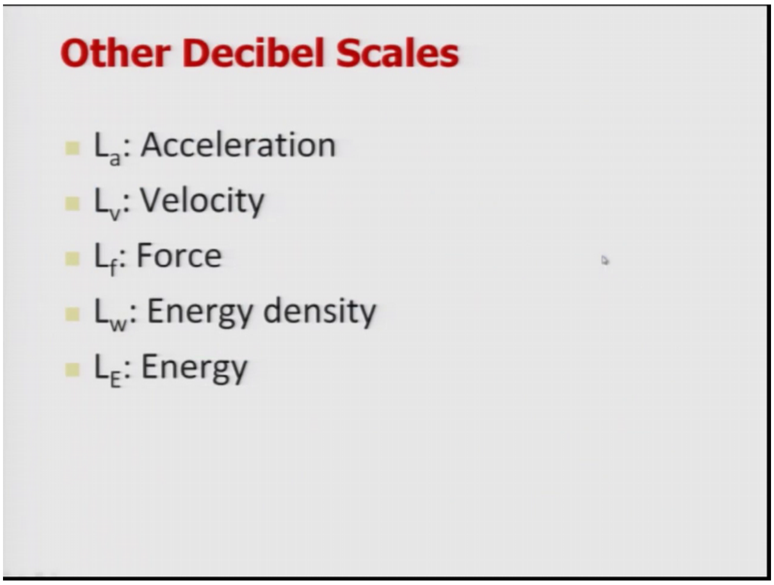


We calculate decibels for acceleration this is known as la for velocity Lv for force LF for energy density LW for energy le and so on and so forth.

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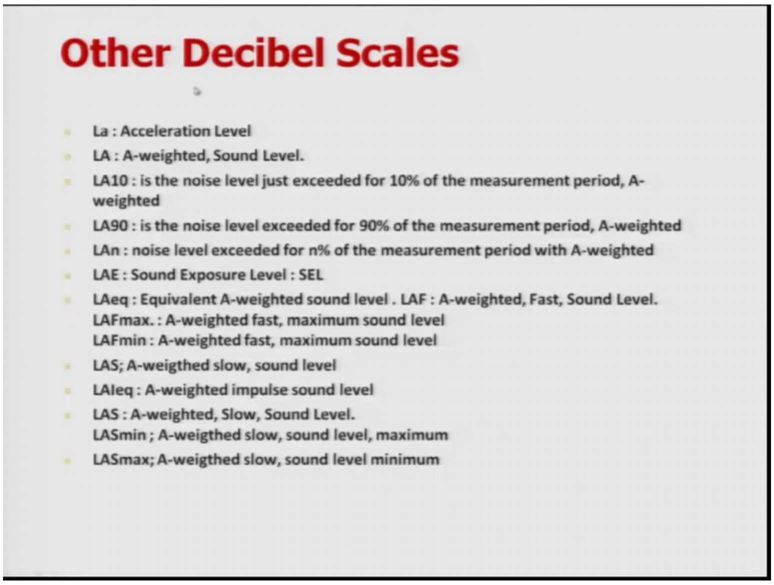


And then there are some more decibel quantities and. So, we will not go about you know in detail for all these things, but the point is that there are lots and lots of decibel scales for different physical quantities and it is important that we do not get surprised if we come up cross some of these other scales it is just that we try to figure out what their relationship is and the mathematics is pretty same.

So, I think that concludes the discussion for today’s lecture we will meet once again tomorrow which will be the last day of this week and till then have a great day, bye.