Machinery Fault Diagnosis and Signal Processing
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Lecture – 34
Basics of Noise

In this lecture and the subsequent lecture, we are going to talk about basics of noise and noise monitoring in machines, well you would realize that if a machine has a fault it would make some abnormal noise and actually the operator or the worker is drawn towards the machine, because of this noise something breaking something dropping something hitting against each other tic tack, loud booms, whistles, bangs.

So, these are some of the noise which draw our attraction to this machine which has a concern; of course people do not use noise per say as monitoring tool because of the fact is you know it becomes very difficult to separate the noise which one hears from a machine it is coming or from a group of machines it is coming.

In other words in a noisy environment if there are 2, 3 machines making noise, it becomes difficult for a new body to really quickly understand where this noise is coming from and so on noise contamination and we will see the reason why this contamination occurs because, of the scales which we use and the levels which we use. So, we will see what this is so with this I want to talk about certain basics of noise. Now what is this noise or you know related field of science is what is known as acoustics, is actually a branch of engineering.

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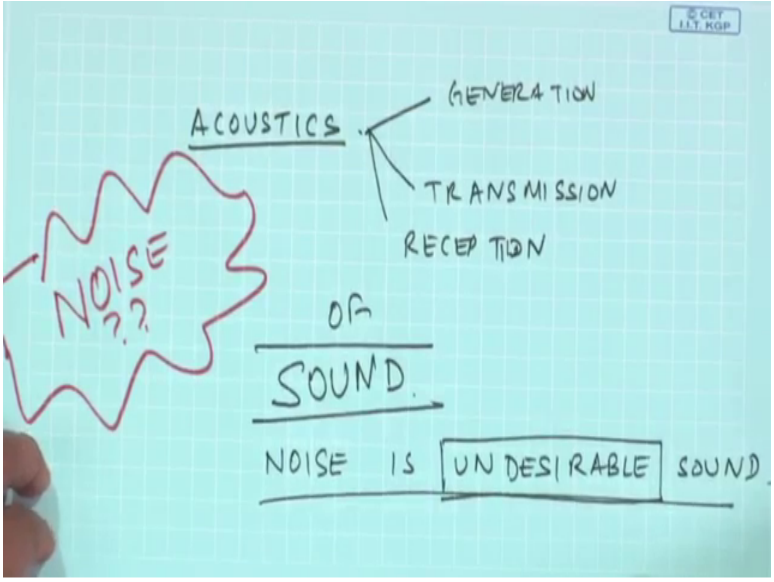

Which deals with the generation transmission and reception of sound and as opposed to you know it is told as or it is known as noise is un desirable sound. So, we have a sound control engineers, we have noise control engineers, so noise control engineers as you can see any machinery which is making noise.

So, noise which is not acceptable by us has to be reduced and that is what the mechanical engineers are we engineers do as noise control engineers or supposed to you must have heard there are sound engineers; you know sound engineers are you know engineers which help in the sound enforcement for example, in an auditorium or in recording studio we have sound enforcement systems both for recording and for reproduction, so these are known as sound engineers.

So, we must make a difference between sound engineers and noise control engineers or sound control engineers noise control engineers, but today in this lecture we are going to focus on this what is known as noise, noise is something not desirable we have to see what this noise is, how to control it and rubs why this is important for machinery condition monitoring and what are the levels associated with it so on.

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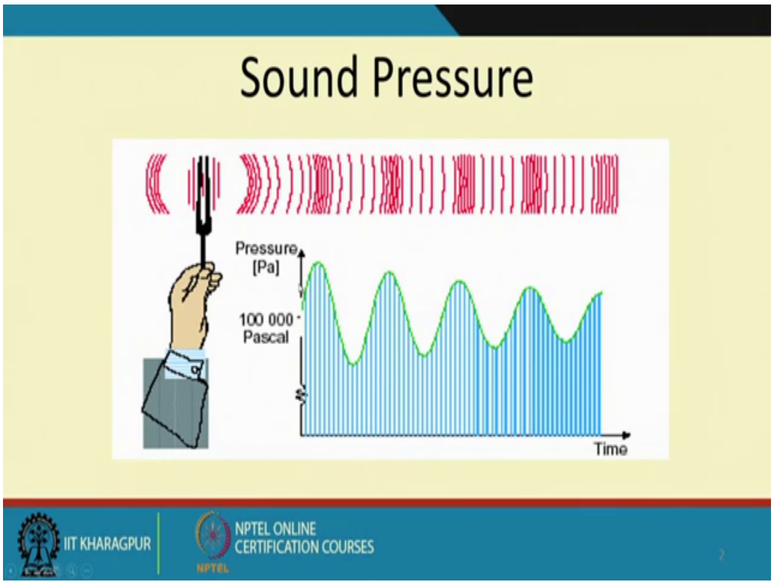

So, if you think of this sound pressure it is nothing but a small of fluctuation pressure in the ambient fluid, which travels from a source to a ear at a particular wave type.

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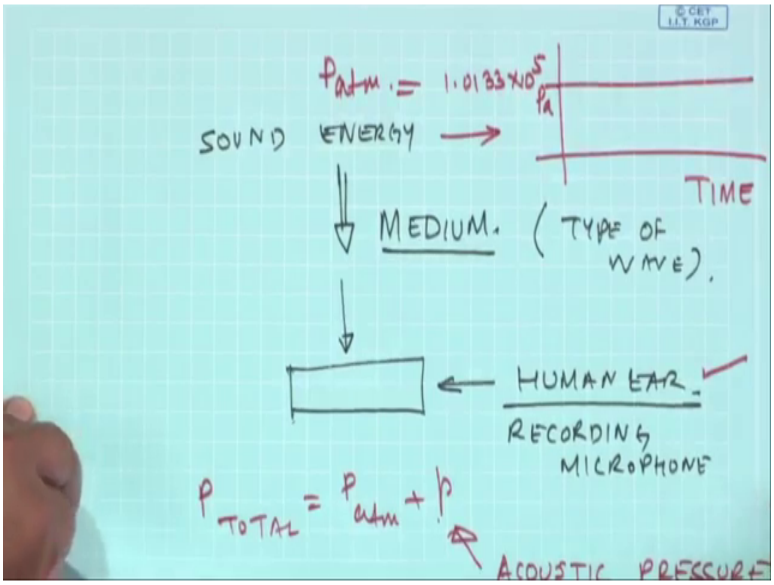

So, this sound energy which is being generated requires a medium depending on the medium and the type of this source, will have a type of wave and then this energy is finally going to be received in our case by the human ear or some recording sensor which is known as recording microphone. Now this sound pressure which we are talking about is nothing but a with time, for example right now in this room the ambient pressure is 1.0133 into 10 to the power 5 Pascal's, which is nothing but the atmospheric pressure here .

So, P total at any point in this room is P atmosphere plus this small acoustic pressure, this is the acoustic pressure which we are going to deal about; you will see this P total is actually sense by the human ear which is incident this energy is incident on the human ear drum and even a very small fluctuation in this small pressure P is loud enough to give us a sensation of hearing ok.

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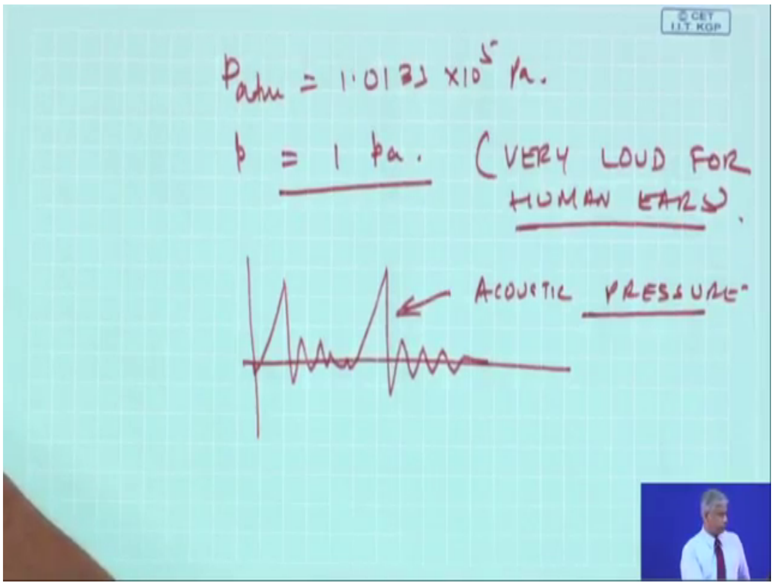

So, if P atmosphere is 1.0133 into 10 to the power 5 Pascal's, on top of it small pressure given 1 Pascal is very loud for human ears, so that is what we have to see. So, if you will see here this is the small fluctuation in pressure which is being incident.

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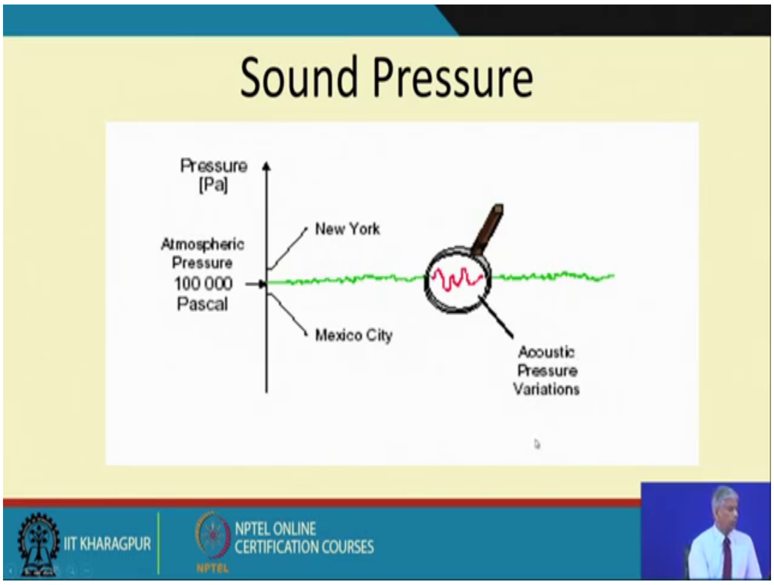

Now if I talk about a value you know you see depending on the altitude from the sea level, this there will be a pressure variation. So, that is the atmospheric pressure, but in an average it is this small perturbation which happens because somebody is speaking the voice signals will go you know somebody is clapping.

So, it is this small fluctuation or the perturbations this is the acoustic pressure, which 1 is interested in when you talk about sound waves. Now this waves this energy will go in terms of longitudinal waves or transverse waves or bending waves we will not discuss much about this in this class.

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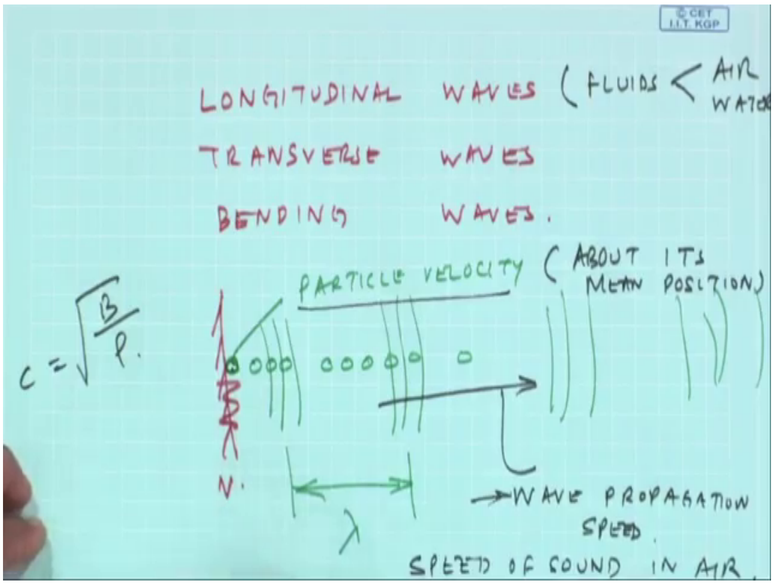

But you will all recall your high school physics that if surface is vibrating here some velocity. So, what happens to the air molecules immediately next to it will have this energy transferred and it will also oscillate about it is mean position and then it will again pass on the energy to this subsequent molecule and then we will have alternate compressions and verifications and this is how the longitudinal waves travel and the distance between each successive compressions or rarefactions in the wave length and this molecules themselves or the particles as they call themselves will not move, but they will oscillate about their mean position with the particle velocity and thus transfer this energy.

But this wave front is moving at speed which is on the wave propagation speed and for longitudinal waves in air in fluids which could be air water, this is nothing but known as the otherwise speed of sound in air. So, there are 2 speeds we are talking about 1 is the speed at which this energy is going and that is the wave front speed, but other is the particle velocity where the velocity the displacement of this particle or the velocity about the particle about it is equilibrium position it is mean position.

So, this oscillations of the particles are responsible for the transfer of energy from one particle to another and so on and this propagation speed moves and this depends you know propagation speed depends on the bulking mode, also the fluid depends on the temperature depends on the density so on and so far.

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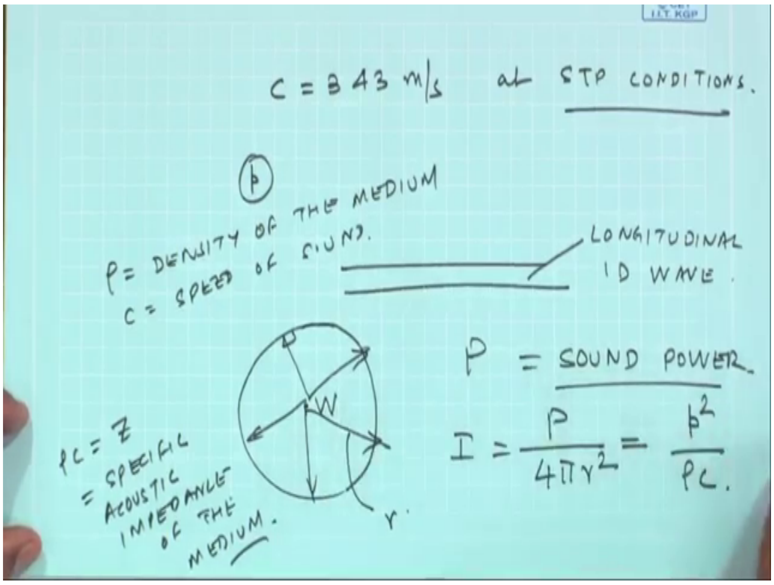

Now, for air this speed is 343 meters per second at STP conditions, they should vary with the temperature and so on.

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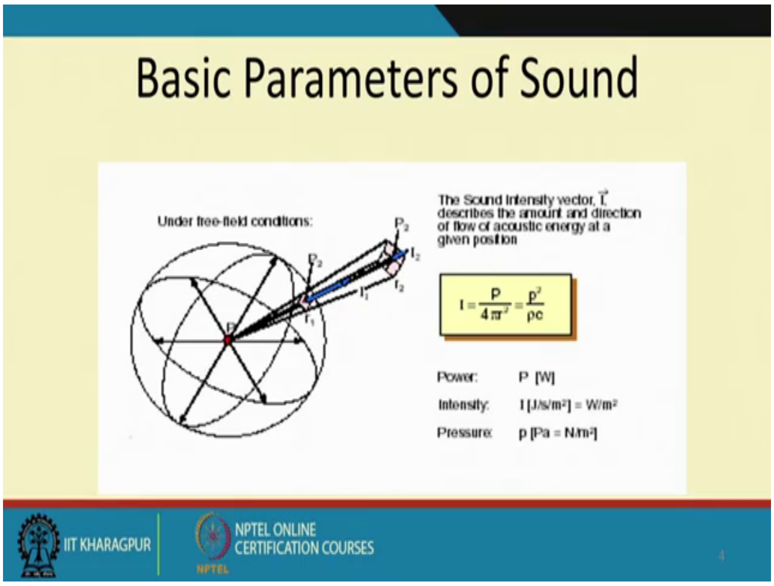

But then if you there is sound particle P and where I had told sound pressure P, where I have told that the pressure is only moving in one direction predominantly and that is a longitudinal one dimensional wave. I supposed to imagine if I have a point source P of some power this energy is going to radiate in all directions around the sphere.

If capital P is the sound power, we have a term called intensity is nothing but the sound power P by the area 4 pi r square where this is reduced r and this will boil down to P square by rho c and I will not go into derivations of this. So, the intensity can be calculated by knowing the sound pressure rho is the density of the medium, c is the speed of sound and rho c is known as the z, z is the specific acoustic impedance of the medium.

As you will see rho and c are the properties of the medium specific acoustic impedance of the medium.

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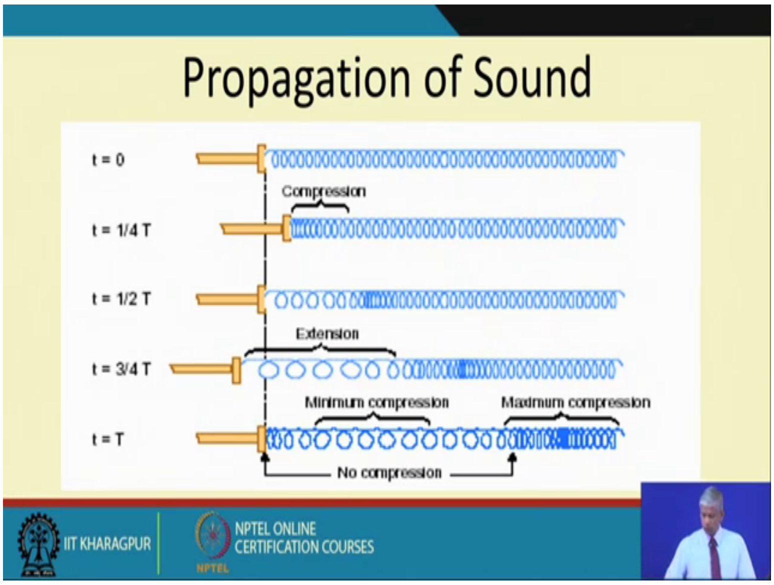

Now this is what I meant by the propagation of sound as longitudinal wave, so there are compressions and with time there are extensions are which are known as rarefactions. So, the entire time period of the signal or of the wave is nothing but if I show it as a transverse wave with time.

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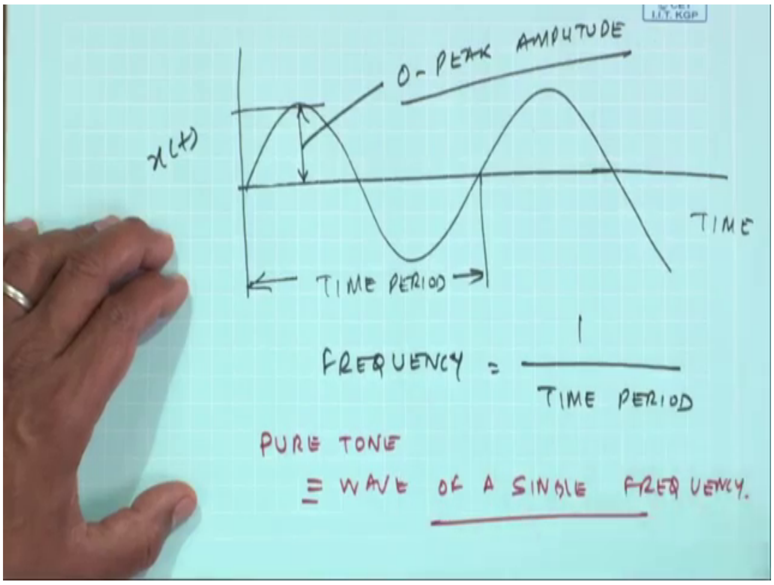

This is the time period and the frequency of this wave is nothing but 1 by time period sum amplitude xt this is the 0 to peak amplitude, just to recall these things we have discussed in our signal processing class which is universally true and because this is just a 1 frequency in acoustics or in sound this is known as pure tone. Pure tone is a wave of a single frequency like a 10 hertz sin wave that is a pure tone of sin waves you knows 10 hertz.

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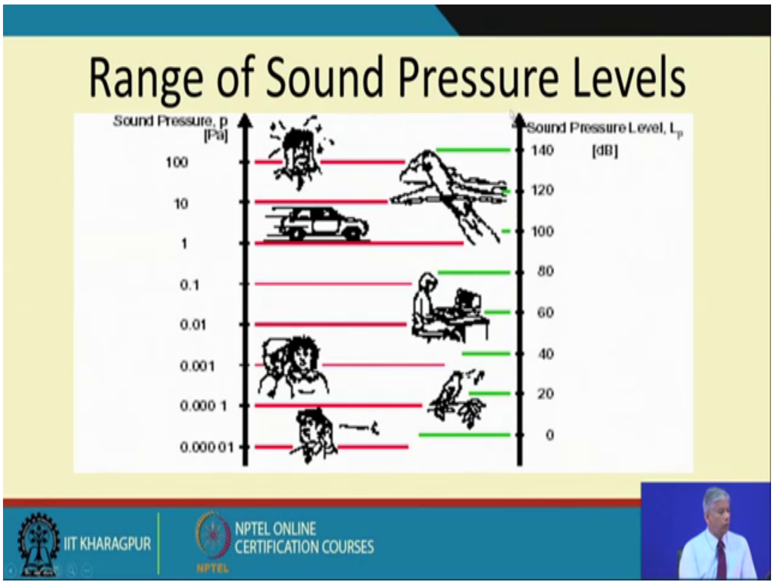

Now, this acoustic pressure which we just described talked about which human ear hears, this can be very low level may be the lowest is20 micro Pascal's human ears, lowest level of perception to a very high value of may be 100 Pascal's.

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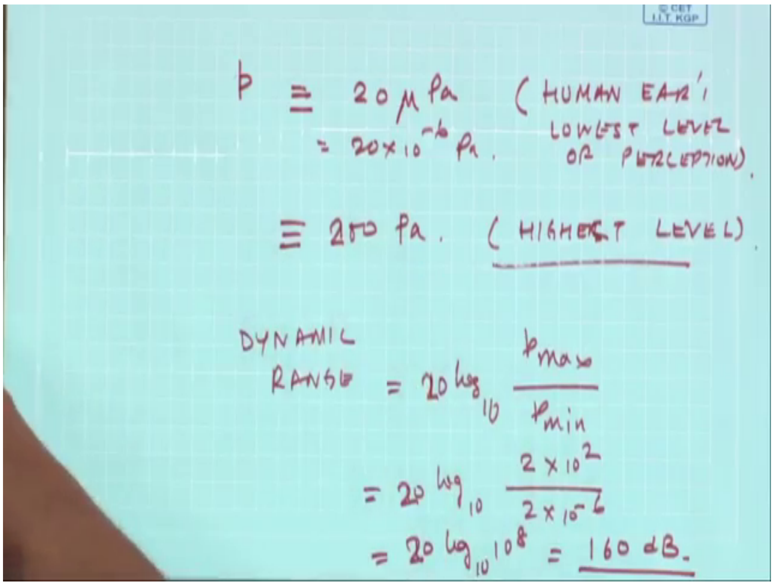

So, this is 20 into 10 to the power minus 6 Pascal's and this highest level higher level order I can make it 200 Pascal also, this for the sake of argument here higher highest level. So, you can see the dynamic range which is nothing but 10 log 10 of P max by P min you will see 10 log 10 of 2 into 10 to the power 2 by 2 into 10 to the power minus 6. So, this becomes 10 log 10 of 10 to the power 8 you know this becomes about 160 decibel. So, human ear god has made our ears the dynamic range is very large ok.

We can hear from the twentieth sound of 20 into 10 to the power minus 6 Pascal's to has highest 200 Pascal's, I will not though kind of warn you at levels higher than 100 Pascal's you know we get a sensation of pain and there will be instant hear in damage; having said that it becomes difficult for anybody to handle such a large range of number from 10 to the power minus 6 to 10 to the power 2 in a linear scale and that is the only reason we use what is known as logarithmic scale to represent a large range of quantities.

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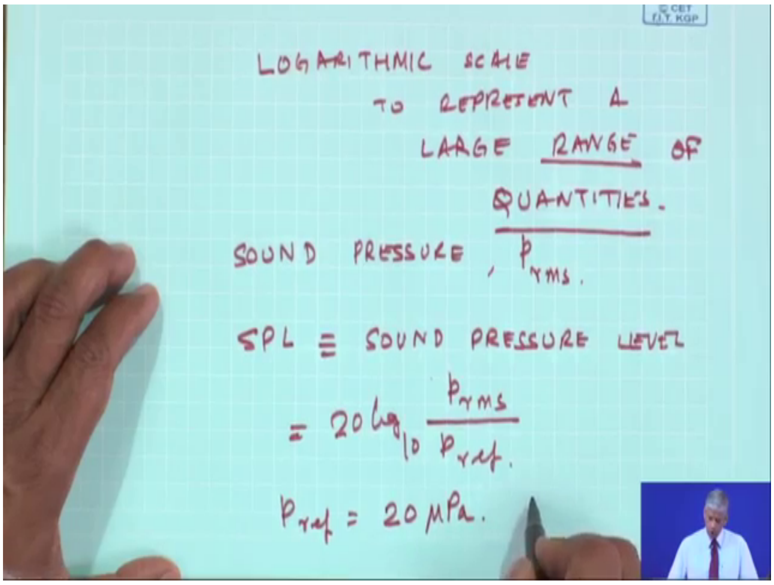

So, for sound pressure P which is p rms the levels are actually represented by what is known as SPL sound pressure level is given as 20 logarithm to the base 10 of P rms by P reference, where the international standard is P reference is 20 micro Pascal's ok.

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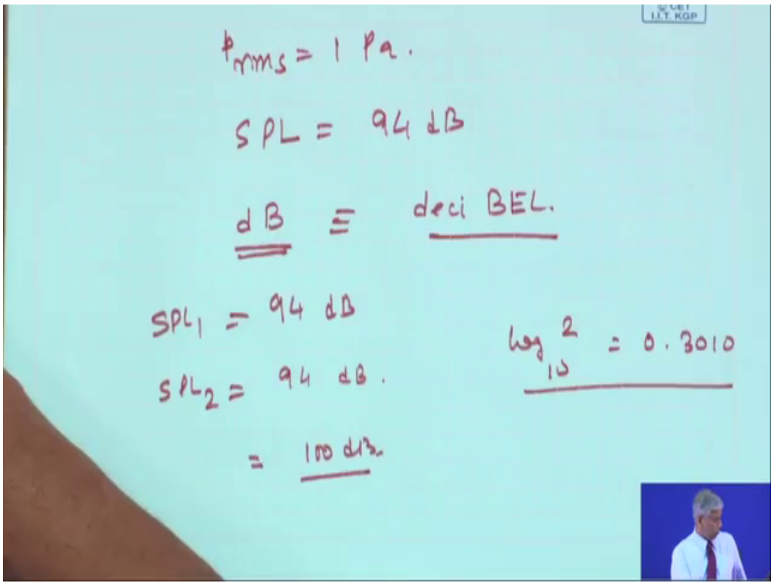

Now, you will we can work out that is P RMS is equal to 1 Pascal SPL will corresponds to 94 decibel by the way the SPL then is given in a value decibel. So, it is written as d B which is nothing, but decibel the convention is to write a d and B. So, 1 Pascal rms value corresponds to an SPL of 94 decibels.

So, you can see here in the slide for the linear scale we have the corresponding values here in green in decibel scale, this sound pressure level they are at the same only thing is that we are conveying linear values in a manageable small values of scale from 0 to 140 decibels and in fact, representing the entire range of sound pressure values which human ear can be subjected to. Now you will see here that some rules of logarithmic addition can be used, for example suppose I have 94 decibel as 1 as SPL 1 I have SPL 2 as 94 decibel ok.

So, I am adding to coherent sources this will boil down to about 100 decibel because, logarithm of 2 to the base 10 is 0.3010 and this values we are going to see later on how much it will increase decrease and so on.

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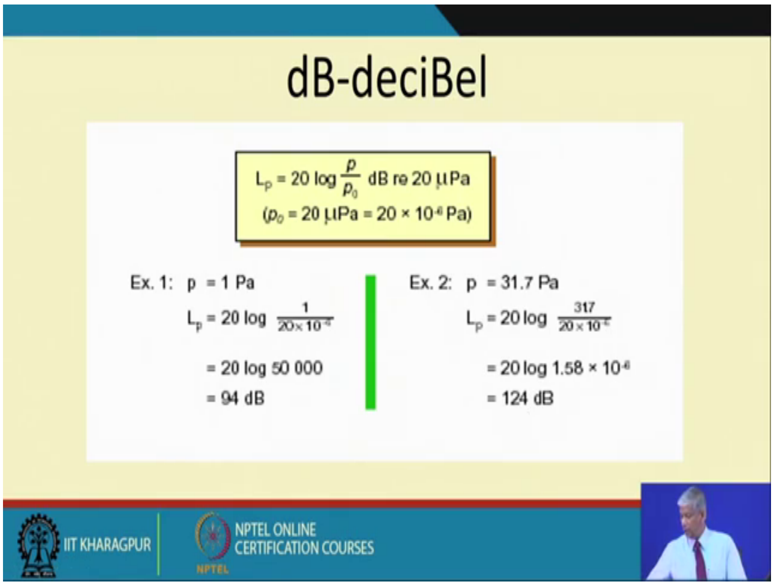

So this is the example which I was just giving you if 1 Pascal then they boil has to 94 decibels, whereas P is equal to 31.7 it is only 124 decibels. So, when you add decibels scales please do not make this mistake because, log of m plus log of n is not equal to log of m plus n this is not equal ok.

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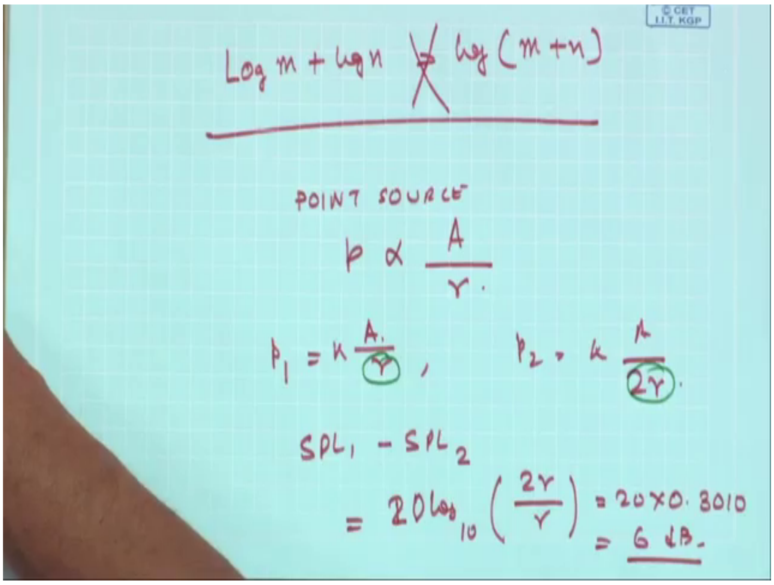

So, never do this, so always do the additions and subtractions in the linear units and then convert your final answer to the decibel scale.

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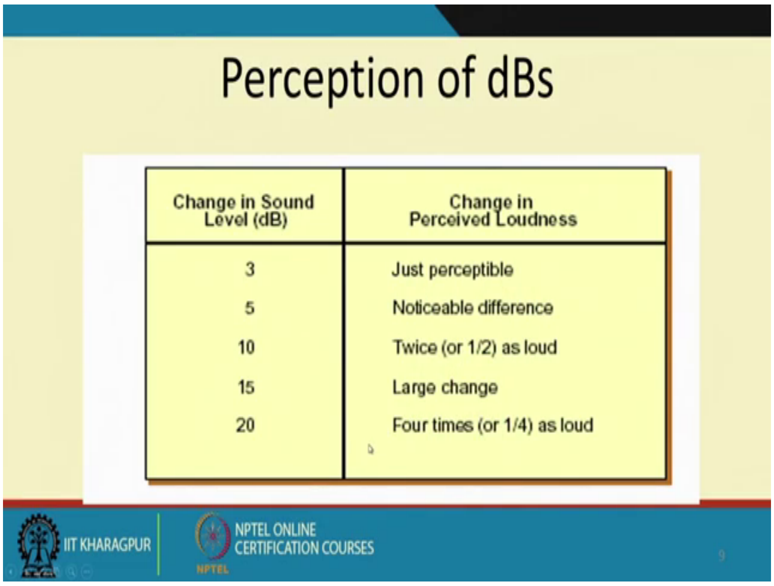

But something I must tell you about the perception of sound amongst human beings, see if 1 machine makes ninety decibel and another makes 87 and 93 2 are human ear, we will notice note difference or human ears cannot perceive any difference less than 3 decibels. So, that is why 1 has to be careful to bring about subsequent reduction in the noise or increase in the noise it has to be 5 or 10 db higher and this I will take a queue to remember this and when we will talk about noise monitoring you will see the influence of this 10 dB.

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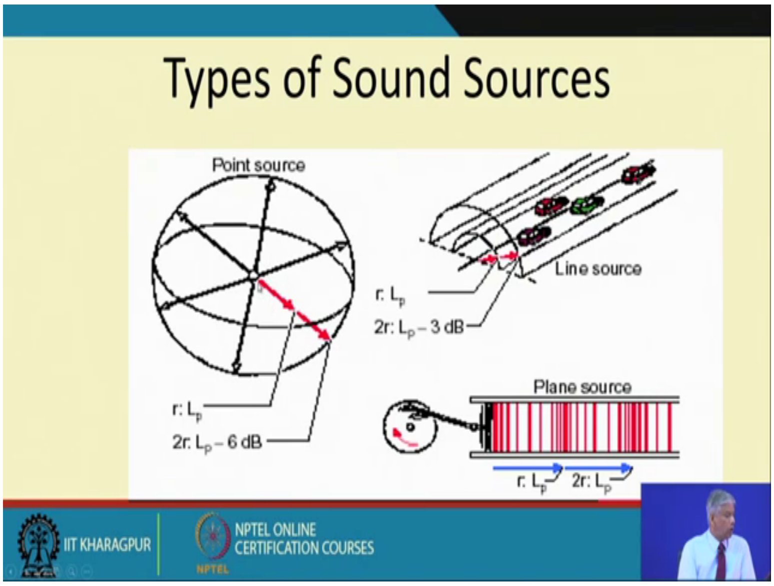

So, on now if you will see here there could be different types of sound sources in our real life, 1 is the plane wave source sound pressure in 1 dimensions at any distance r it is the same the SPL becomes the same and if I have a cylindrical source like a high wave noise, this sound pressure level at any distance r which is twice the original distance will only decrease by 3 decibels. Whereas, if I have a point source the sound pressure level will actually decrease by 6 decibels and when I am talking about a point source I will the pressure is actually proportional to a by r.

So, inversely proportional to the distances from the source r, so if P1 is equal to sum constant a by r and P 2 is equal to sum constant a by 2 r, you will see SPL 1 minus SPL 2 will be nothing but 20 log 10 to the base of 2 r by r and then this will become because logarithm of 2 to the base 10 is 0.30 into 20 times 0.3010 this will be about 6 decibels. So, with every doubling of the distance the sound pressure level will decrease by 6 decibels and we will see later on.

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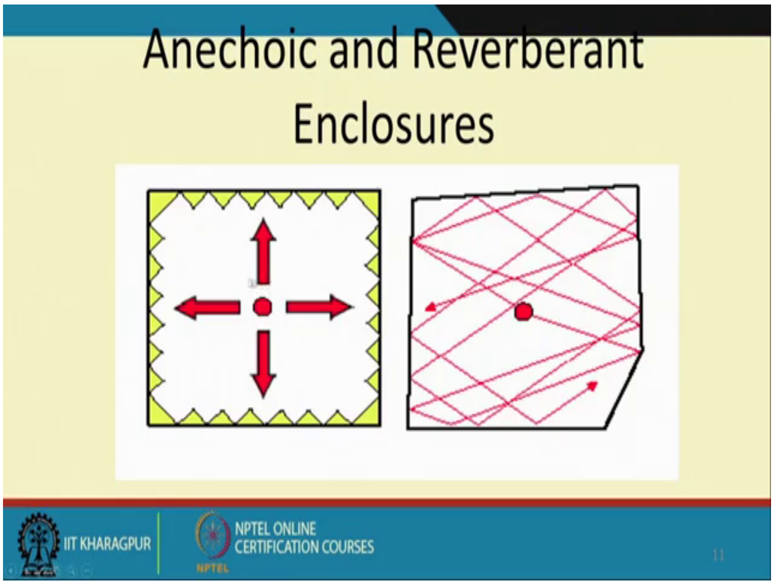

How such rooms are available in places where the sound gets absorbed at the boundary these are known as anechoic chambers and it get gets reflected these are known as the reverberation chamber.

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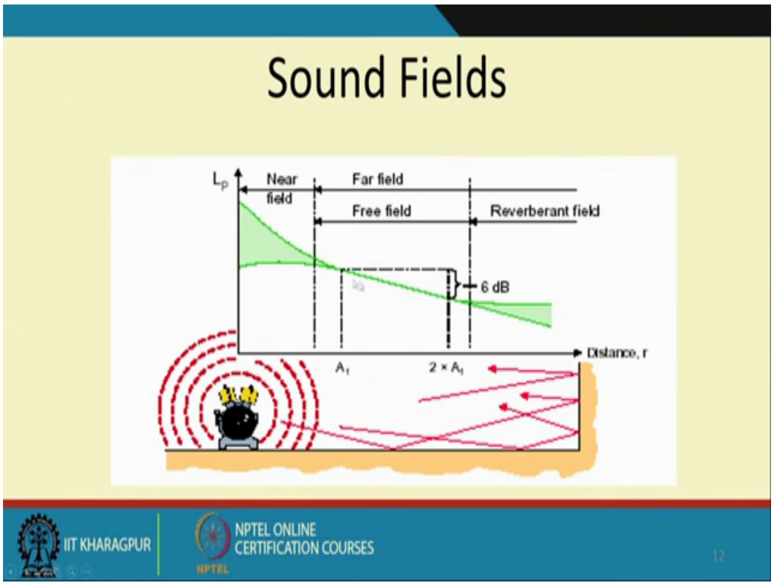

So, sound fields in the free field is actually we have the condition where the sound processer level decrease by 6 decibels and all the measurements sort of machines have to be actually done in the free field and if you go close to the boundaries they will reverberate or they will reflect and the sound levels may increase.

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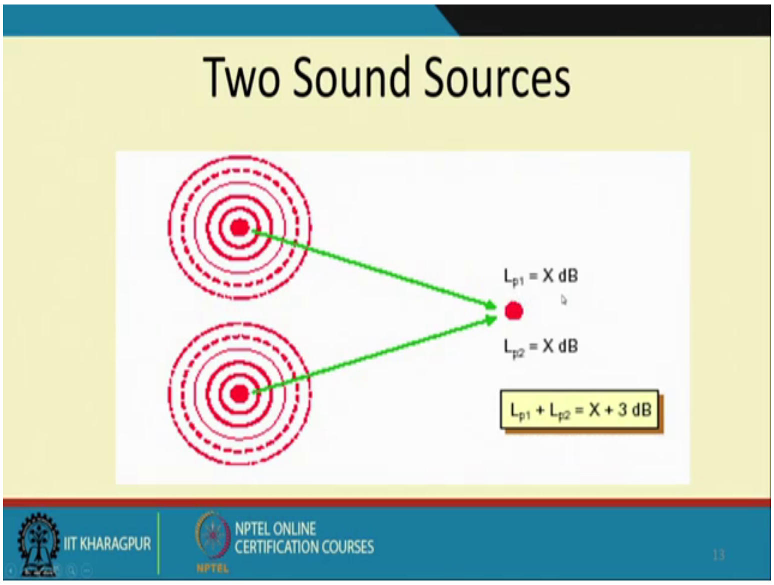

So, I will talk about additions and so on in the later classes.

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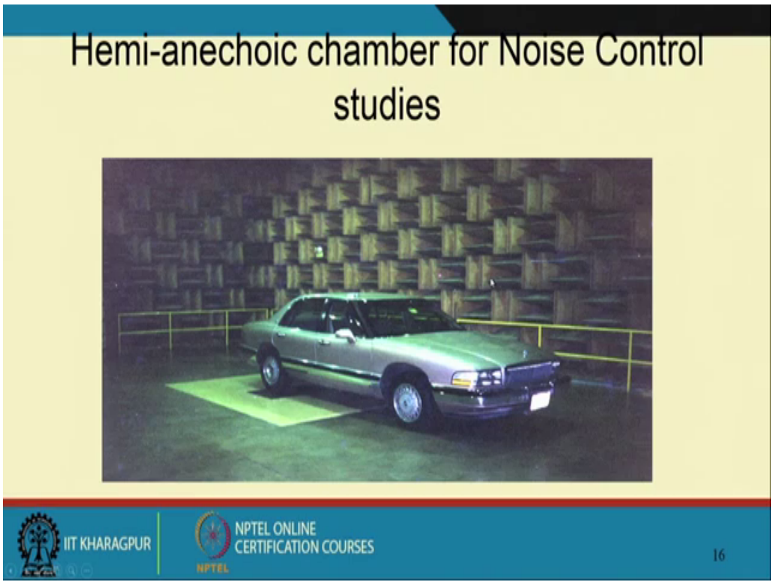

Such chambers are used for noise control in automobiles ok.

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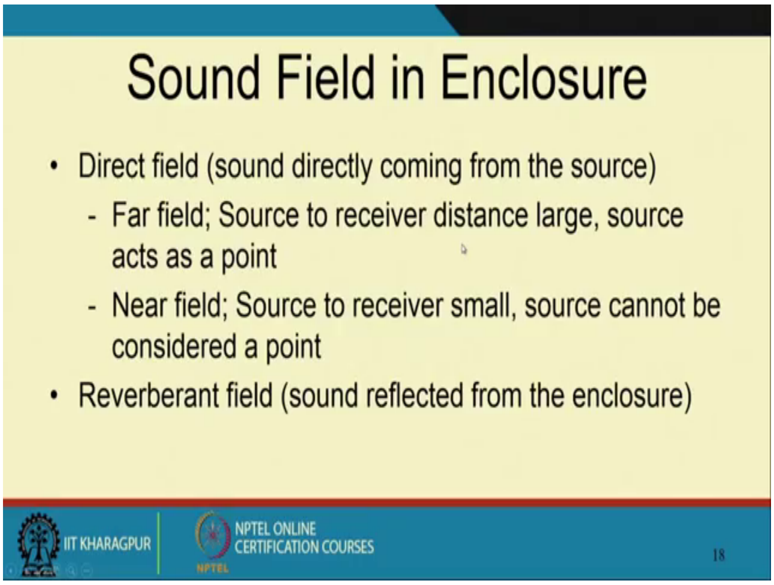

So, sound field in enclosure there is a direct field sound directly coming from the source, far field is source acts like a point near force source cannot be considered as a point.

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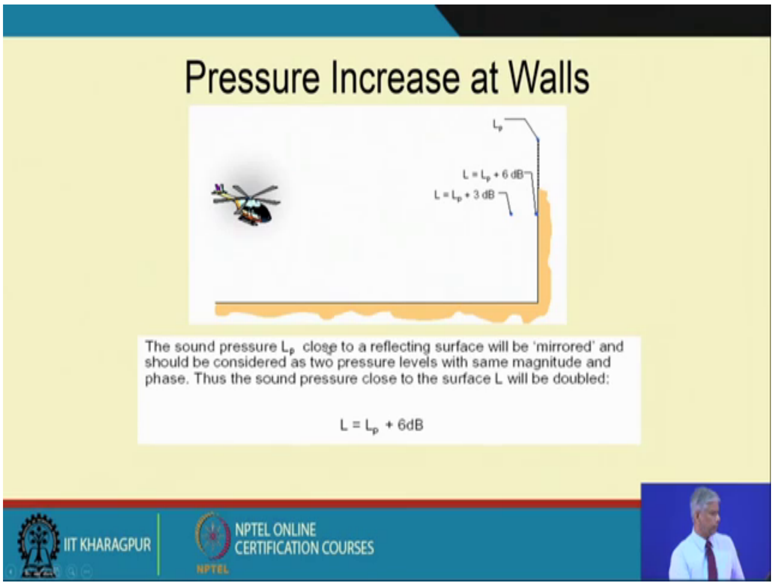

And now obviously, pressure would increase at the walls because of the reflection 3 decibels 6 decibels and so on right we will talk about.

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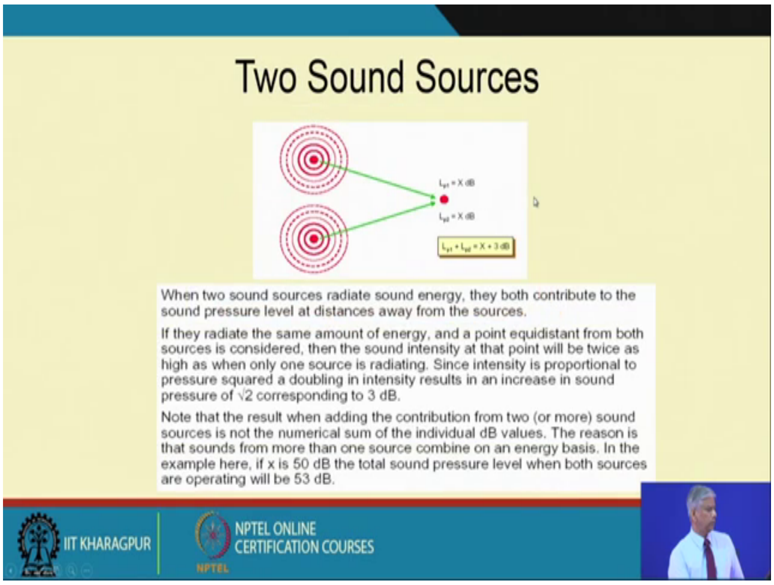

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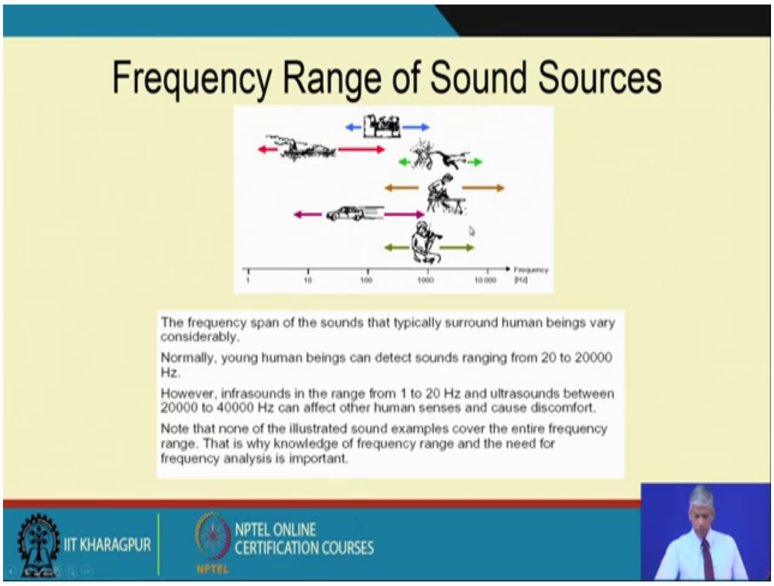

Frequency range in this sound which we talked about human beings can hear anywhere from 20 hertz to 20 kilo hertz and this is the audible range.

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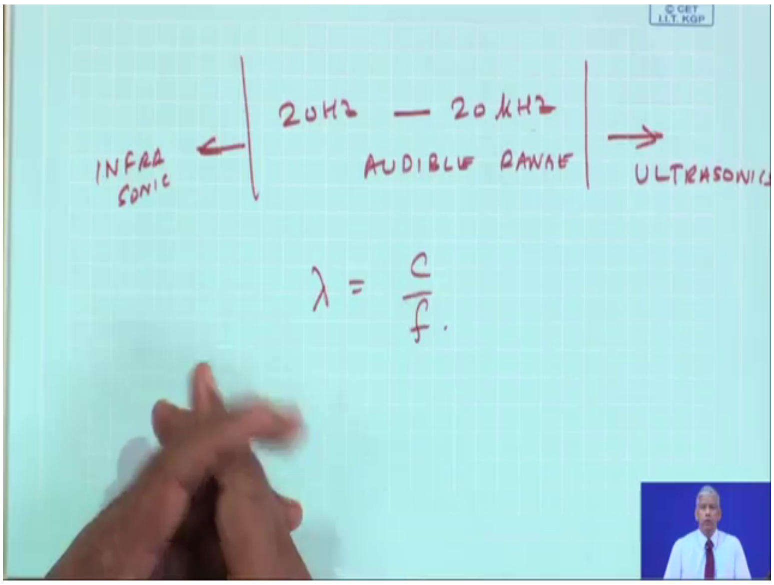

So, anything beyond this is the ultrasonic's, I think less than this is infrasonic; of course, we will see that different machines create different kinds of noise, these will talk about in noise monitoring and so on they say know dogs can hear.

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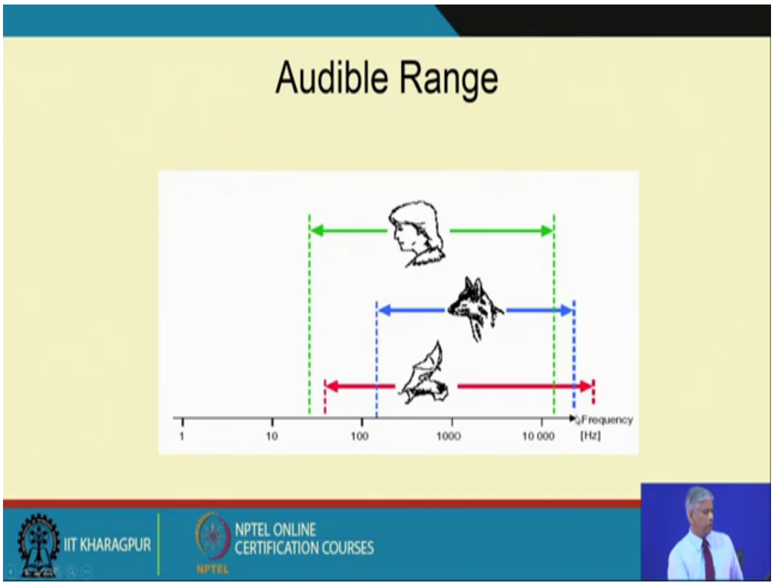

Beyond 20 kilo hertz bats use ultrasonic waves for their navigation and so on.

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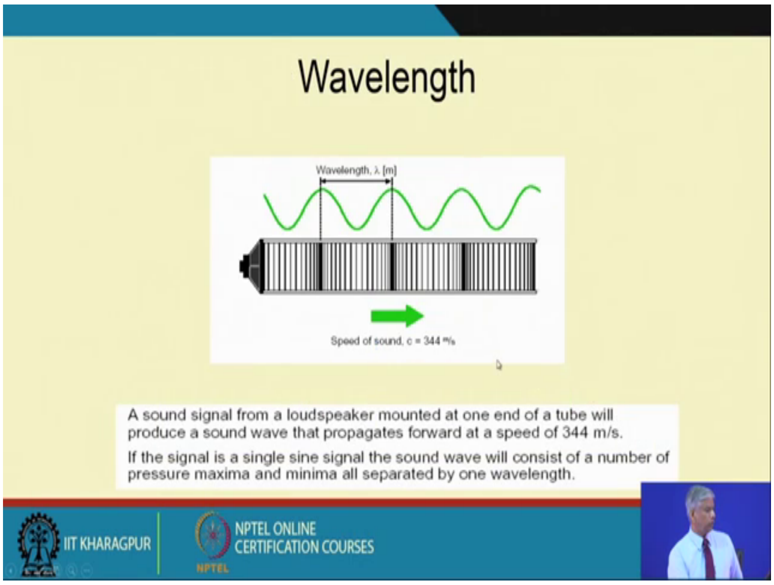

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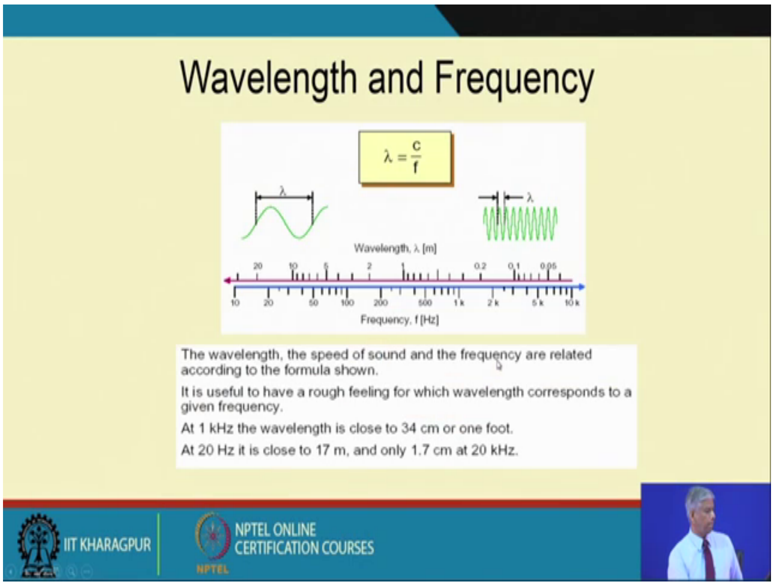

And of course, there is a relationship between wavelength and frequency as the frequency increases the wavelength would decrease and so on.

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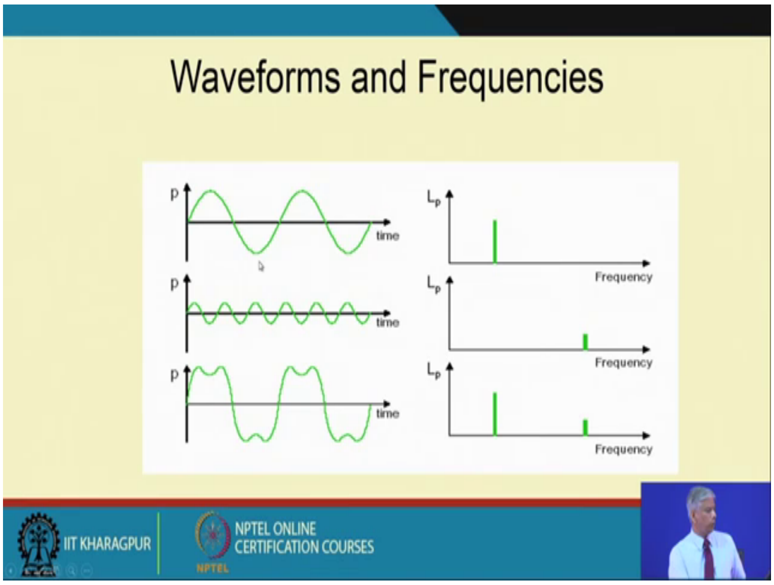

We all know this from signal processing this pure tone of lower frequency, this pure tone of a higher frequency these are true signals because, it can see in the frequency spectrum and so on right.

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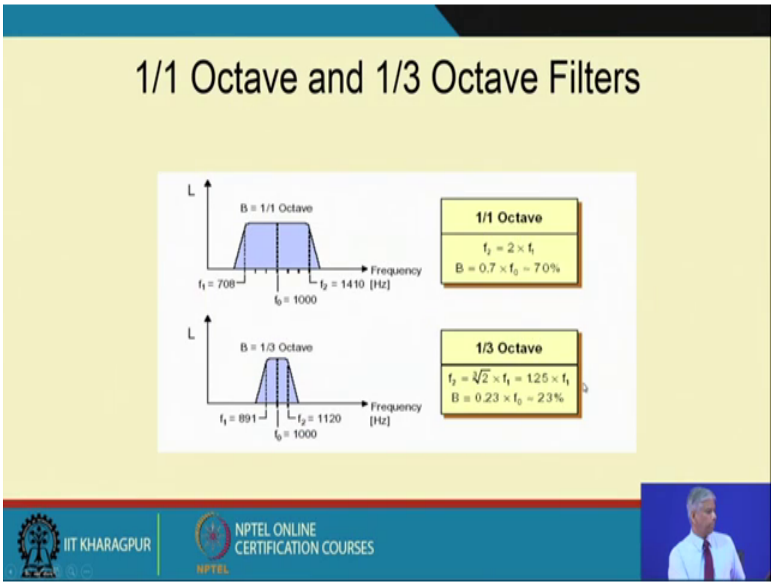

And we will talk about this filter in the next class and so on, more of this you can find in my book.

Thank you.