Mechanical Measurement Systems
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Lecture - 36
Sound Measurement

I welcome you all in this course on Mechanical Measurement Systems. And today we will discuss about the sound measurement. And today's lecture we will start with the sound waves and then acoustic measurements, how the acoustic measurement is done that is method of acoustic measurement.

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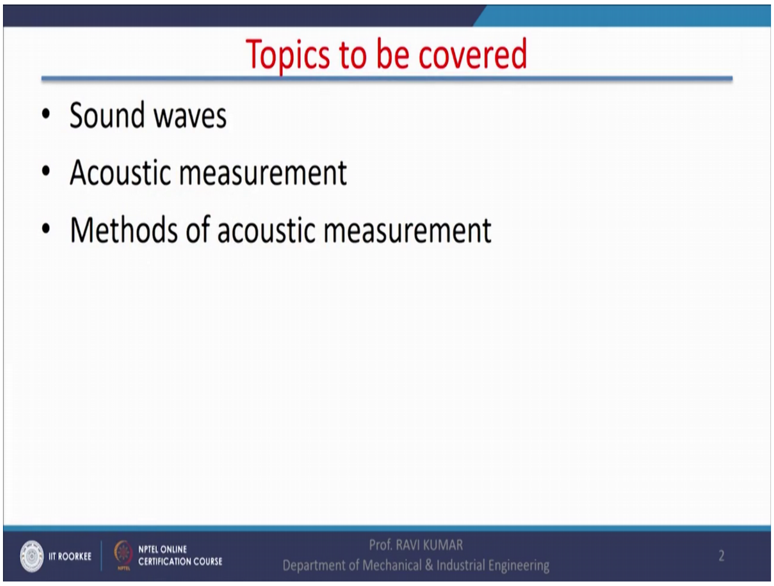

So, sound is a vibratory phenomenon; sound is a vibratory phenomena and it requires a medium also without medium the sound cannot travel.

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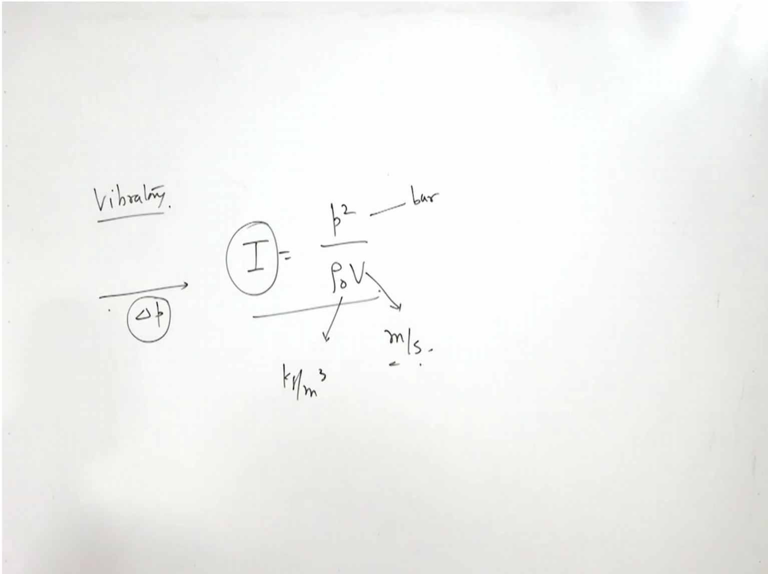

So, it is a vibratory phenomenon, and it requires a medium and through that medium only the acoustic waves, they move. And in course of the movement of the waves; there is a fluctuation in pressure right and they are also characterized as the energy flux per unit area per unit time.

So, intensity and this pressure fluctuation, these can be the two parameters, which can help us in the measurement of sound measurement.

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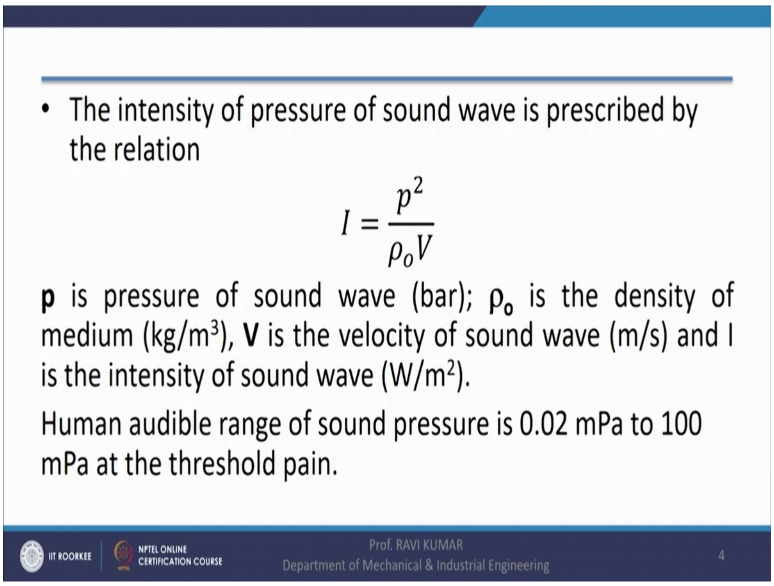

So, the intensity of the pressure of sound waves, that is I is equal to p square divided by rho o V; that is the intensity of the sound p is the pressure of sound wave it is in bar; p is the pressure of sound wave in a bar; this is the density of the medium it is kg per meter cube, and this is the velocity of sound in meters per second and this will give us the intensity of the sound I right.

And pressure pulse is there, because there is a phenomenon, which is related with the variation in pressure and variation in the intensity of the sound.

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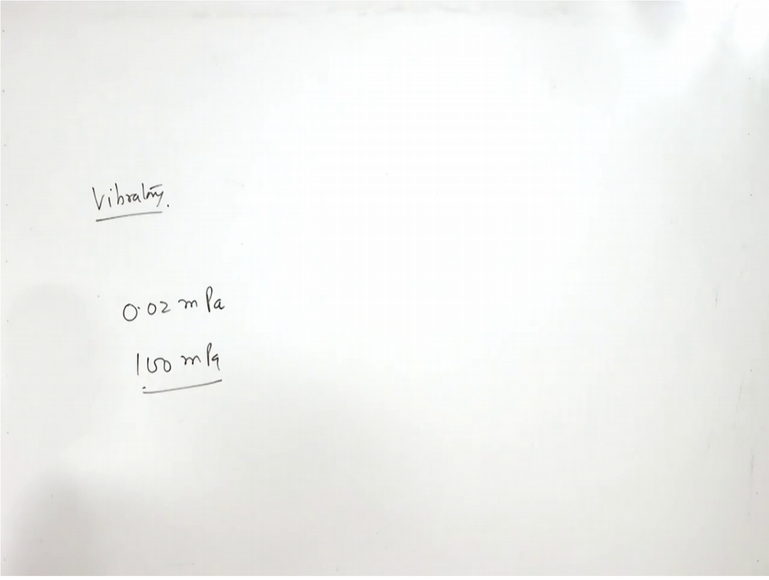

The pressure we can I mean here it is 0.02 milli Pascal to 100 milli Pascal, if the pressure on a on our eardrums is more than 100 millipascal, then the hearing is very painful; the painful hearing starts from 100 milli Pascal pressure. So, it harmful for the body for the body itself or harmful for the ear itself; so the pressure should remain less than 100 milli Pascal and below this we cannot hear zero point this is the threshold limit.

So, it is a standard practice in acoustic measurement to relate sound intensity and sound pressure to certain reference value Io and po.

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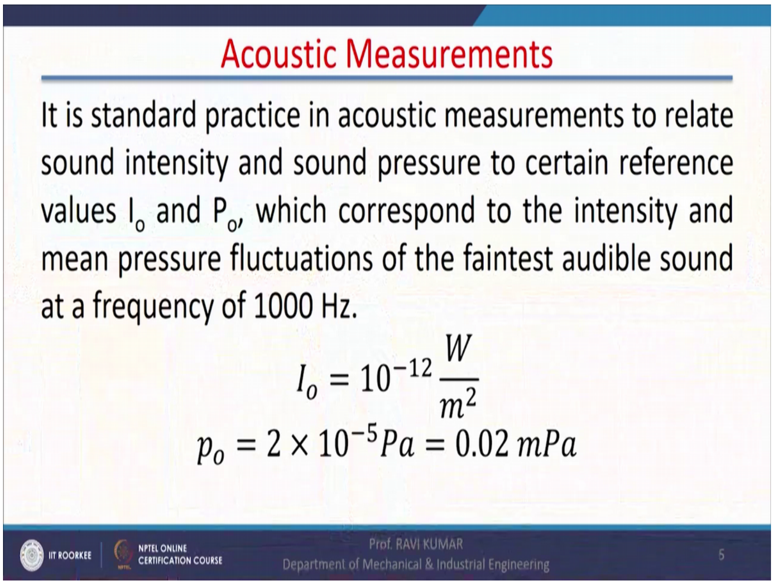

So, there has to be a certain reference value for intensity of the sound and pressure right.

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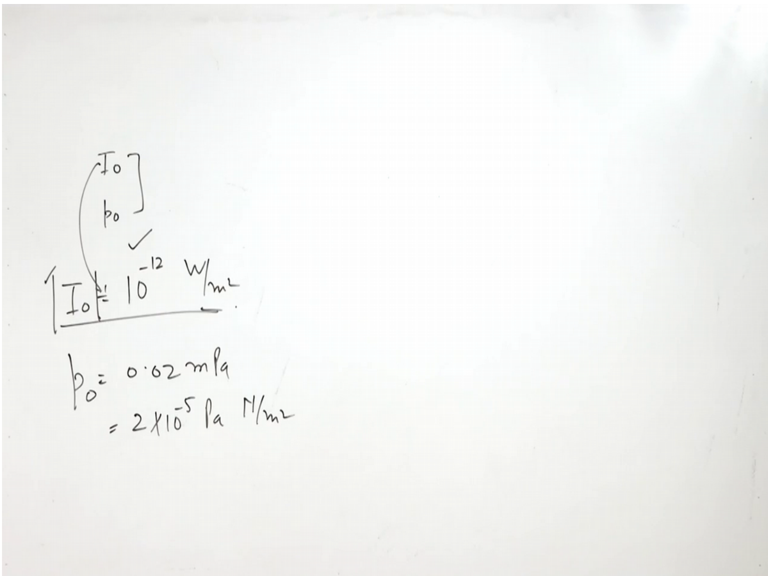

And Io is reference value is, it is 10 raised to power minus 12 watt per meter square. This is the energy dissipation, this is the energy dissipation reference value ok.

So, all the energy with the sound wave will be compared with this the reference value ok. And for pressure, it is as I said earlier it is 0.02 milli Pascal or it is 2 into 10 to power minus 5 Pascal or Newton’s per meter square. So, these are the difference values and these values are used for finding out the intensity of the sound or the magnitude of the sound ok.

So, sound intensity is measured in terms of decibels db.

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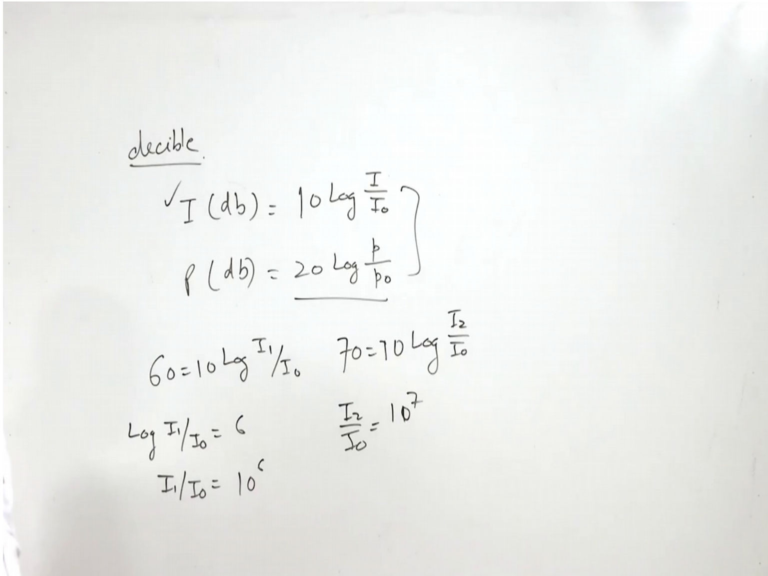

Sound is always expressed in decibels right; and it is it varies from let us say 30 decibel or 40 decibels 200, 125 or 130 decibels right. 125 decibels very painful sound very loud sound, and intensive intensity level decibel is expressed as 10 log I over I, pressure level decibel, because intensity is proportional to pressure square right. So, it is 20 log p by p o, it is also called sound pressure level intensity and pressure level the sound pressure level 20 log p by po both are same.

So, intensity and pressure level is usually called sound pressure level s p l. Now, suppose I have sound of let us say 60 decibel and 70 decibel, how to add them; I mean one source is giving 60 decibel sound, another source is giving 70 decibels sound. So, should we take 60 plus 70, 130 or under root 60 square plus this is normal standard practice in mathematics 60 square plus 70 square under root or under root 60, 70 what we should do?

Now, here as it is clear from here, 60 means 60 means 60 is equal to 10 log I1 by Io it means log I1 by Io is equal to 6 or I1 by Io is equal to 10 to power 6. Similarly, we can find 70 is equal to 10 log I2 by Io right. So, it is going to be; so I2 is going to be I2 I2 I2 by Io is going to be 10 to power 7.

This is 10 to power 6 and this is 10 to power 7.

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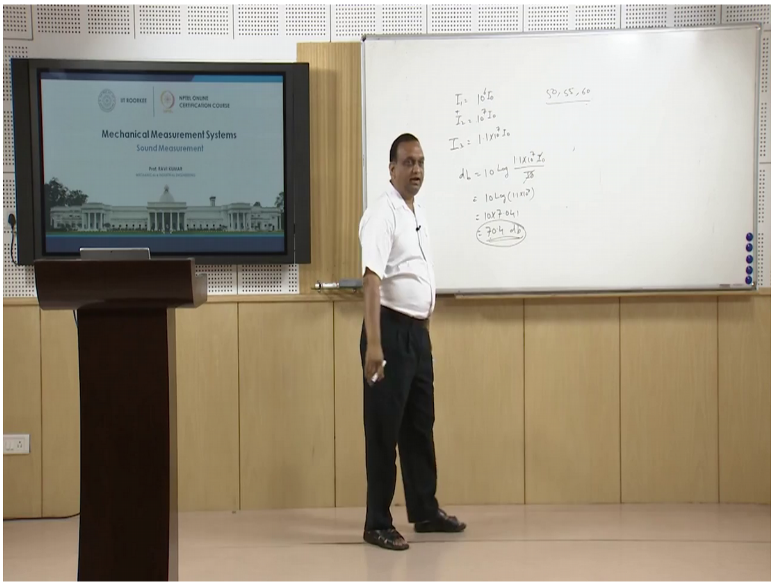

Now I1 and I2; now I1 is; now I1 is 10 to power 6 Io, I2 is 10 to power 7 Io plus here simply we will add the energy and after adding 10 to power 6 and 10 to power 7, this is 10 to power 6 plus 10 to power 7. We are going to get ah; so 10 to power 6 plus 10 to power 7, 1.1 into 10 to power 7 Io right.

Now, we have another value I and result in sound level can be determined by taking simply log off; this is let us say I 3, 10 sorry this is decibel. So, decibel is 10 log I3 is 1.1 into 10 to power 7 Io divided by Io; and this Io will be cancelled out and we will be getting 10 log 1.1 into 10 to power 7 and log 1.1 into 10 to power 7 7.041 10 into 7.041 is equal to 70.4 decibels. So, when we are adding the sound 60 decibel and 70 decibel you can imagine this scale, because they I mean 60 decibel and 70 decibel the resultant sound will be only 70.4 decibels right.

Suppose, we have to add 3 frequencies; 3 sounds let us say 50, 55 and 63 sources of sound one is 50, another is 55 and third one is 60 right.

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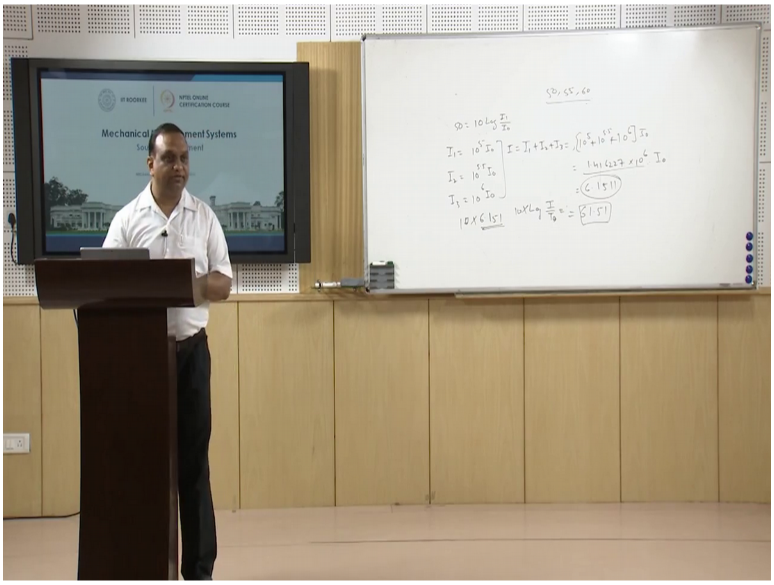

In this case we will simply follow this method, and then 50 is equal to 10 log I1 by Io. So, I1 is 10 to power 5 Io. Similarly I2 is 10 to power 5.5 Io and I3 is 10 to power 6 Io right. And now we are adding these three sources and we will take the log. So, log off 10 to power 5 plus 10 to power 5.5 plus 10 to power 6, it is 6.151. So, it is going to be 6.151 multiplied by 10.

What I have done? I have taken I have just added; so I1 plus I2 plus I3 is equal to 10 to power 5 plus 10 to power 5.5 plus 10 to power 6 Io. And this gives me 10 to power 5 plus 10 to power 5.5 plus 10 to power 6 this gives me 1.416227 into 10 to power 6.

Now, I take log of this and I get 6.1511. So, log off I; so this is I. So, log of I by Io and this is multiplied by Io. So, I by Io is equal to this divided by Io and we are getting this value and when we multiply this by 10; the resultant decimal is 61.5. So, we are adding 50, 55 and 60 we are getting the final or intensity of the sound as 61.51 decibel.

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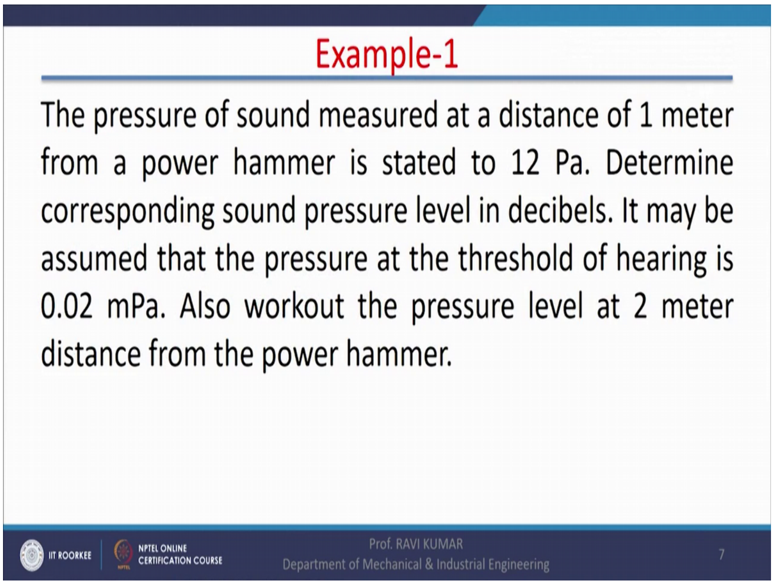

Now, let us take one example pressure of sound measured at a distance 1 meter for power hammer stated is 12 Pascal. So, there is a power hammer and power hammer creates a pressure of 12 Pascal at a distance of 1 meter; 12 Pascal that is pneumatic pressure wave is of 12 Pascal.

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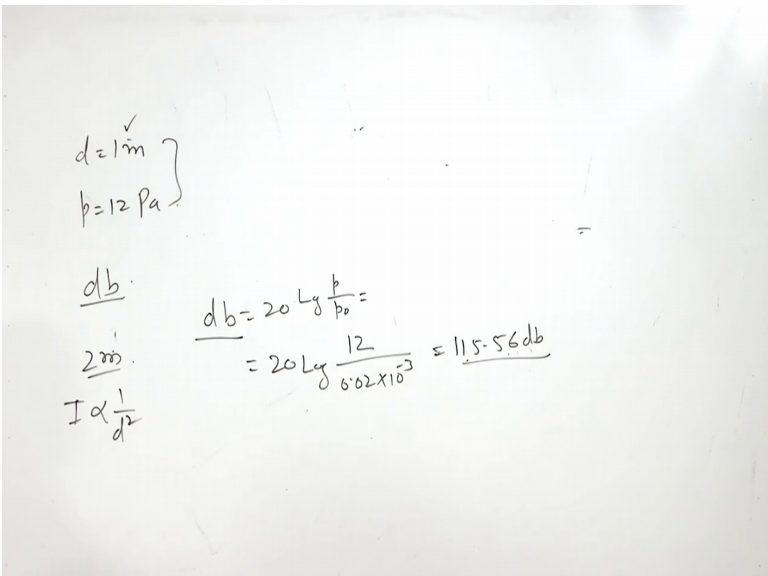

Determine the corresponding sound level in decibels. What is the order of the sound? What is the sound level in decibels?

So, in order to find that the sound level in decibels, we will just take 20 log p by po, p is 12 Pascal. So, it is 12 and po is 0.02 into 10 to power minus 3 right; and we will take log; log here; so just a minute we will write like this equal to 20 log 12 divided by 0.02 into 10 to power minus 3, and this is when this is expressed in decibels it is 115.56 decibels.

Now, in the second part of this question, workout the pressure level at 2 meter distance from the power hammer. Now instead of 1 meter distance I need right the intensity at 2 meter right, and intensity is inversely proportional to the distance. So, I is distance square right.

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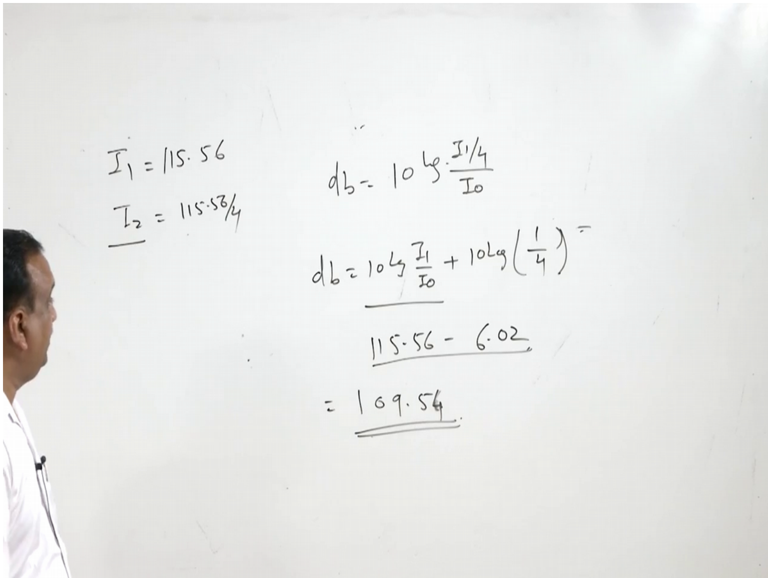

So, definitely here so for 2 meter, because it is 115.56 decibel, that is I1 right and then I2 is going to be 115.56 by 4, because it has moved from 1 meter to 2 meter. Now, we have to measure the intensity at 2 meters. And now if you take decibels as 10 log I1 by 4 by Io right; and when we take 10 log I1 by 4 by Io, then it turns out to be db is equal to 10 log I1 by Io plus 10 log 1 by 4 by Io plus no not Io; into 1 by 4.

So, it is only 1 log 1 by 4 ok. Now this is with us 115.56; now if you take 10 log 0.25; so log 0.25 it is 6.02 this is 6.02. So, the difference of these two will be equal to 109.56 or 54; 54 this is the final decibel.

So, when you are moving instead of 1 meter, if you are measuring the sound level at 2 meters it is reduced from 115 to 109.

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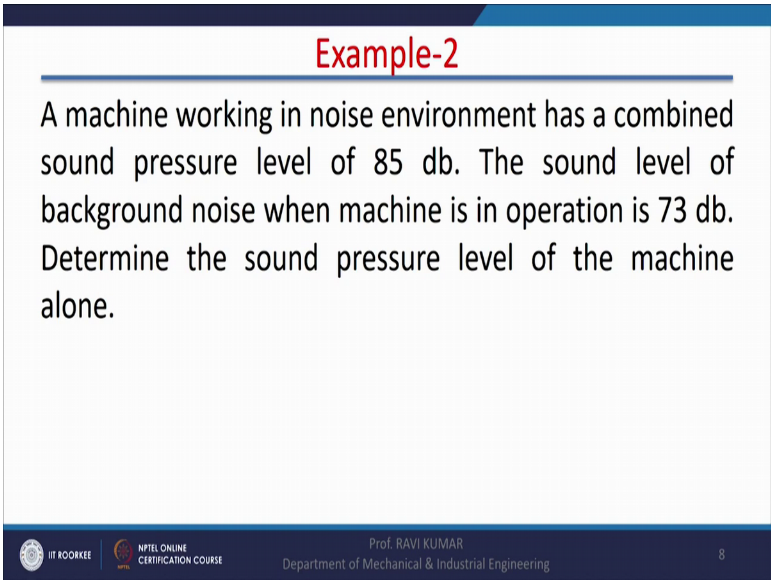

Now, we can take another example. A machine working in noise environment has a combined sound pressure level of 85 decibel. It is a combined sound pressure level is 85 decibels right.

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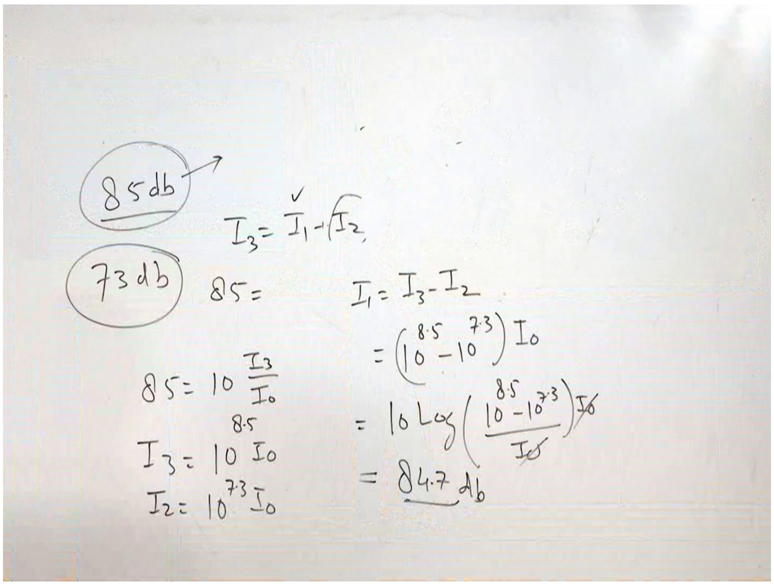

The sound level of background noise, when machine is operation is an operation is 73 decibels. So, this is the background size sound, this is total sound background plus machine sound. Determine the sound pressure level of the machine alone.

So, the total sound I is equal to I1 plus I2, I1 is a machine sound. So, I is 85 decibel. So, 85 decibel first of all 85 is equal to 10, I1 by; so this is total no total I by or I3, I3 by Io. So, I3 is 10 raised to power 8.5 Io right. Similarly I2 is 10 raised to power 7.3 Io, if you take difference of these two we will get the sound level of machine.

So, sound level of machine is I1 not I2 sound level of machine; so, I1 is I3 minus I2 right. So, I3 is 10 raised to power 8.5 minus 10 raised to power 7.3 Io right and then we can solve this and then we can take log of 10 log of 10 raised to power 8.5 minus 10 raised to power 7.3 divided by Io multiplied by Io this will be cancelled out and the sound level of machine is this is 10 raised to power 8.5 minus 10 raised to power 0.3 log it is 84.7

So, this is coming 84.7 decibels. So, this is the sound of machine this is sound of background 73 decibel, this is 84 points in decimal and final sound is 85 decibel.

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Now, methods of acoustics measurements methods, how to capture this phenomena; how to capture this phenomena? So, it is sound measurement is done using microphones, even what the sound coming from my mouth is also captured by this microphone. So, all microphones are required; microphones are required to capture the sound it is a microphone is like a it consists of necessarily consists of a diaphragm a diaphragm. When sound pressure is exerted on this diaphragm it starts vibrating right. And this displacement if you are able to capture, if this displacement we are able to capture and then this displacement is converted into the EMF it may be very weak, because we weak vff can be amplified using the amplifiers right.

So, this displacement if we are able to measure, then we can simply capture the sound.

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So, there are three types of microphones one is capacitive second is piezoelectric and third one is electrodynamic type mainly there are three types of microphones. If you start with the capacitive type of microphone, the diameter is very thin, because we have to capture very low pressure of air. So, the diameter is of the order of 2 microns in such type of microphones right. And in the body of the microphone, the diaphragm is fixed like this is the diaphragm and behind the diaphragm, there is a rigid wall and both of them together they work as a capacitor.

When due to vibrations when the distance between these two rigid wall and the diaphragm, then the change in the gap between these two right EMF will be generated. And for equalizing the pressure on the both the sides, a capillary is provided here, because if pressure difference is high; then the diaphragm will break or it will rupture. And in the rigid wall also holes are provided for the same purpose through and through holes are provided for the same purpose right. And when the sound pressure is on the membrane, the capsular will be change and this can be measured with the help of a measuring unit.

On this principle the capacitive type of microphone works; another is piezoelectric type. In piezoelectric type of microphone diaphragm is same, this is this diaphragm let us make diaphragm like this, the diaphragm is connected to a piezoelectric crystal, and the force which is exerted on this diaphragm pressure which is exerted on the diagram is converted into the force and the force is exerted on piezoelectric crystal. And when the force is exerted on the piezoelectric crystal, it gets charged and just simply measuring the output, we can relate with the sound pressure and subsequently the measurements can be done.

So, piezoelectric crystal we can go for natural quartz they are naturally available piezoelectric crystals there are quartz. Another is Rochell salt and there are a certain synthetic type of piezoelectric crystals also, they are lead lead zirconate and barium titnate.

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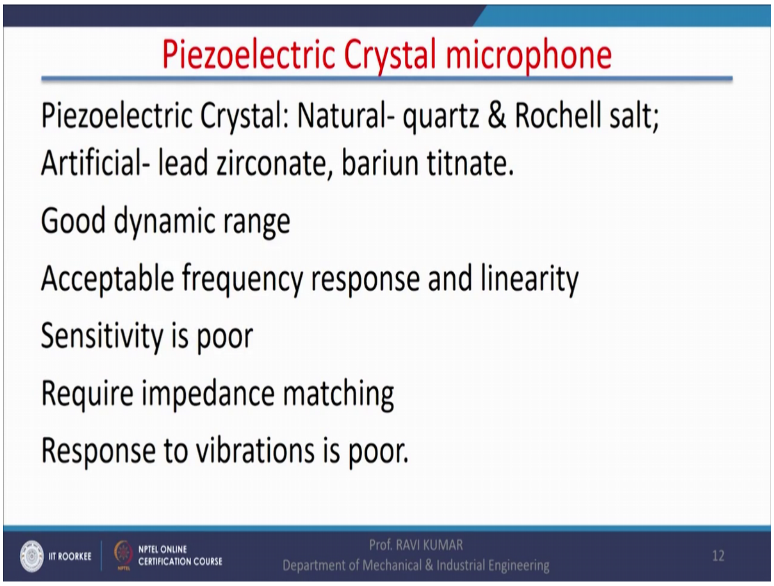

The benefit of using that piezoelectric crystal is first of all they have very good dynamic range. Piezoelectric transducers here have a very good dynamic range, and the frequency response is linear and acceptable here in the case in this type of application; however the sensitivity of piezoelectric crystals in this table because the pressure is very low. The sensitivity is not that good; sensitivity is poor. So, impedance matching is also required in the case of piezoelectric type of microphones.

The last type of or the kind of microphone is based on the principle of electro dynamics right. So, when a conductor is placed in a magnetic field, when there is a movement in the conductor the EMF is generated. So, here in this microphone membrane is there; one membrane is there and there is a magnet and there is a coil or core and coil here; coil and there is a core.

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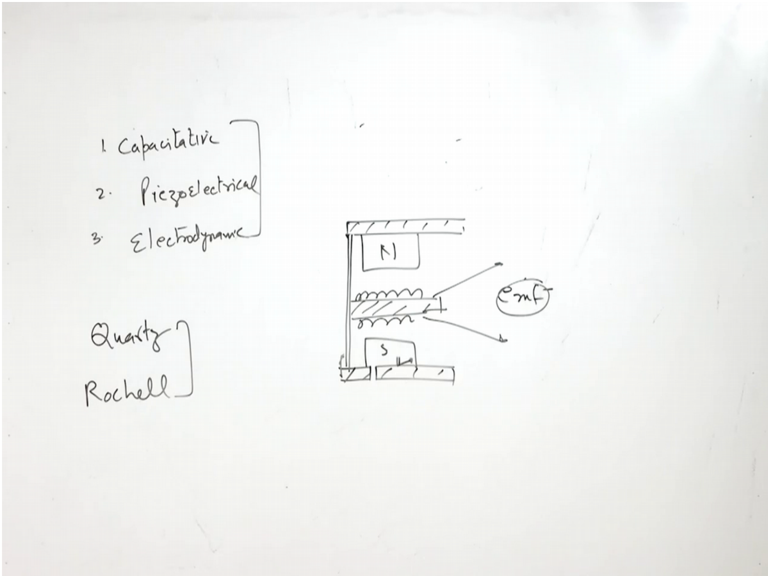

So, when pack pressure is exerted on the core, there is a movement in the core. When there is a movement in the core it is in the magnetic field there is a movement in the core EMF will be generated; and these type of I mean microphones are found I mean the microphones with this electro dynamic arrangement are found in many of the applications or many of the devices in day-to-day life.

First of all; they are self generating the benefit of these type of speakers is they are self generating. And they have very good sensitivity, if you compare with the piezoelectric type, they have very good sensitivity range is quite wide. So, so that is, why; that also goes in the favor of these type of a speaker.

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The rage is white, but linearity is poor electro dynamic this speakers the linearity is poor and frequency response is also poor.

So, there are certain things, which go which I mean they are beneficial for one kind of a speaker and they certain things, which are not beneficial with certain kind of speaker. But the fact remains in most of the applications in day-to-days life, where electromagnetic type of microphones are used. So, electromagnetic microphones find a wide application in day-to-day life that is all for today.

Thank you very much.