Architectural Acoustics

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Lecture – 03
Frequency and Octave

Good morning students, welcome to the NPTEL lecture on Architectural Acoustics. This is the third lecture where we will discuss the Frequency and the Octave. If you remember in the lecture number 2, we have discussed about the general propagation of the sound in a media like air or in any other kind of a media. And we have actually thought of some kind of the parameters and we have actually given some kind of a relations to one parameter to the other.

We also found out the, what is what should be the appropriate propagation equations are so. So, there we have discussed one typical parameter of the sound has the frequency and this frequency plays a major role in building acoustics or any kind of the acoustical phenomena.

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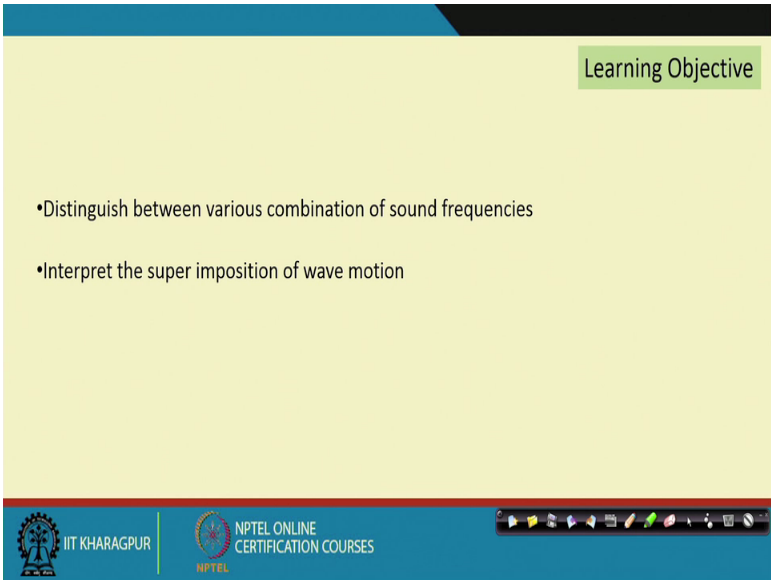

So, in this lecture there are two learning objective. So, if there are various combinations of the frequencies, how to differentiate at the distinguish between them that is the first objective of this lecture. And second objective is the interpret the super imposition of the wave motion.

That is also given to be happened because of the if sound cannot be cannot be a single frequency sound, it is actually in the mixed frequency sound. So, how the sound is super imposed with the other and that kind of a scenario we have to see.

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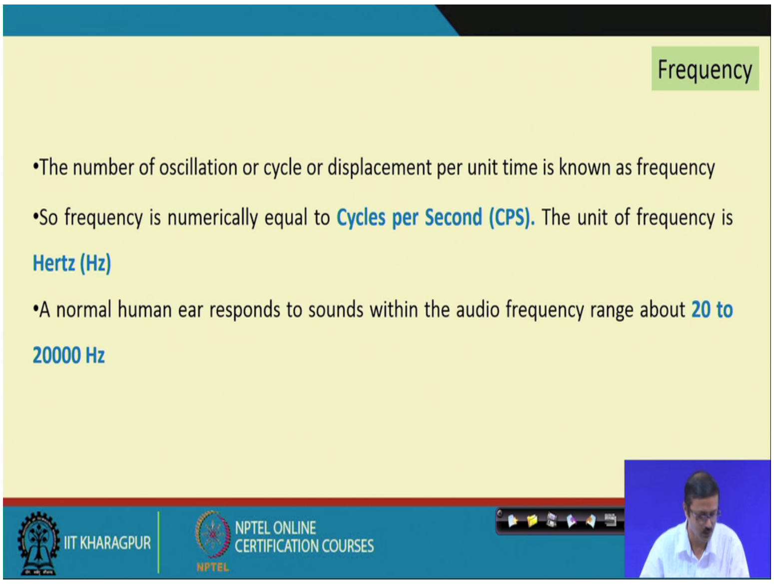

So, the frequency as we discussed as we already discussed in the lecture number 2 is the it is a number of oscillations of the or the cycles that is going to be displaced in the unit time in a wave motion and its the unit is hertz or cps, and out of the 100's or out of the 1000's of the frequency is available in the nature, the human being can only response to 20 to 20000 hertz frequency.

Now, this spectrum is also very huge, huge spectrum of the frequency we can actually mapped in our brain.

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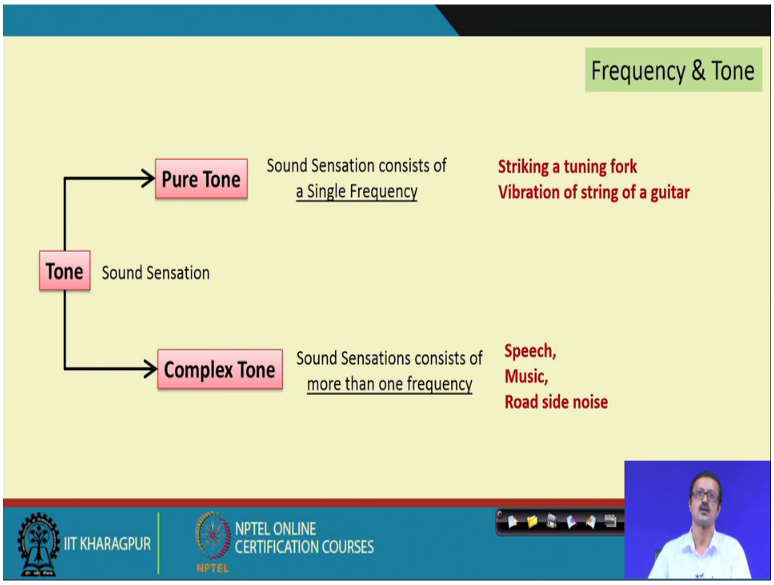

Now, let us let us discuss about this frequency how this frequency has create this kind of a sensation and that is called as a tone a sensation sound sensation because of some kind of a frequency is called tone. There are two type of tone, the one is called the pure tone.

The pure tone is the single frequency sound, only a particular frequency nothing else a sticking of some kind of a vibrating object like is tuning fork or maybe a some kind of a guitar string is a pure tone its involve only one frequency. There is second type of tone is called the complex tone, where there are two or more than two number of frequency mixed together.

So, that is a speech that speech I am giving to you or may be some kind of a music, any kind of noise in roadside and practically in nature 99 percent of the sound is a complex tone or the mix frequency sound. So, when this mixed frequency goes into that. So, we will have some kind of superimposition.

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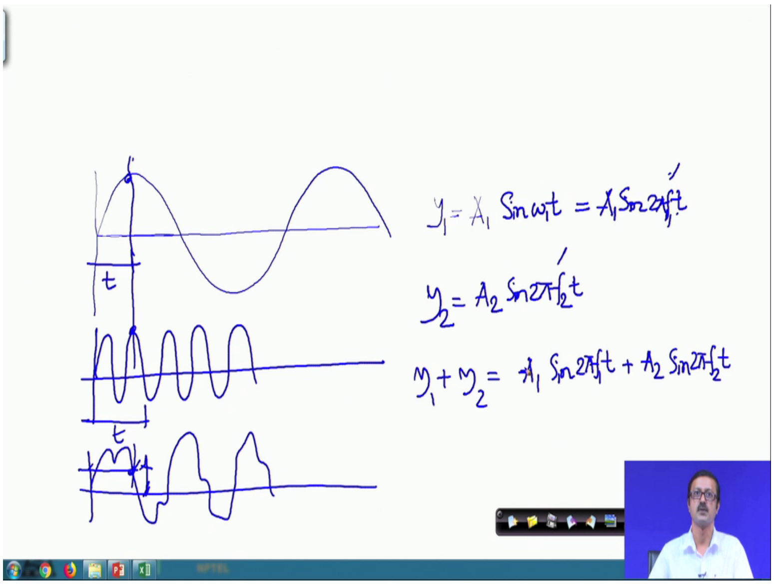

The superimposition will go to in a way that a sound wave is having suppose a simple motion like this, which can be talked as suppose this is the first sound wave that is why I am writing y 1 is suppose sum amplitude 1 sin omega 1 t or this can be written as A 1 sin 2 pi f t. This is another frequency suppose something like this, which can be written in like this A 2 sin 2 pi f 2 t, where your this f 2 and f 1 f 1 are the 2 different frequencies.

Now, at a particular time t, this both the frequency if you add when the both the frequency is actually merged together, we will get a different type of frequency and this 2 superimposition in a particular time t gives you some different type of the addition of this y 1 plus y 2 will be equal to your A 1 sin 2 pi f 1 t plus A 2 sin f 2 t. And because of the variation of this A 1 and A 2 because of the variation of your f 1 and f 2 you will get different type of frequency and different type of the amplitude in nature.

So, it is only 2 there maybe 3 there may be 4 and if it is much more the things will be very much complicated.

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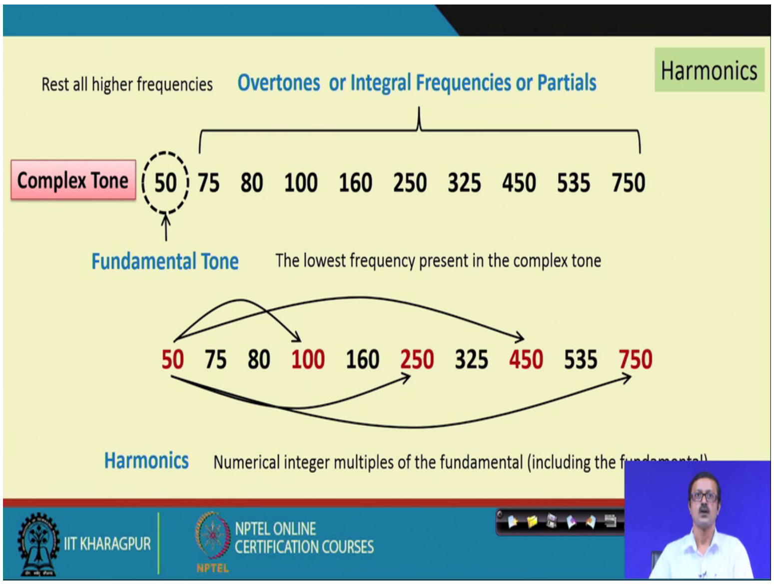

So, let us take a complex tone. In the complex tone is a mixed frequencies. So, I have taken a series of complex series of frequency, which gives me a complex tone its starts from 50 then 75 like that. So, in this I have identified a first frequency the minimum one the lowest one out of this particular bracket and this minimum one in a particular complex tone, that minimum frequency or the lowest frequency is called the fundamental tone.

And the rest frequency which is the higher than this particular fundamental tone or called over tone or the integral frequencies or the partials there are lot of names. So, what tones probably the best fitted kind of a thing.

Now, in that over tone if I see there is a good relation with the fundamental frequency there are some frequency may exist in this overtone which may have a very good relation with the fundamental tone. Suppose this red color ones the 50 is a fundamental tone, you see this 100, there is 250 also there is a 450 also and there is a 750 also their the a numerical multipliers of the fundamental tones. So, 20 2 multiplied by 50 is your 100 something like the 9 multiplied of 50 is your the 450.

So, those red color frequencies in that complex tone is called the harmonics. So, harmonics is a part of the partials or the part of the over tone. So, I may say that all harmonics are overtones, but all over tones are not harmonic.

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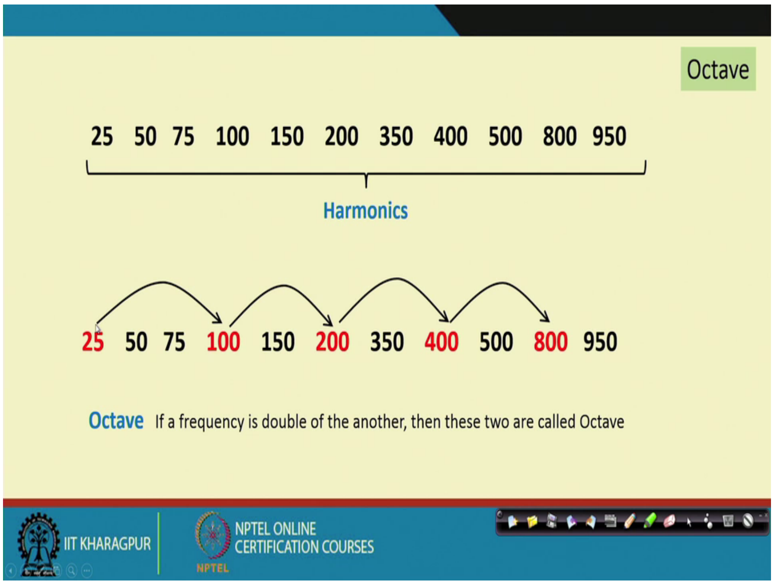

Then let us take this particular band of the spectrum of the complex tone, where this 25; 25 is your the fundamental tone and it has lot of I mean I mean in fact, it is a series of it is a harmonic. So, it is all are harmonic, in every fair frequency is the multiplier the interior multiplier of the first frequency the lowest frequency or the fundamental frequency, but again there is a good relation exist between them.

If you take 25, if you take 100, if you take 200, 400 and 800 they are definitely harmonics, they are definitely multiplier the integer multiplier, but they are double of other.

I mean there is this one is also going to be sorry.

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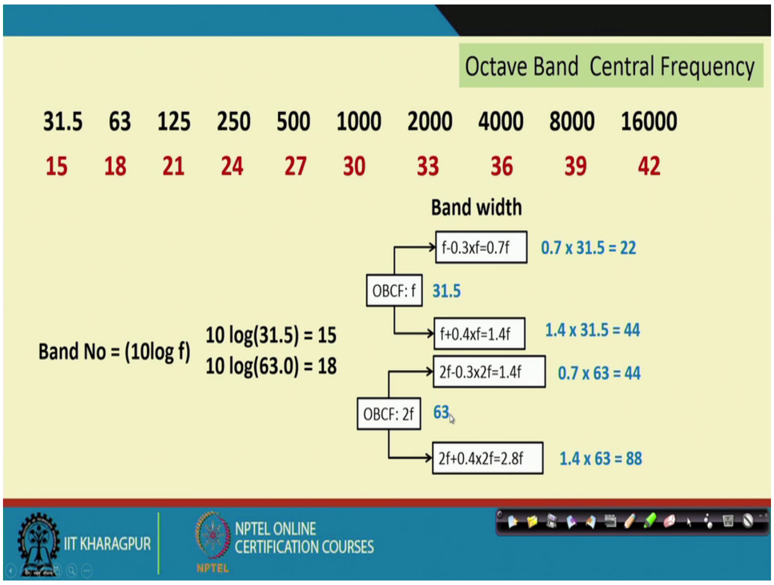

Doubled of other and this is called octave. So, now let us go to the octave band central frequency, the problem with says that we have lot of frequency to be handle from 20 to 20000. So, out of that, this 10 frequencies are identified, which are a compute set of octave which covers the total set of audible frequency its starts from 31.5, then double of that 30 double of 31.5 is 63, then almost double of that is 125 and like that its goes up to 16000.

So, this 10 frequencies are called octave band, and this octave band has taken as the criteria for any kind of a testing or any kind of the statistical output to generate for any kind of a noise or any kind of a sound atmosphere, to test or maybe making some kind of a benchmarking or so; So, here if I take the logarithmic of that particular octave frequency and multiplied that by 10. So, it is 10 of log of that f, f is that frequency. So, something like 10 log 31.5 is almost going to be 15. Similarly, 10 log 63 the next one is 18. So, this particular 10 log the frequency that called band number.

So, these are the band number for each those 10 octave band central frequency and very interestingly, this band number is jumping by 3. First it starts with 15, then it is 18, 21 24 like that where the frequency actually going to be doubled with another it is a gp series, but this is a arithmetic progression series. Now, this 31.5 or 63 whatever may be the frequency, let us say that frequency is f and it has 2 arm one is lower arm and one is the upper arm. So, lower arm is f minus 0.3 times f are almost 0.7 f is the lower bandwidth limit, and the upper bandwidth limit or the upper arm is something like f plus 0.4 times f which is 1.4 f.

So, if I go to the 31.5 frequency, by virtue of this calculation I find 22 is the lower band lower limit of that band of 31.5 and 44 is the upper limit of the band of 31.5. Now let us see the second one, second one 63. So, similarly if I put 63 and this f is now twice of f, because it is in the in the in the octave. So, I will find this is point one fourth of f this 2 are matches with each other and this is 0.28 2.8 f. So, now, if I multiply with 0.7 into this 63, which comes from this particular here it is 44 and this is 88.

So, the 44 and the 88 is the limit of lower and upper limit of 63, 44 and 22 are the limit for 31.5. So, like that each will have its lower and upper limit and once the frequency, which is the earlier frequency the upper limit will be the equal to the lower limit of the other next higher frequency.

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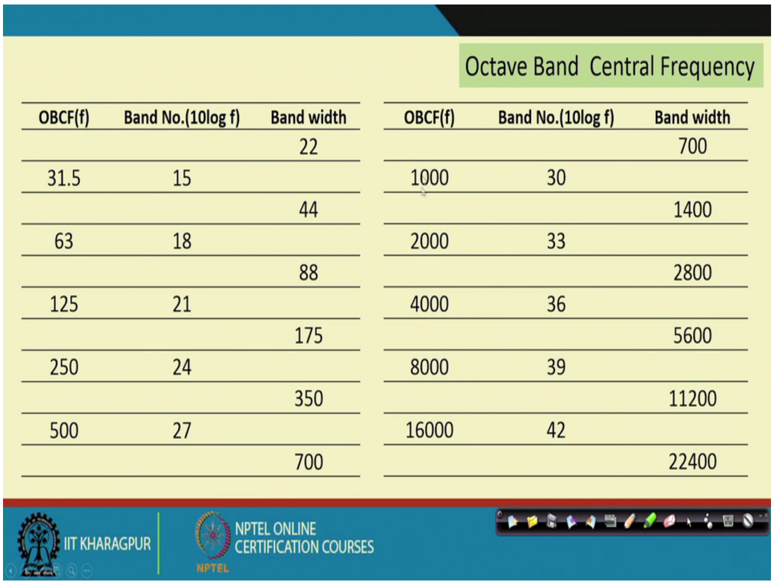

OBCF(f)	Band No.(10log f)	Band width	OBCF(f)	Band No.(10log f)	Band width
		22			700
31.5	15		1000	30	
		44			1400
63	18		2000	33	
		88			2800
125	21		4000	36	
		175			5600
250	24		8000	39	
		350			11200
500	27		16000	42	
		700			22400

And by virtue of that I can rewrite this particular band number and the bandwidth like 22 and 44 is for 31.5, 44 and 88 is for 63; 88 and 175 is for 125 like that.

So, all the spectrum and the octave band central frequency that is OBCF the band number and the band width are ready for you. So, then if you see from the band width or the frequency from the 22 frequency 22400 which is in our audible range is covered by all those 10 OBCF. Now, what is the necessity of the octave band? The necessity of the octave band is very simple and straight forward.

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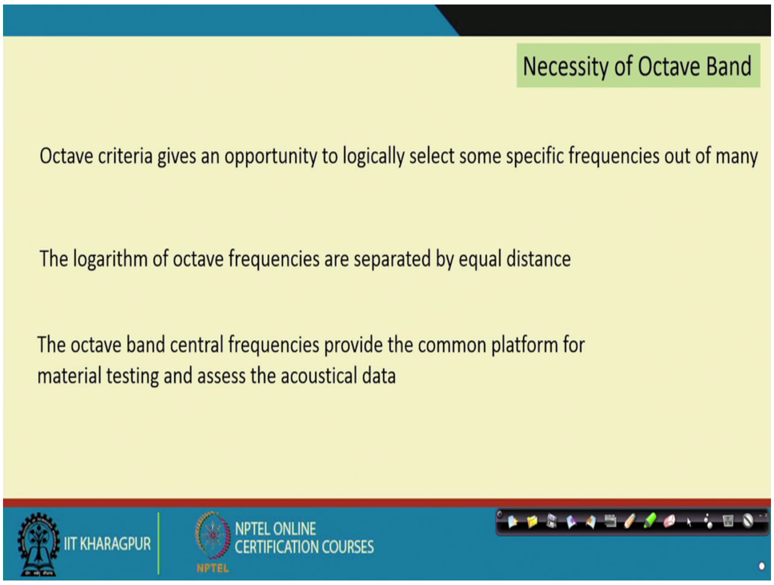

The first one the octave band gives a logical set of some frequency out of many. Because I have problem I have problem, because I have I have frequencies from 20 to 20000 which is audible; audible by a human being.

So, from that if I want to select something, select some may be 10 15, I need a certain amount of logical understanding and its gives me that. Number 2 the logarithmic logarithm of the octave frequencies is separated by the equal distance, because I have seen that the logarithmic of one is separated by 3 to the next higher on the 3 to the next higher.

So, while I will plot a graph, plot a graph in the in some to test some material or some kind of the environmental acoustics, I have only 10 such equal distribution line. If I have taken the all the 20 to 20000, then the x axis of the particular frequency will be too high to handle. The third important thing is that the octave band central frequency provide a common platform for any kind of material testing and assess any kind of a acoustical data.

So, worldwide globally it has been taken as this octave band that 31.5 to 16000 are this 10 frequencies are set for any kind of acoustical testing and any kind of material data handling and all the kind of the noise and acoustical data purpose.

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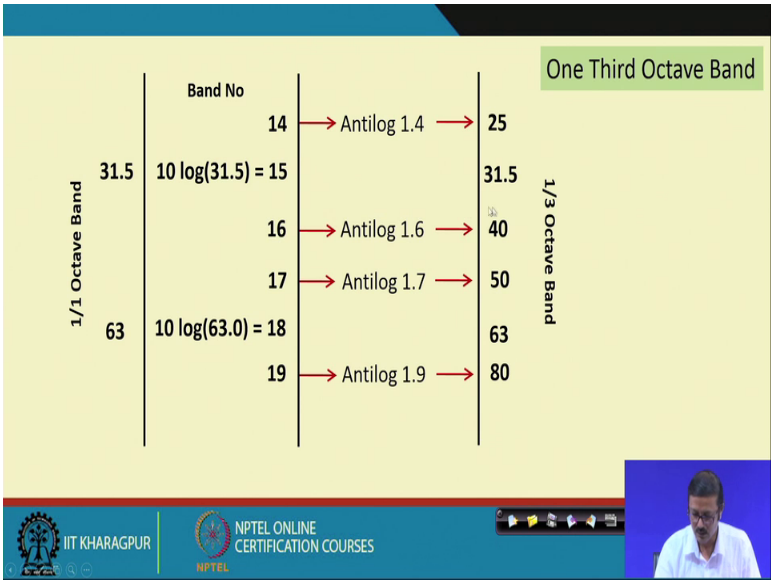

Now, there is a one third octave band, people are not very happy with this 10 frequency. Now, they go much more better because there are lot of parameters in the noise or maybe the sound transmission, through which can be understood by this 10 frequencies, but we need may be some more set of frequency to understand that particular phenomena better. So, that is why let us consider some other set of frequency and let us make that particular set larger instead of 10 may be more than that 20 25 and how to generate that one that is the very important and the logical way let us generate.

So, as we know this 31.5 is octave band and also the 63, whose band number is 15 and band number is 18. So, in between this 15 and 18 we have 2 more number 17, and 16 and 17 and like that. So, let us write all those band number. So, fill the gap or between the 15 and 18 by virtue of 16 and 17 and then do the antilogarithmic of that and divided by 10 and antilog of that and then if you get you will get the another set of frequency.

So, we will feel this particular the band number by 2 more digit and equally spaced, and antilogarithmic of that will give you another set of frequency and that frequency set is your octave band I am sorry the one third octave band. This one third octave band is filled by 2 more frequencies in between the octave frequency. So, see this 31.5 and 63, which are the octave which is also called 1 by 1 octave band is field by another 2 frequency 40 and P in between and make it as a one third octave band.

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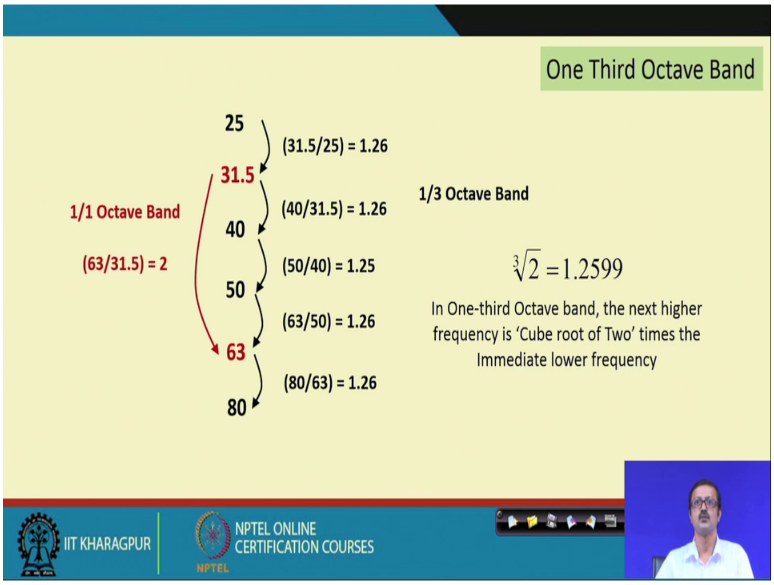

So, each of those 10 we will now produced like this. So, this is red colors on the one by one octave and this black colors of are the one third octave.

So, as we know the one, 1 by 1 octave is twice of other 31.5 into 2 is your 63, but what is the relation between them? If you just divide 31.5 the 25 40 with 31.5 will get almost like 1.66 one points I am sorry 1.26 1.25 like that and if you see generally, this one third octave band is separated by the other with the cube root of 2, this particular factor which is very near to 1.2599.

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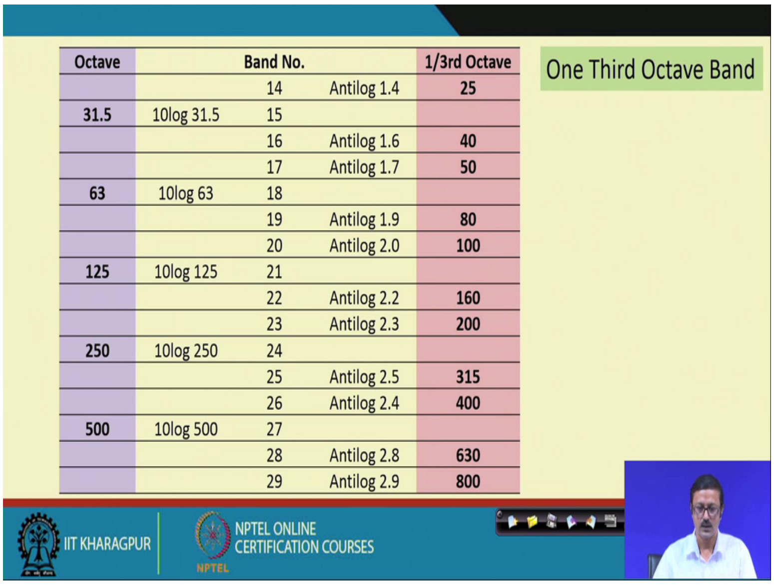

Octave	Band No.			1/3rd Octave
		14	Antilog 1.4	25
31.5	10log 31.5	15		
		16	Antilog 1.6	40
		17	Antilog 1.7	50
63	10log 63	18		
		19	Antilog 1.9	80
		20	Antilog 2.0	100
125	10log 125	21		
		22	Antilog 2.2	160
		23	Antilog 2.3	200
250	10log 250	24		
		25	Antilog 2.5	315
		26	Antilog 2.4	400
500	10log 500	27		
		28	Antilog 2.8	630
		29	Antilog 2.9	800

So, here in this table, we have this purple color the column which is the octave and there are the series of band number, the antilog of that band number and again this with this last column gives you the one third octave.

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Octave	Band No.			1/3rd Octave
		31	Antilog 3.1	1260
		32	Antilog 3.2	1600
2000	10log 2000	33		
		34	Antilog 3.4	2500
		35	Antilog 3.5	3150
4000	10log 4000	36		
		37	Antilog 3.7	5000
		38	Antilog 3.8	6300
8000	10log 8000	39		
		40	Antilog 4.0	10000
		41	Antilog 4.1	12500
16000	10log 16000	42		
		43	Antilog 4.3	20000

And this is the till that we can go till the 200000 as the one the last one is the one third octave.

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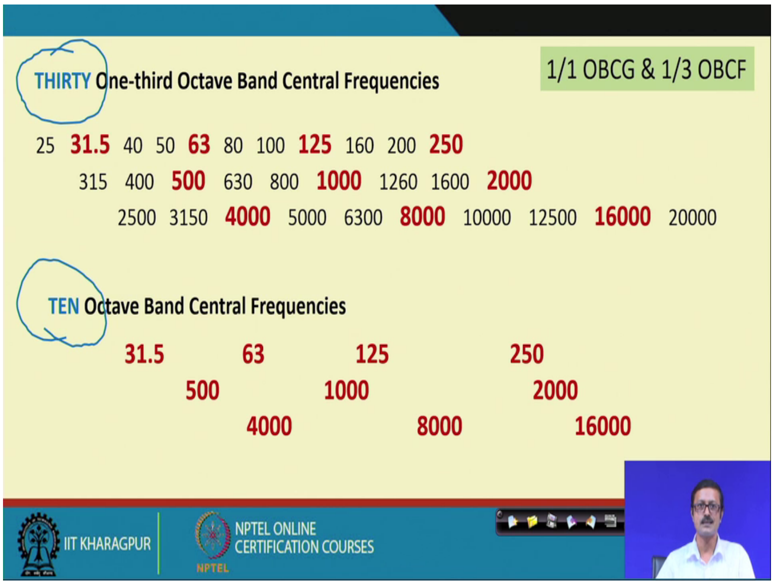

So, there are 30 such one third octave band frequency starts from 25 to 20000 and out of that we have 10 number of this red color one, which are the octave band which is the 1 by 1 octave band; So, 10 octave band and 30 one third octave band.

So, most of the cases for testing or any kind of a general purpose we take 10 octave band, but sometimes we need to do the critical analysis, we need to do some kind of the confirmatory kind of analysis for any kind of a material testing or any kind of a acoustical surroundings to check whether it is perfect or not, then we go to the this one third octave band and the 30 such frequencies. And this 30 frequencies or the 10 frequencies are very much wide again.

Again it is very much wide. It starts from 25 to 20000 and here it is that is from 31.5 to 16000. So, here the behavior of the sound also not perfectly synchronized with the all frequencies.

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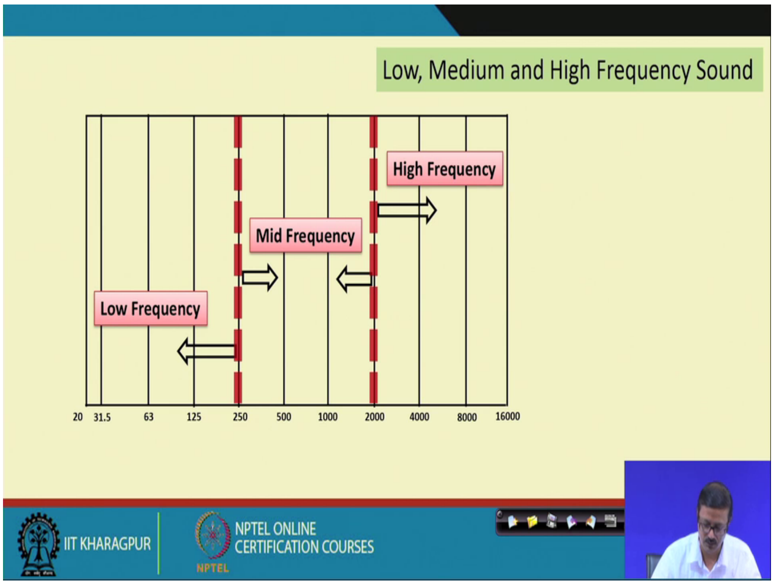

So, here for that we are categorized the frequencies as a low medium or the high frequency. So, as you see this is 20 to the 20 16000, where all the octave are separated by the equal distance, which is maybe the 3 by the logarithmic in by virtual its logarithm, and if I draw to perpendicular line from 250 hertz and the 2000 hertz, this total spectrum is divided subdivided into 3 parts.

At in this 3 parts the first part which is called the lower frequency, which is 20 to 250, the middle frequencies are 250 to 20000 and the higher frequencies 20000 to that onward to till the 20000 22,000 to 20,000.

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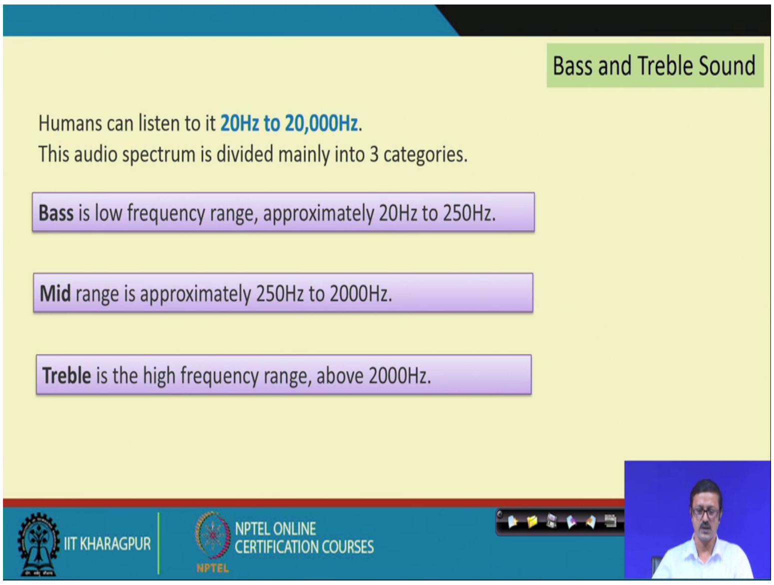

And the human can listen 20000 to 2000 frequencies as you know, in the spectrum is mainly have to this 3 categories which I have just now tell you like the low medium and the high frequency is also has the different name bass. The bass is the low frequency range of sound, which is cover almost 20 to 20 250 hertz, which is very sound like a tabala or sound like some kind of sound which is having some not a that much of intense speech kind of the sensation.

The middle frequencies are come within that 250 to 2 2000 hertz, which is very normal and which is very much widely used for any kind of the music or any kind of speech. The treble sound which is called the high frequency sound, which is more than 20000 hertz also some part of the music and some part of the human voice also comes into that particular the zone. The treble zone where there are some kind of a machine some kind of the equipment gives some kind of a treble sound, which is very high frequency zone.

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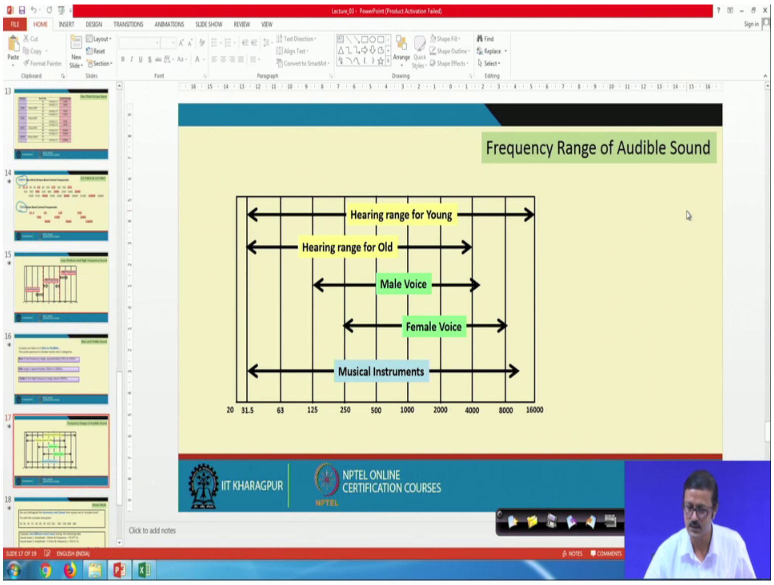

Next let us discuss the frequency range of the audible sound and all. In inaudible sound also in case of that also we have this the octave in separated by equal distance and this audible sound is generally of something like this nature.

The hearing range of the young person like you people, are almost the full spectrum, but if you are olds somebody is old. So, then the spectrum of the hearing will gradually spring down and its maybe limited to four the 4000 frequencies or so. Now, let us discuss about the male and the female voice. Male voice stars from little bit of bass towards the for 4000 also female voice is separated a bit.

There the female voice is bit of for the treble kind of a thing, where it is 250 to the 8000 is the range of the female voice or so. Music next is the music, the musical instrument again take a very wide range it is the bass music which is in this zone till 250 is are so, there are mid frequency is also and there are very high frequency is also.

So, by virtue of that we can have differentiate frequency level, we can have different type of the quality of the music based on that particular thing and let us go to let us go to the a excel chart and we will see how a superimposition can be done in a excel chart.

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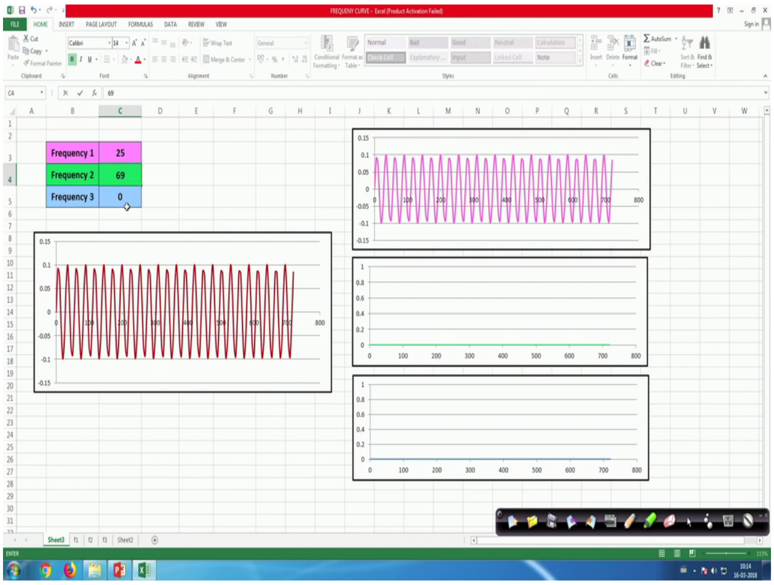

So, let us open this one. So, I have I have 3 frequencies can be mapped over here.

So, in the first frequency if I say, suppose this is some frequency like 25 and its gives me the frequency 25 in pink color. And the second one suppose I give some frequency let us suppose 69. So, its give some frequency like 69 this is in green color second one.

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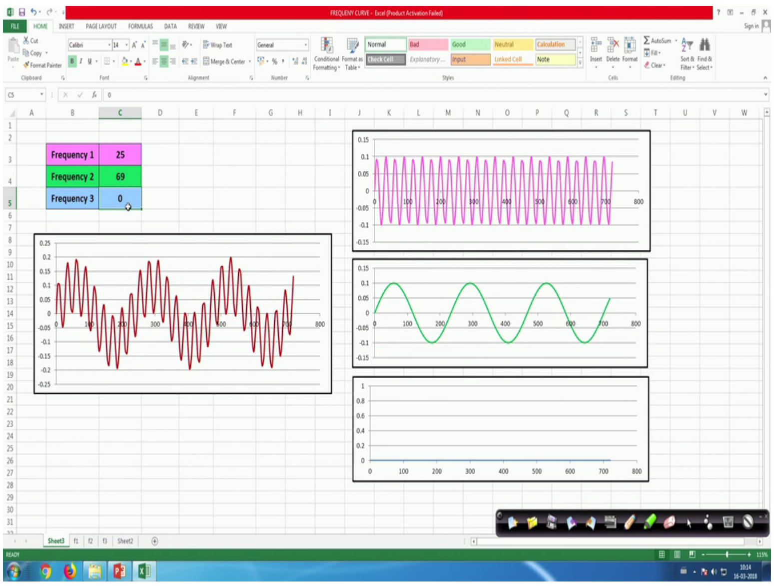

And the third one and this two the first frequency 69 and the second frequency 25 you superimpose suppose and you will find out this the this one, this one is the your the superimposed signs frequency of the song are the propagation of the sound. Let us take the third frequency as some little higher frequency, suppose 1200 and then you will get the blue lines, which is 1300 this one and the if you add this and this.

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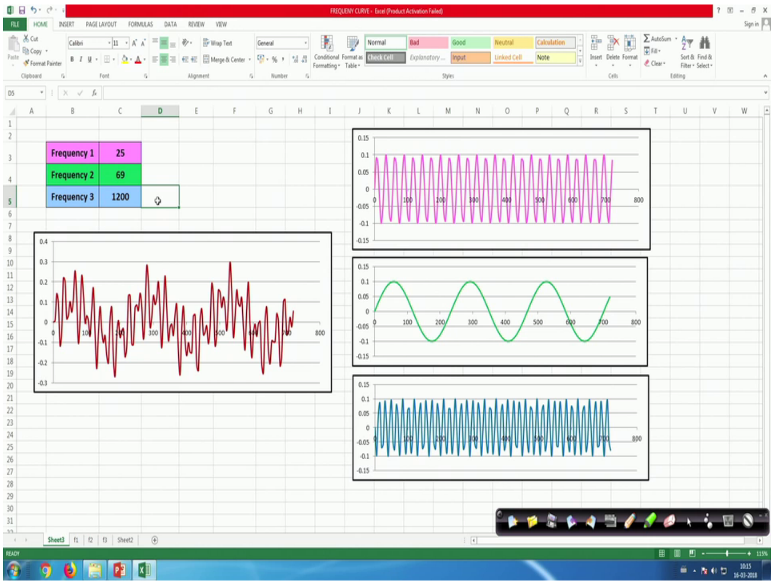

This 3 wave front you will get a very complex kind of a thing. So, this is your complex frequency or the complex tone and this is your one tone pure tone this is another pure tone this is another pure tone. So, if those pure tones are in a in a some order, suppose this is 25. So, suppose I made it like 50 and if this is I made it like 75.

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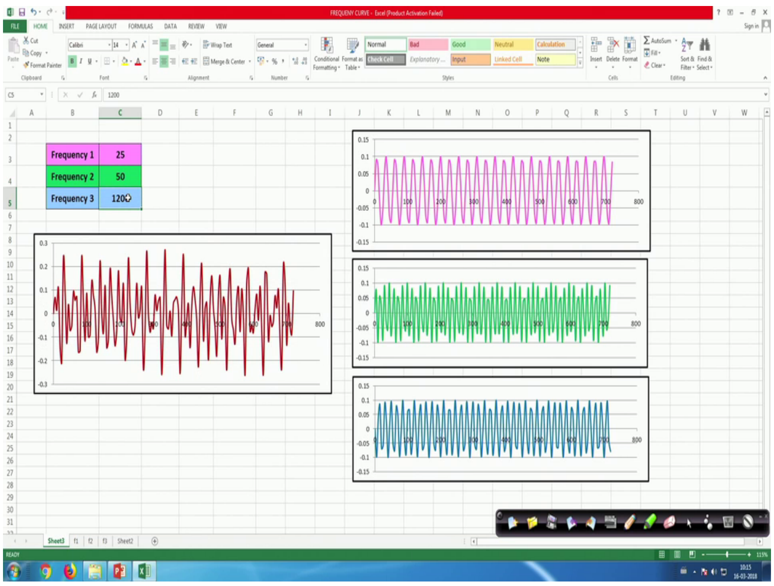

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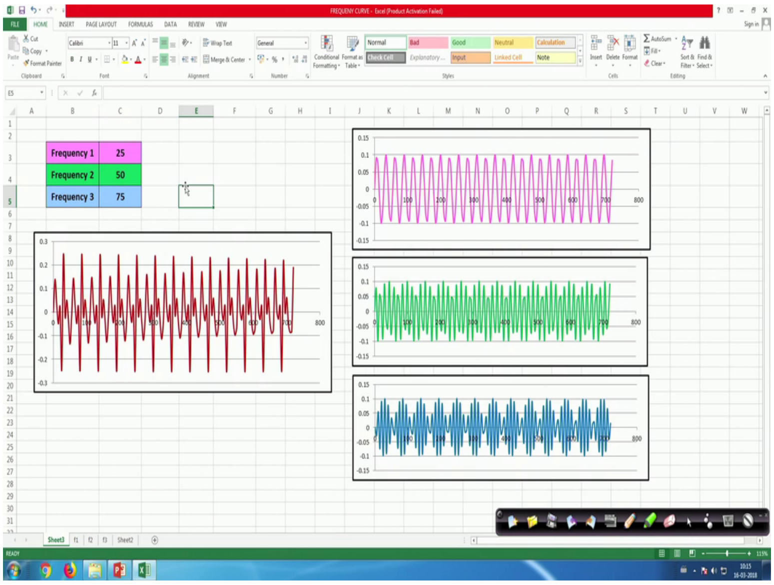

So, you will get some kind of a the rhythmic action rhythmic kind of a thing in the harmonic. So, they are in harmonics, they are in harmonic. So, they get some kind of a rhythmic harmonic.

So, as an when you are the frequencies in the complex tone are more in harmonics, you will find the music or this particular the sound is very interesting very interesting in character there are some ups and downs.

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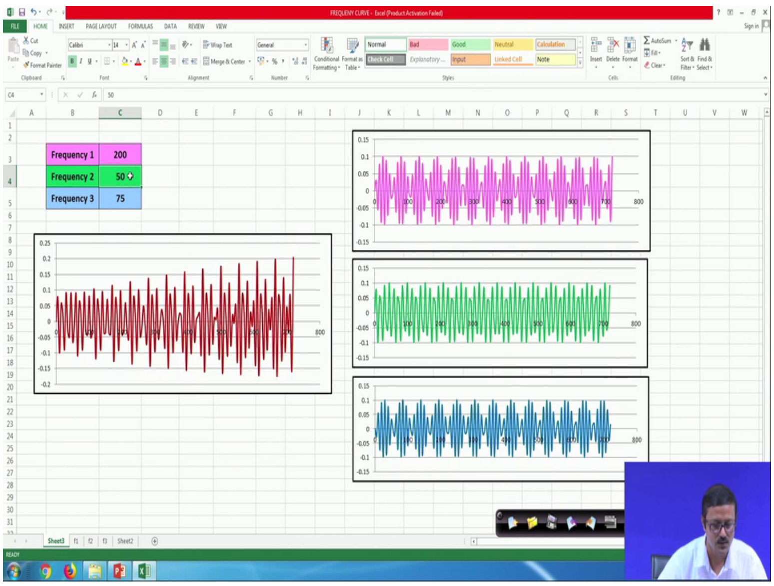

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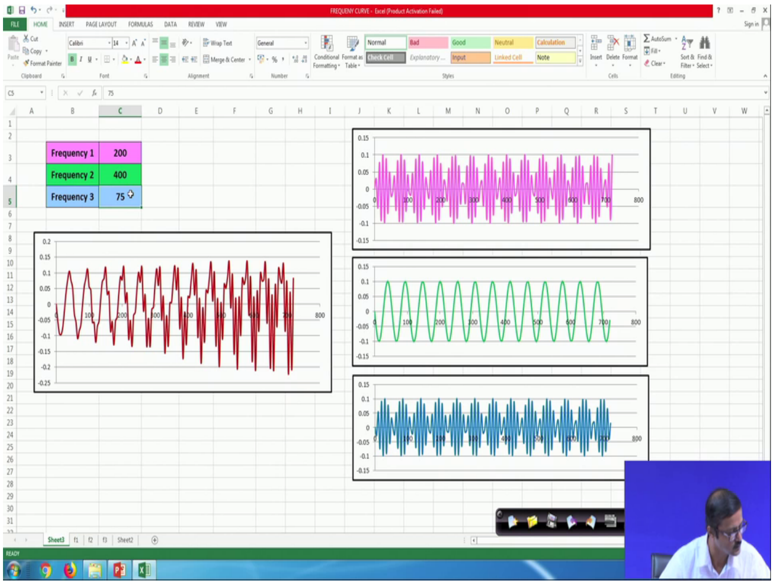

Let us see if I have something in octave so, suppose this is 200. So, the next in case of octave, it is twice of that and this is 800 and you see it is also gives you some kind of a beat some high and low kind of the propagation on the those kind of a thing.

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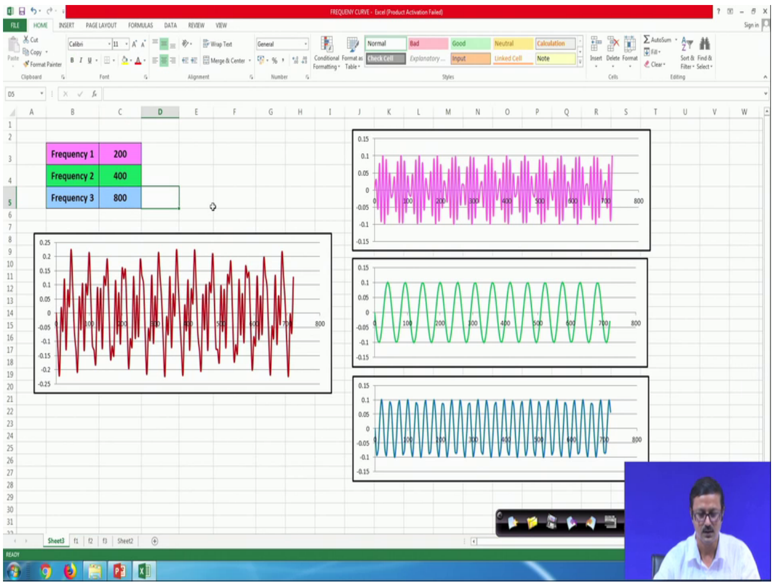

So, we understand that how a tone and the 3 such the 3 such tones pure tones can be made into a complex tone in the in this by addition of this frequencies and in the equation the frequency equation.

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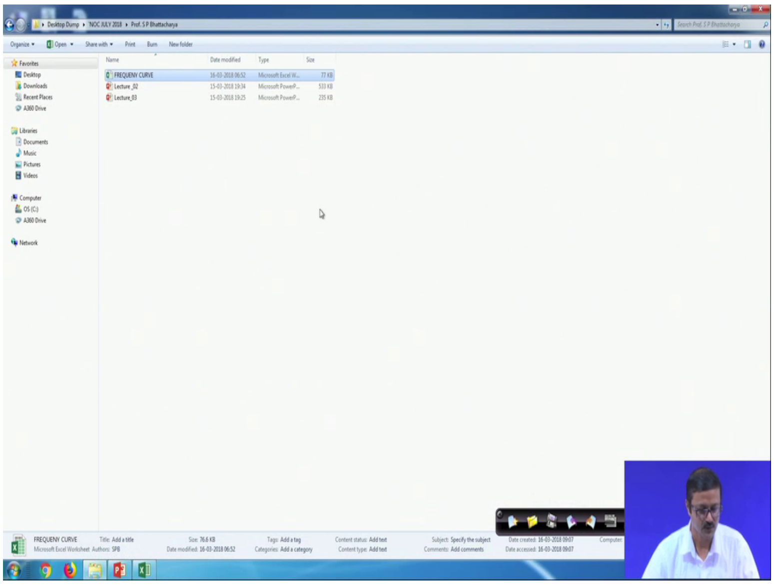

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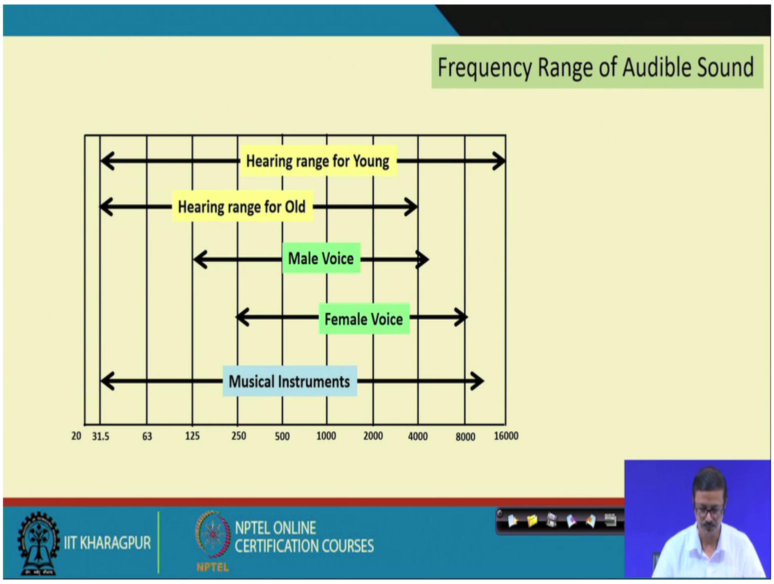

So, again let us go to the power points light and come to that the last slide.

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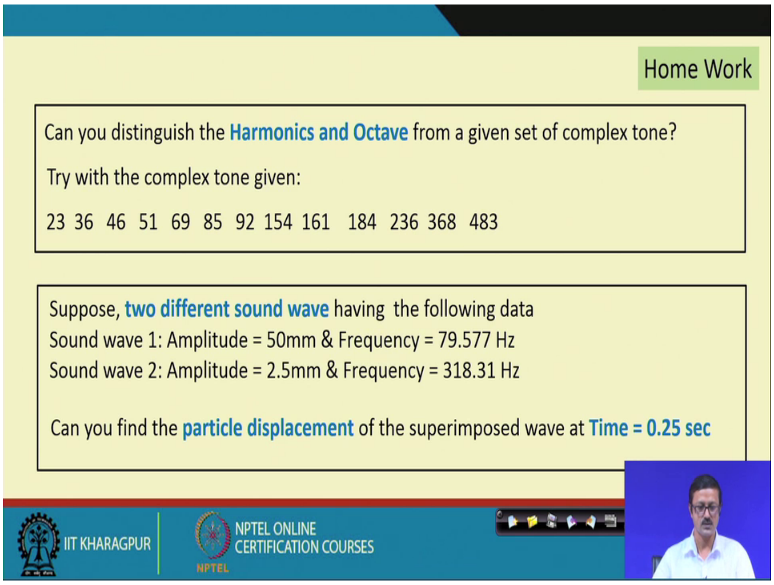

And as again it says kind of a homework kind of a thing. So, the thing is that the can you can you the distinguish the harmonics and octave from a given kind of a complex tone, let us suppose if I give you a kind of a set frequencies like 23 36 and all can you find out the octave and the harmonics out of the complex tone it is very simple. Now, next one probably you can just to calculate, you can just calculate in a piece of paper.

Suppose there are two different sound wave I have given to view. The sound wave one is having a amplitude of 50 mm and the frequency of 75 point I am sorry 79.577 hertz and the second wave having a lower amplitude, but higher frequency 318.39 hertz is the frequency.

So, they are to typical fundamental or the typical 2 tone 2 2 pure tone. Now, can you superimpose them and can you find out what could be the particle displacement, the value of the y that is y 1 plus y 2; y 1 comes from the sound wave and y 2 comes from the sound 2. And can you find out the what should be the that y 1 plus y 2 that is the particle displacement after a time interval of 0.25 try it.

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If you have any problem, you can contact for that, but try it try it by your own and in the next lecture we will go to the we will go to the sound pressure level and the sound intensity level, which is going to create a kind of the initial benchmark scenario for understanding the reverberation time and all other sound physics level, which is very very important in the building acoustics so.

Thank you very much.