Fundamentals of Acoustics
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Lecture – 05
Key Terms in Acoustics

Hello, welcome to Fundamentals of Acoustics. This is the fifth day of the first week of this particular course and what we will be doing today is essentially I will be introducing you to some of the important terms which are used in the area of Acoustics because it is important that you understand these terms. These terms are used very frequently in acoustics. So that is what I will be doing in today's lecture.

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Some of the key terms which we will be introducing would be decibels. What is the decibel; I mean that is something we have already discussed. So, we will not talk about that, but some other terms are octaves, what is the decade? Another term which is used very frequently is bandwidth, wave number, tones and pink noise and white noise. So, these are some of the terms we will be using. So, we have already discussed what is a decibel.

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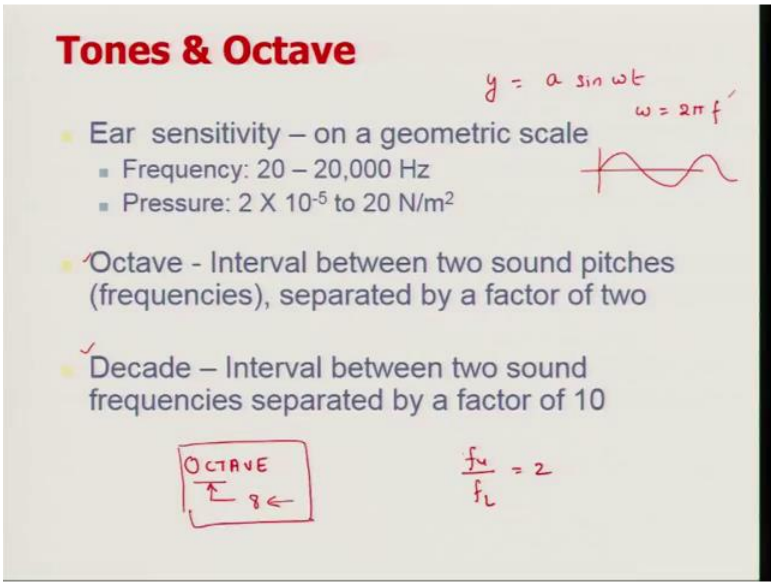

Now we will talk about tones and octaves. So, what is the tone? Essentially, it is a signal or a wave which is purely harmonic in nature. So, if I have wave form, let us say y equals a sin omega t, where omega equals 2 pi f.

Then if I plot it, then it will look something like this and a sound wave which is purely harmonic in nature is known as a tone. So, in this case, the frequency of the tone is f and the angular frequency of the tone is 2 pi f which is omega. So, that is what, a tone is all about another interval. Another term, which is very often used in Acoustics is this term called octave. So, what is an octave? It is range of frequencies such that the ratio of the upper frequency and lower frequency is exactly 2.

For instances, there could be lots of frequencies between 100 hertz and 200 hertz and the bandwidth or if the sound content is between 100 hertz and 200 hertz, then it is an octave band because the ratio of upper frequency which is 200 hertz and lower frequency which is 100 hertz is exactly 2 in this case.

Another example of an octave would be 32 hertz to 64 hertz, once again in this case also, the ratio of upper frequency which is 64 and lower frequency is 2. So, it is not that the difference has to be 2, it is says that the ratio of upper frequency limit and the lower frequency limit, they have to be, it has to be 2. So, that is an octave. Then there is another term which is used and it is decade and this is pretty similar to an octave. The only difference here is that the ratio of upper frequency limit and the lower frequency limit is 10.

Octaves and decades are very often used in Acoustics and now I wanted to give you some idea as to why this term octave is used even though the ratio of frequencies is 2. Here we have this o c t or oct and that relates to the term 8. So, I just wanted to give you some idea where this term is coming from. Even though for an octave, the ratio of upper frequency limit and the lower frequency limit is 2. Now this term octave; essentially comes from music and let us look at the nodes in western musical system.

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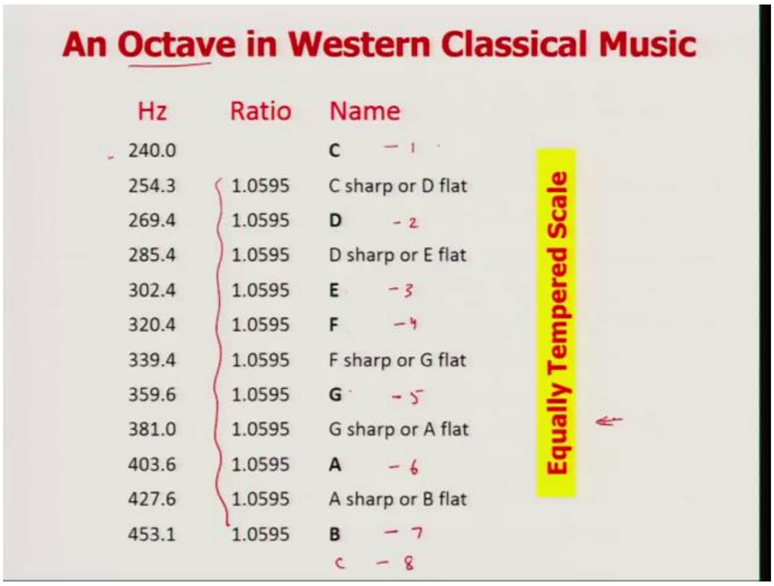

This is an octave, well western classical music and let us say the starting frequency on a particular scale is 240 hertz and then as we go up on the frequency scale you go to, so this is starting frequency is C, then we go to node D, then node E, then F, G A and B and then the next node is again C. So, if we count the number of frequencies here. So, this is 1, 2, 3, 4, 5, 6, 7 and then the next node. Once the next cycle starts is 8 and it turns out that we use it the way they western musicians have defined the frequency this that the interval or the ratio of the first C and the subsequent C, there the different ratio is 2 and because there are 8 nodes in this entire band from 1 C to the next C that is why the entire frequency band is known as an octave. That is where this octave term is coming from.

It also turns out, it is also the cases that between 2 adjust nodes. So, you have C and D, the ratio and then there is another node between these 2 and you can either call as C sharp or D flat. So, the ratio between C sharp and C is 1.0595. Similarly the ratio of frequency is between D and C sharp or D flat is 10.595 and so on and so forth.

If you multiplied all these numbers may be each other, you will end up with the overall ratio as 2. This particular scale of nodes or the musical scale in western classical music because the ratios are fixed between 2 adjacent nodes, it is known as equally tempered scale when the reason that because the ratios between 2 adjust nodes is equal. So that is why the scales go up in a particular fixed ratio and these ratios are equal when we move from one node to the other node.

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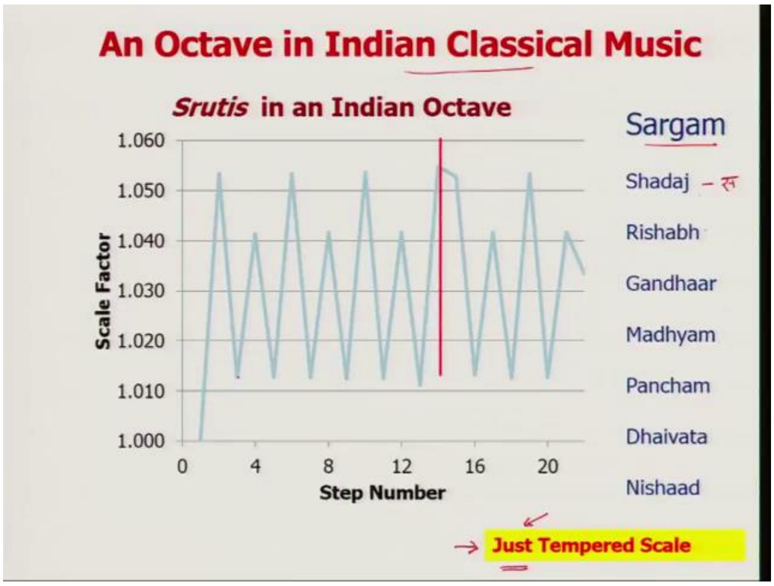

Now, let us look at an octave in Indian classical music. So, in an Indian classical music, those who are familiar with these terms, an octave in Indian classical music is known as a Sargam and a Sargam has 7 nodes. We often call those nodes as Sa Re Ga Ma Pa Dha Ni Sa and these are actually abbreviations of actually full terms. So, Sa corresponds to this term called Shadaj. So, the actual name of the node is Shadaj and it is abbreviated as Sa. Similarly Re is the short form for a node known as Rishabh, the node Ga is the short form for the name Gandhaar. The node Ma is the short form for Madhyam. Pa is the short form for Pancham. Dha is the short form for Dhaivata and Ni is the short form for Nishaad. So, these are 7 nodes. So, you start with Sa Re Ga Ma Pa Dha Ni Sa and then the next Sa when you go there also, the ratio of frequencies from one Sa to the higher Sa is 2.

In Indian musical system also the ratio of these 2 frequencies from one Sa to other Sa is 2 and there also there are 8 nodes. So, there also it is make sense to call this entire scale as an octave, but there is a fundamental difference between an octave and in Indian classical music system and an octave in western classical music system. So, on western classical music system, what we had is we saw that the ratios are fixed between C and C sharp, C sharp and D and so on and so forth.

In Indian system, the ratio from what 1 Sa to the next Sa is a still 2, but the ratio of frequencies from Sa to Re, Re to Ga, Ga to Ma, Ma to Pa, Pa to Dha, Dha to Ni is not necessarily fixed at you know factor of 2 rather, the frequencies vary within a narrow bandwidth. So, this is the scale factor which you see here and these frequencies are determined on the basis of how good the particular Sa of frequency sounds to the ear.

In western system, it is the mathematics which is important. So, the ratios are fixed in the Indian musical system, it is how pleasing the frequency is to the ear and for that reason, this particular scale of frequencies is known as just tempered scale, just the term just is used because you can argue that this type of musical scale because it does is more pleasing to the ears, it does justice to ears. So, that is why it is known as just tempered scale. So, this is the reason why we use this term octave and it was originally used in music and the same term has now been adopted in engineering practice.

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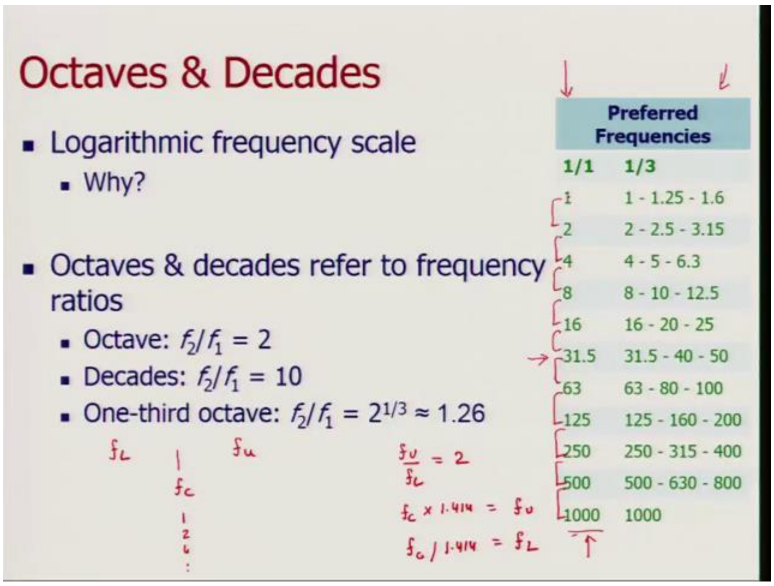

Other thing I would like to mentioned about octaves is that even though I can go from let us say 3 hertz to 6 hertz that would constitute an octave 6 to 12, that will constitute another octave, but in general, we prefer some specific bands because when we are in engineering world, we try to standardize things. So, there are standard octave bands which are used. So, whenever we do measurements for automotive noise or analysis of humans speech or whatever we tend to use some specific frequency bands.

So, what this table shows is that some of those standard frequencies. So, and these are the central frequencies. So, these frequencies are 1. So, the central frequency would be 1 then and if we are going up than octave scale then it is 4 no 2 then 4 8 16 31.5. So, here just see that there is a slight difference because we want to end up at 1000 hertz. So, from 16 we do not go to 32, but we go to 31.5 then when we double it. So, it is 63 125 250 500 and 1000 and then from 1000 we can again start the cycle again. So, the next cycle would be 1000 2000 4000 8000 6000 thousand and so on and so forth.

These are preferred frequencies and the preferred associated preferred octave bands will be 1 to 2, 2 to 4, 4 to 8, 8 to 16, 16 to 31.5, 31.5 to 63, 63 to 125, 125 to 250, 250 to 500 and 500 to 1000, one last thing, so in an octave you have f u and you have f l, actually I should written it in the other way.

The lower frequency is f l and the higher frequency is f u and then within these 2 frequencies, there is a central frequencies and I will call it f c. Now we know that f u over f l for an octave is 2. The preferred frequency is in this column, they are the central frequencies. So, the central frequencies are 1, 2, 4 and so on and so forth. For this central frequency, if I have to calculate the value of f u, then it will be f c times 1.414 and so this is equal to f u and similarly f c divided by 1.414 is f l. The actual band corresponding to this central frequency of 1 would be 0.707 hertz to 1.414 hertz and so on and so forth. So, that is how we do this. So, it is important to note that these are not the upper frequencies or the lower frequencies. The frequencies which are listed here, they are they correspond to f c which is the central frequency. This concludes our discussion on octaves and similarly we can also construct decades.

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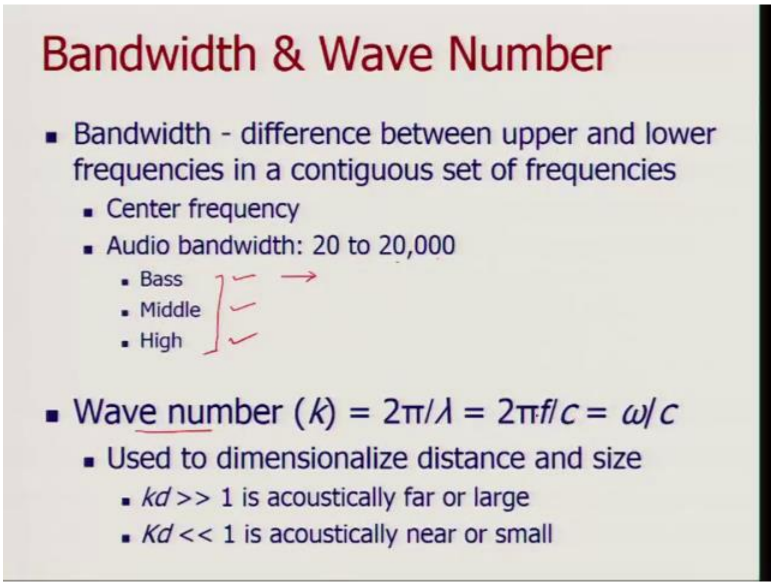

The next thing I would like to talk about is a bandwidth. So, we have already discussed, what is the bandwidth? It is a bunch of frequencies lying between an upper limit and the lower limit. So, that is what it and each bandwidth has a upper limit and lower limit and a central frequencies, the overall audible bandwidth for human voice or human hearing is 22 to 20000 hertz. So, that is equal to 3 decades because the ratio of 2000 and 20 is 310 to the power of 3. So, that corresponds to 3 decades.

In this bandwidth, lot of time these 3 terms are used bass middle and high. So, bass refers to frequencies which are at the low end, typically less than 500 hertz, also middle frequencies are refer to frequencies which are in the middle of the spectrum. So, you may start from 5 or 700 hertz to 2000 3000 hertz and all other frequencies are high pitch tones and so, those are high end frequencies.

These are another, these are some more terms, bass frequencies and middle frequencies and high frequencies they correspond to the spectrum of human hearing and where these frequencies are located in the spectrum then there is this term called wave number. So, wave numbers; several of you may already be aware, lot of times it as designated by the latter k and it is nothing, but 2 pi divided by lambda where lambda is the frequency and if you want to express it in terms of frequency or angular frequency. So, it is 2 pi f over c where c is the speed of sound and since 2 pi f is angular frequency we can also call wave number defined wave number as omega over c.

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Finally, we have also discussed, what is tone? Another term which is very often used in Acoustics is this term called noise. This noise, mathematically or from an engineering stand point noise is unwanted sound and typically it has all sorts of frequencies into it. So, it is a mixture of all frequencies and they have different types of noises and the categorization of this noise is based on the ratio of amplitude of different frequencies which are contained in the noise. So, if you have white noise, there is a one particular type of noise known as white noise. This noise is such that for a given bandwidth, it as equal power within the fixed bandwidth for any central frequency. So that is what is white noise or in other terms you can say that it as constant power spectral density.

Then you have pink noise and here the power is spectral, density is inversely proportional to frequency or in other words you can also see that it has equal power in each octave not bandwidth of the not band of the same width, but for a octave and a lot of times, it is also call it as 1 over f noise because the amplitude of this noise of this of each frequency, it decades in a 1 over f fashion.

This concludes our discussion on terminologies and we will continue the discussion on Acoustics tomorrow, but today I wanted to covers these basic topics related to terminology; important terminology which is used in Acoustics and I look forward to seeing tomorrow.

Thank you very much; have a great day, bye.