Architectural Acoustics
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Lecture – 28
Meteorological Conditions and Sound Propagation

Gradually we have come to lecture 28; where we see the topic is Meteorological Conditions and Sound Propagation. Now all these days in the previous lecture; so we were discussing mostly on covered spaces are confined spaces, that is room acoustics, where we discussed different pa kind of spaces, and finally we ended up with auditorium design. After that Professor Bhattacharya highlighted on the electro acoustics. And mean while you are also equipt with near field propagation and far field propagation concepts.

So, when we talk of meteorological conditions, we are trying to see how the atmospheric conditions; like, the temperature, the wind flow, and the humidity, all these how they affect sound. Because we have to look into spaces where it is not covered or it is not really room acoustics, we have to take care of the noise, which is created at some point which may be carried to another point where some acoustical quality is required. Say for example, the open air theater.

So, we will try to see one by one how these meteorological conditions help in sound propagation, or whether the affect sound propagation or not. And, we see the objectives of this particular lecturer is how sound and; sound is observed while it passes through the air.

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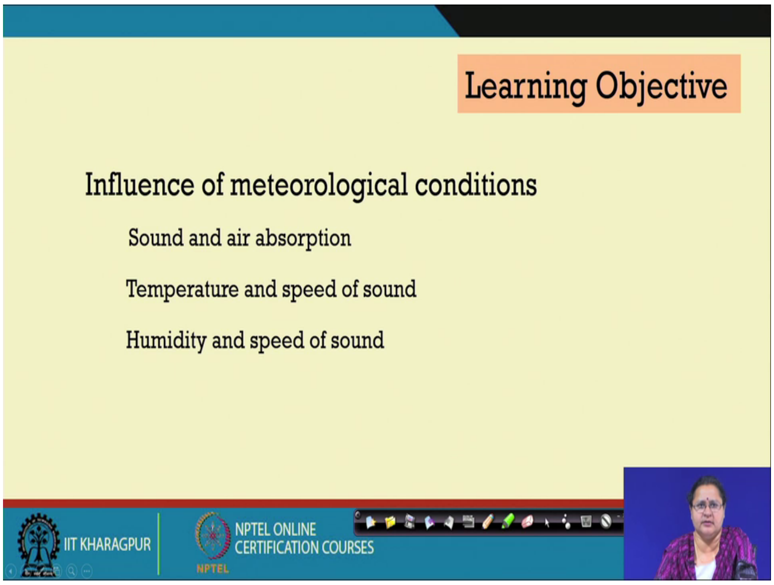

How temperature and the speed of sound gets affected, along with humidity; we will see them one by one.

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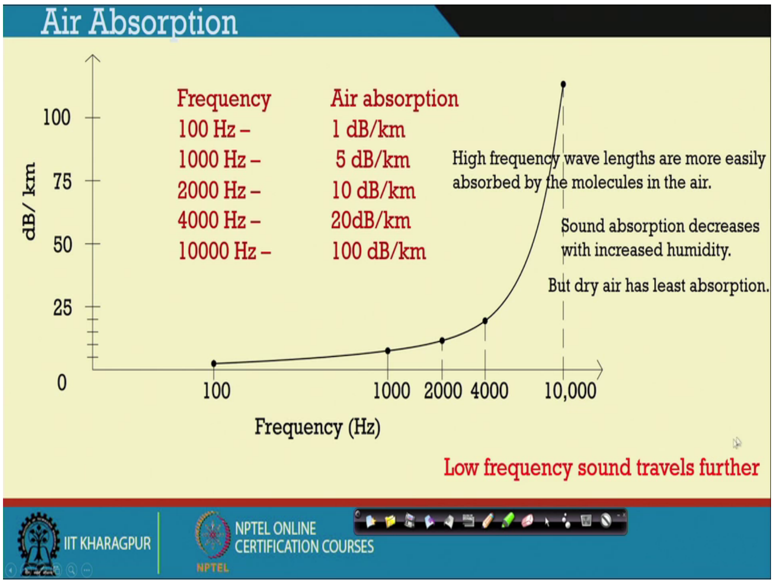

So, coming to the air absorption: we see a curve where we see frequency of 100 hertz is minimally absorbed in air, whereas a frequency of 10000 hertz is absorbed say up to 100 disables per kilometer of travel of sound; so we see that it is not necessarily that all frequencies are absorbed equally while it is passing through the sound. So, high frequency wave lengths are more easily absorbed in between the molecules of air. And that is why there is a reduction of sound of the higher frequencies; whereas there is negligible reduction of sound when it is of the lower order frequency.

So, we see that sound absorption, we also see that sound absorption decreases with increased humidity, whereas, dry air has the least absorption. So, with this understanding we see that, sound when it is of a large frequency band is moving through air, it own p d c, all of the sound will not be reaching at same level, but they will be absorb at different levels while it is passing across the air. So, low frequency sound travels farthest. Whereas, higher frequency sounds does not move to the desired extent.

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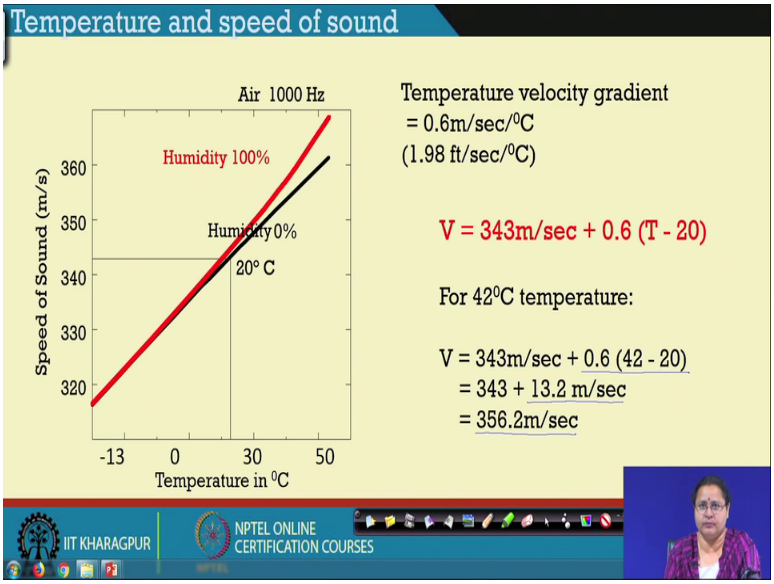

Now, coming to the temperature and speed of sound; this is very much important for us, so that we understand how temperature change, how temperature changes the speed of sound. Here you see a graph which has been drawn at air while passing while sound passing through air which if of 1000 hertz. Where you see at 20 degree centigrade, we see 343 meters per second precisely, which has been divide. Here you see in the x axis, there are temperatures where you see 20 degree is somewhere here.

And 343 is somewhere here, and that is specifically for 1000 hertz of sound. Here is a formula which has been derived; v is equal to 343 meters per second plus 0.6 t minus 20; where T is the temperature in degree centigrade, and that is the gradient. So, at t is equal to 20, the velocity of sound is 343 meters per second. And for every degree change of temperature degree centigrade to change of temperature the change in speed is by 0.6

meters per second. So, 0.6 meter is not a very small amount. So, try to keep this in mind that 0.6 meters per degree centigrade change of temperature is a big amount when we talk in terms of wave length of sound. In feet it is around 2 feet per second.

So, we see with humidity more or less up to 30 degree centigrade, it is behaving in the same manner. So, temperature is temperature and humidity remains do affect above 20 degree centigrade. You can see the red line when humidity is around is around 100 percent you seen the red line has shifted from the black line mostly, above 30 degree centigrade to 50 degree centigrade. So, it is the gradient is further more when humidity is more. So, we have to account for these changes in speed, when we are talking of or when we are doing any outdoor space design.

So, you can calculate say for 42-degree centigrade temperature, the velocity of sound in air would be 356.2 meter per second. How we come to it? The steps are given. It is 0.6 into 42 minus 20, which gives you additionally 13.2 meters per second. And you come out with the result of 356.2 meters per second.

Now, we will try to understand why is it so important when we are planning for any outdoor situation.

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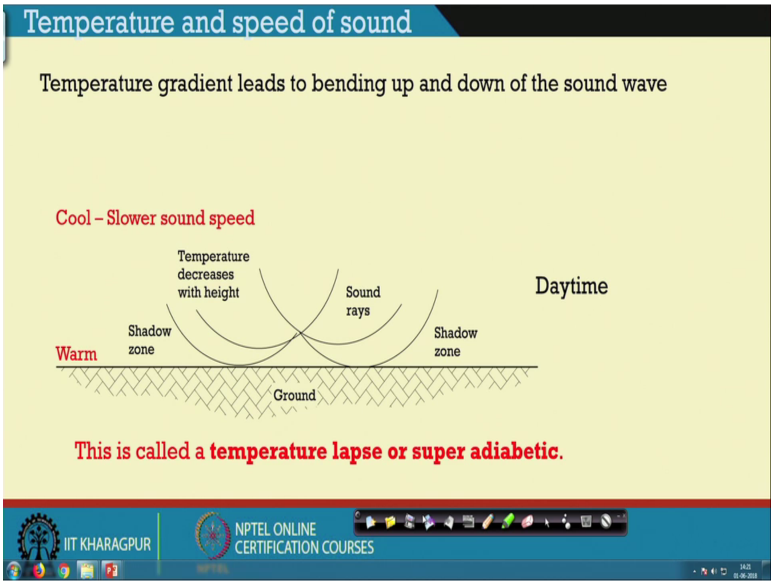

So, when it is day time, let us try to understand, the ground is warm, the ground is warm and the atmosphere above it is cool. So, the sound speed above the ground is having a slower sound speed. Whereas, the sound speed below is having a higher sound speed. So, what is happen, happening? If the sources somewhere here if your sound source is somewhere here, it is producing sound at this particular level, and what is happening if we see the process of compact the process of compression and rarifaction by which the sound travels ?

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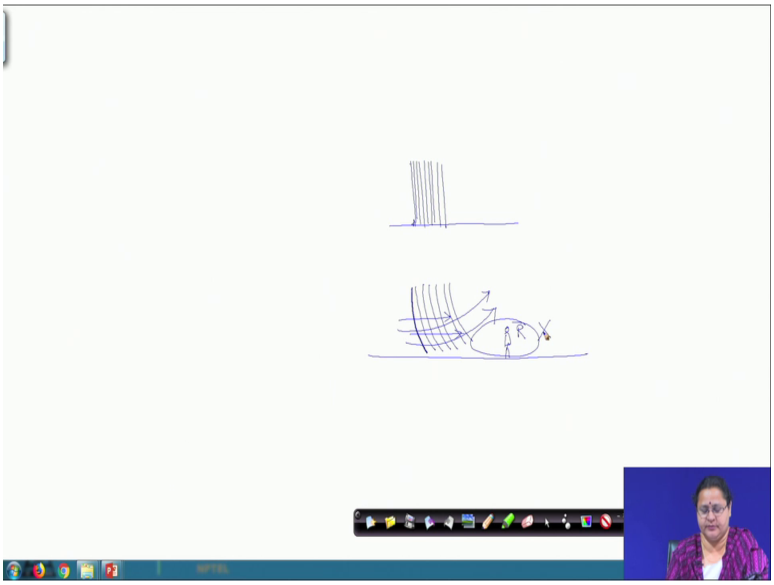

We will see that at the lower that at the lower portion, the sound will be moving faster as compared to the upper part.

So, if the direction is this, there will be change or the sound wave will move upward. This will lead to no sound zone in this particular area. So, if a receiver is standing here, he will not get sound. So, this area becomes a sound shadow area. So, here you see that the sound rays from the source are drifting upwards, and creating the sound shadow zone in the day time at close to the ground.

So, even if the source is close, the people around may not be getting the sound. Whereas, the sound energy is drift is moving upward. And this is called temperature lapse or super adiabatic. So, temperature gradient leads to the bending up and down of sound waves and during daytime the ground being warmer, the sound moves upwards. Hence creating sound shadow zones in the close to the ground.

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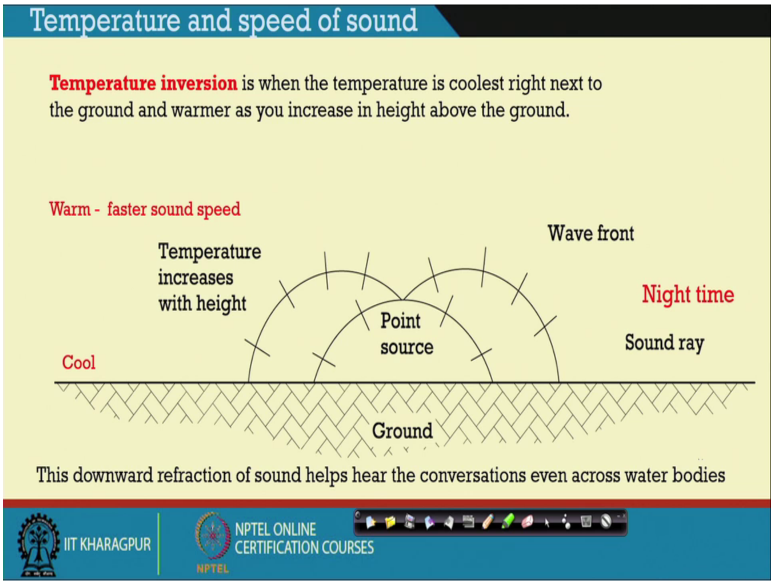

The similarly the opposite phenomenon or an inversion happens when it is night time. At night time the ground surface is cooler, whereas, the surface above for the atmosphere above is warmer where the sound tries to move faster leading to a inversion, leading to a inversion which you can see the sound is bending downwards or move towards the ground. And this is called as temperature this is called as temperature inversion. And this is happens mostly at the night time, and is when the temperature is the coolest tries next to the ground and warmer as you increase in height above.

So, you can actually have sound very close to you, and this happens mostly in front of across water bodies. So, this downward refraction of sound helps to hear conversations even at not much, even across water bodies and even at much distance is particularly at night time. So, you can listen to certain sounds which you may not listen in a quiet daytime, but you can here at night times. So, distant sounds are usually hard at night times rather than day times particularly, because of this temperature inversion.

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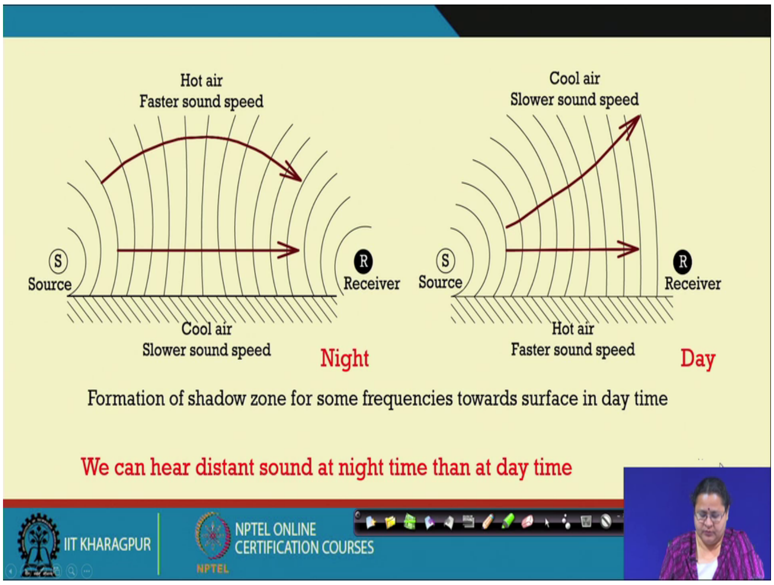

So, this is what you see as a summary, that hot air moves faster and when it is night time it is move bending towards the ground towards the receiver from the source. And when it is daytime the hot air is drifting the sound upward and leading the receiver with very less sound.

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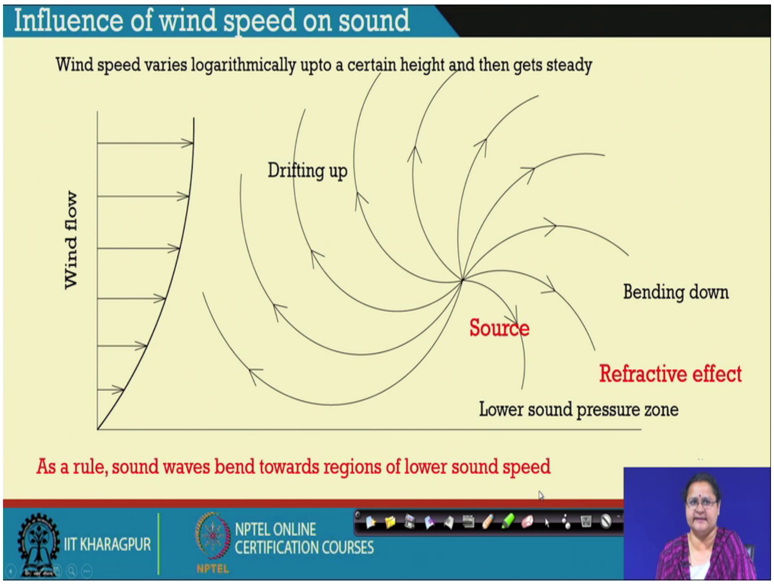

Now, coming to the influence of wind on the sound; now when wind is flowing it is and it is found out that wind speed varies logarithm logarithmically up to a certain height say a 32, 30 meters 200 meters depending on the speed of the wind. So, at the initial stage it moves very rapidly. It is logarithmically it is flowing and after a certain height it becomes steady. So, what happens when the wind encounters the sound? So, sound as when it is originating from a particular source. It is drifted by the wind when it is coming in the direction of the when it is travelling in the direction opposite to that of the wind flow.

So, the sound energy is drifted up because the sound source is producing sound in all directions. So, a portion of the sound which is in the opposite direction to that of the wind gets drifted up. And on drifting up what is happening? Some low sound pressure zones are created in the opposite direction and the sound actually bends down to fill up the spaces; so as a rule sound wave bends towards regions of lower sound speed.

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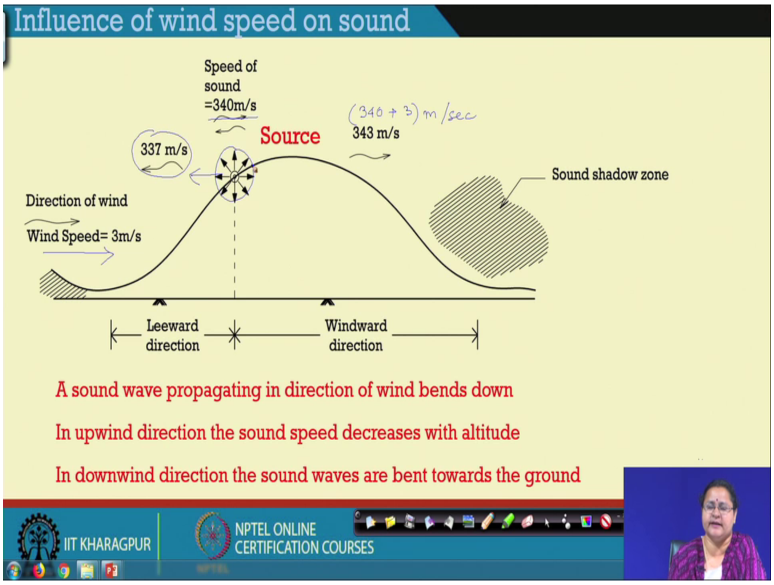

And we see that this drifting up and bending down causes refractive effect of sound in the particularly when the wind is there. And we also see that when it is steady sound, when sound is moving steadily, against the wind against the wind. We see that in the direction of the wind, it the wind speed get summed up. And in the direction opposite to the source opposite to the when the sound is moving opposite to the wind direction it gets subtracted.

So, here you see when the source is here, and the wind is blowing from this direction. At 3 meters per second, the sound which is produced in the direction opposite to the sound opposite to the wind, we see that if we consider speed of sound as 340 meters per second, 3 meters per second get subtracted from it.

So, here we are considering it is steadily flowing, and hence we are just subtracting the values of the speed at the particular unit. So, here it is meters per second 340 meters per second minus 3 meters per second, which gives you 337 meters per second. On the other hand, the sound which is moving on the direction of the wind, the particular amount of sound energy will be moving faster at 340 plus 3 meters per second.

So, if you have units in miles per hour for the wind which is particularly say we can convert down into meters per second or feet per second. And accordingly add it or subtract it from 340 meters per second or 1100 foot per second. So, what we see that if we have a source and the wind is considered flowing steadily at a particular speed, we subtract the value in the direction that is livered direction that is in the negative direction. And we add the wind speed to the sound source to the to the source sound speed which is 340 as considered here. And we can carry out the calculations.

So, along with it we also say that sound wave propagating in the direction of wind bends down. In upwind direction, the sound speed decreases with altitude. In downwind direction the sound waves are bent towards the ground. What we had seen in the previous slide. So, we can some of saying this.

Now, when we are trying to do something in space or in open air, we have to think of the combined effect. So, there will be wind, there will be humidity, there will be temperature change, there will be air absorption. So, we have to account each of them and try to look into the look into the phenomena how the speed of sound is are getting affected, because with speed of sound actually the distribution of it will be considered.

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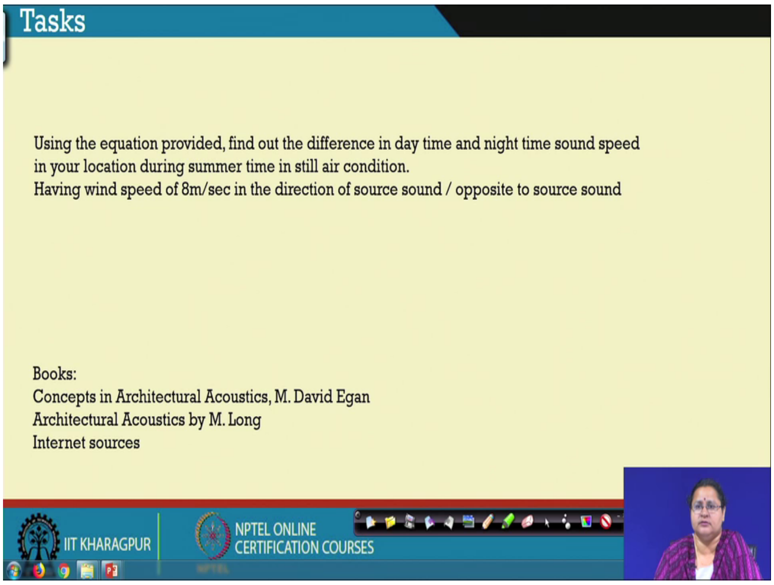

So, I leave you a task like using the equations provided, find out the difference in daytime and nighttime sound speeds in your location, wherever it might be in within India. During summer time in still air condition and having a wind speed of 8 meter per second in the direction of the source, and also in the direction opposite to that of the source sound.

So, we will continue with the next lecture, where we will try to see the how the topography also affect the sound. Because when we are standing in outdoor condition, we have to think of the air, we have to think of the trees, the foliages the topography, the landscape, and then only we can come up with the solution for open air design.