Architectural Acoustics
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Lecture – 02
Introduction to Acoustical Physics

So, Good morning students welcome to the NPTEL course on Architectural Acoustics. Today we will going to have the lecture number 2 and in the lecture number 2, we will introduced with the architectural physics. In the last lecture Dr. Sumana Gupta has presented the outline of the course and if you were just go to that the last lecture, we have compartmentalized the whole course into 8 week program. And in this first week this is the lecture number 2 and we will be introducing today the physics of acoustics.

Now, at this particular moment when we talk about any kind of the architectural building or may be any kind of a built environment and the built environment is basically deal with some kind of the sound and the reinforcement of the sound or maybe the acoustical quality, the physics of the sound is the most important thing.

So, in the first module we will going to have that physics part of the building where we will take care of the propagation of the sound in the first, then we will go to the frequency and the octave. And then and the third not in the third, the fourth lecture we will take talk about the intensity of the sound and the how the sound pressure level fluctuate in that different media? And the fourth lecture we will conclude with the near end and the far end propagation of the sound and also we will discuss about the loudness.

This first module we will going to give you a benchmark or maybe the foundation where from we will take you to the second to the 8 module, where the application of the building physics in the arena of architectural design will be taught.

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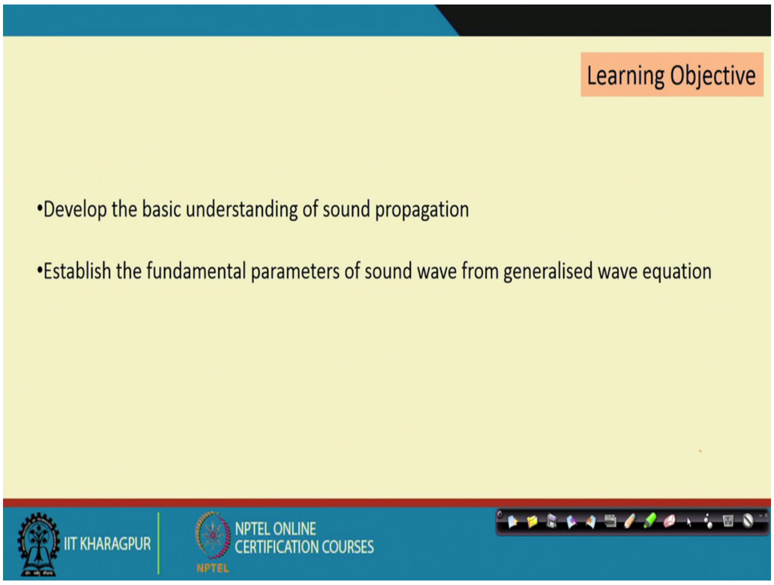

So, let us go to the first slide in that slide I have taken two objective or this particular learning or this learning objective is basically for this particular course or this particular this particular the lecture. We will what we will over here we will develop the basic understanding of the sound wave propagation and we will try to establish the fundamental parameter of the sound wave.

And this fundamental parameters of the sound wave how it will going to generalized in the form of the propagation and the various phase of the distribution.

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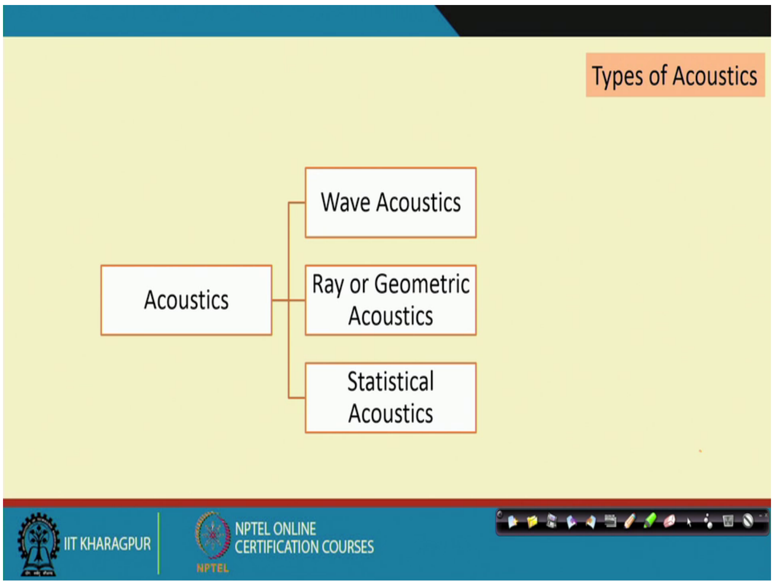

Now, let us go to the typical as study of the acoustics how the acoustics can be deal with? In that we have 3 type of dealing with the acoustical study and in that particular acoustical study when I am talking about; it is talking I am talking about in terms of the building physics or the architectural acoustics.

The first one is called the wave acoustics where a sound is taken into a wave front and the wave propagation and the that particular fluctuations of the wave the pressure fluctuation has to take into account. This is bit of mathematical, but in the second part of the study we will go to the geometric or the ray acoustics fare wave front or the sound wave is generally categorized as a line diagram.

So, a line is actually replace the wave in a logical and understanding format inside a room. So, maybe the reflection, refraction or maybe the absorption of the sound has been logically translated in terms of a ray. We will mostly deal the architects will mostly deal the acoustical problem in any sort of the built environment in the ray acoustics diagrams and the ray acoustics principles.

The third one is also very important which is a statistical acoustics this is another domain; in this domain as you know that a particular noise or a particular sound you may have various amount of frequencies and various types of the sound pressure levels or maybe the sound intensity levels.

So, if I want to give a certain type of sound with a certain type of quality and in a certain area has required some kind of a quality. So, for that we need some kind of a statistical techniques to be handled for to deal with that lot of frequencies and the sound pressure. This particular statistical acoustics is directly implemented in any kind of material testing, in any kind of noise in the I mean noise in the built atmosphere or the surroundings and probably deal with the lot of categorization of the character of the inside a building or so.

So, in this particular the slide gives you basically 3 type of acoustics and we will mostly put our thoughts, put our logical understanding into the geometric or the ray acoustics part.

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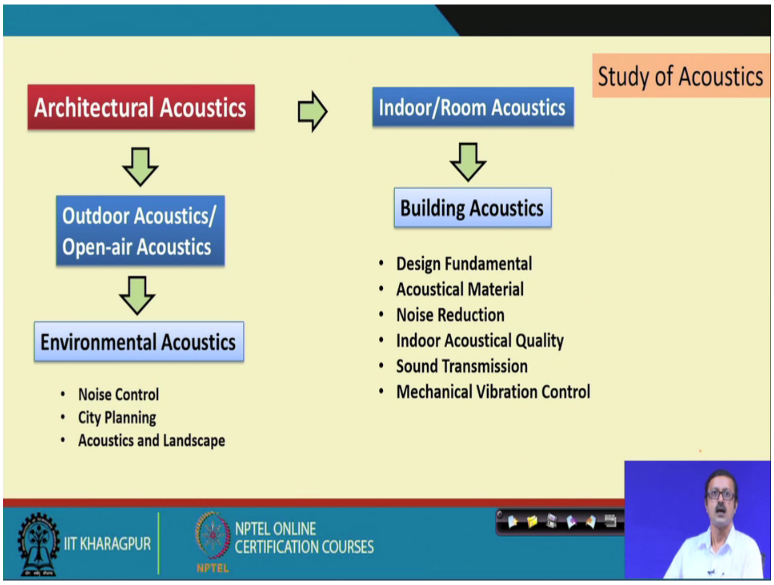

Let us now discuss something about the architectural acoustics and how the architectural acoustics deal with various spaces. If I say the architectural acoustics is going to behave in a inside a building in different format and that format will going to change when we will deal the same sound or the same intensity of the sound and the frequency of the sound in outdoor. So, from the point of view we have two general classification of the architectural acoustics.

The first one is called indoor or room acoustics or it is also known as some kinds of sometimes the building acoustics. It includes the design fundamentals, it includes the acoustical material treatment, it includes the noise reduction noise reduction quality of the indoor acoustics, sound transmission from one point to other. And how to increase sometimes the sound transmission, sometimes how to shield that particular sound transmission and then the finally, it is the mechanical vibration control and all. We will touch up all this particular points in the following lectures from the module number 2 to module number 8.

The another type which I have just now discussed described as the outdoor acoustics or the open air acoustics; sound will behave entirely different way if it goes into the open air. So, in that sections we will discuss about some kind of a noise controlled, some typical parameters or the physical fundamentals of the city planning and also we will do some kind of the discussion about the landscape and the acoustics also.

This as a whole in is terms as a the environmental acoustics or so. Now, when we will start this discussion of acoustics or may be the building behavior the behavior of the building in the sound and all.

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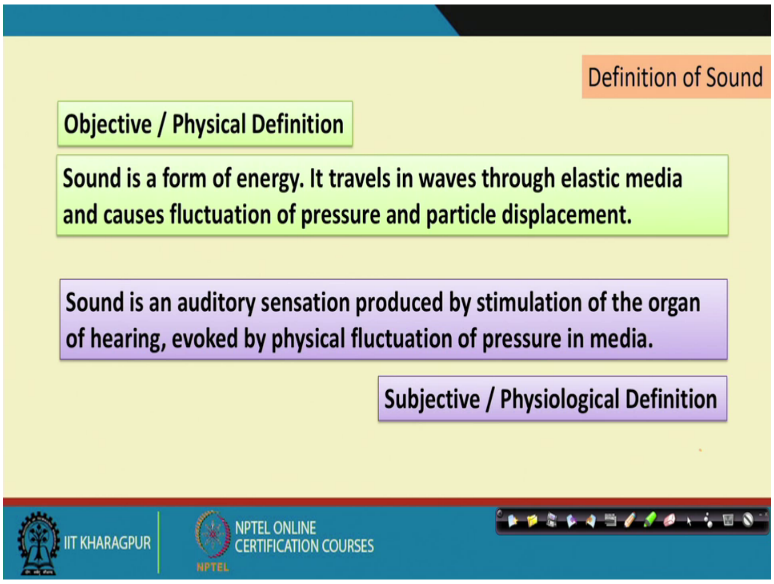

So, first thing that comes to our mind is that what is a sound? And the definition of the sound and the definition of the sound is has lot of variety I must say. Variety in the sense of it may have different prospective views, some people may say that it is a mechanical propagation or the mechanical the energy transmission from one point to other.

Some may be say it is a fluctuation of the pressure, some may sense it in a some different way, how it is synthesized the mind or synthesized the brain? So, from that perspective we have basically two definitions in our hand; one called the objective definition or the physical definition of the sound where the energy from one point to other point travels through a elastic media by virtue of some kind of a pressure distribution or pressure fluctuation and the displacement of the in the media particle.

In another form, we can say this is a subjective or the psychological definition of the sound where sound can be sensed by the human brain or sound can be mapped by the by the human brain by the pressure again by the pressure fluctuations and all. And typical different type of frequencies and different type of power labels or the intensity label gives you different type of fluctuation and finally, map different way in our human brain.

So, there are two subjective and the objective classification of the sound can be dealed with an our in our architectural acoustics. Now, let us say something about the wave motion; so, because sound is the wave; sound is a propagation of the wave from one point to other. And this particular wave is a actually take the some energy from point a to the point b.

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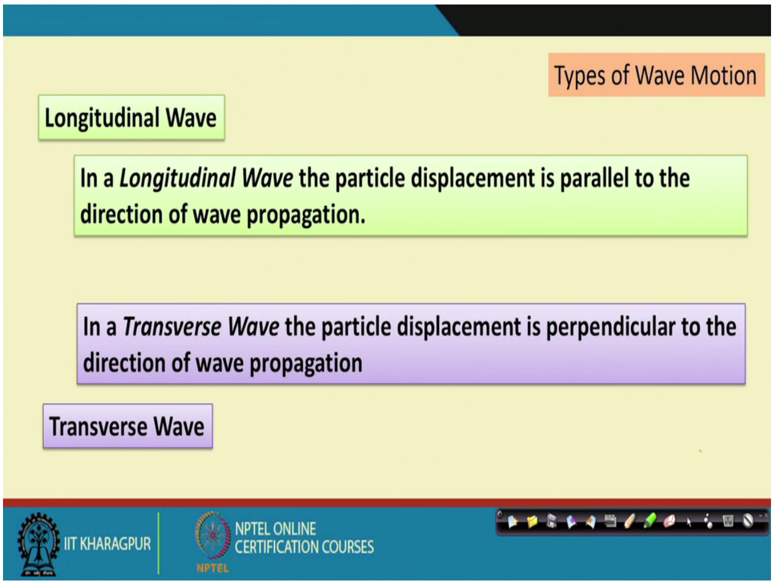

Now, here we have two type of wave propagation in general; the one called the longitudinal wave, where the wave is propagating in a certain direction and also it will give the particle also will displaced in this parallel direction.

In the transverse waves is just the reverse or the just the reciprocal of it, where the way we will propagate from one point to other, but the particle we will move from the orthogonal direction. So, let us discuss in a in some other way.

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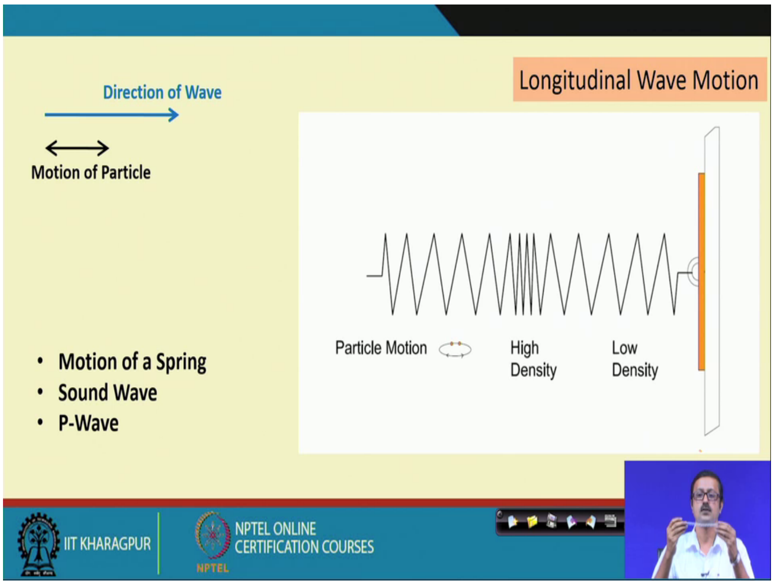

Suppose this is a longitudinal wave and suppose I have a spring with me and that particular spring is compressed on the it is compressed and suppose stretched like this.

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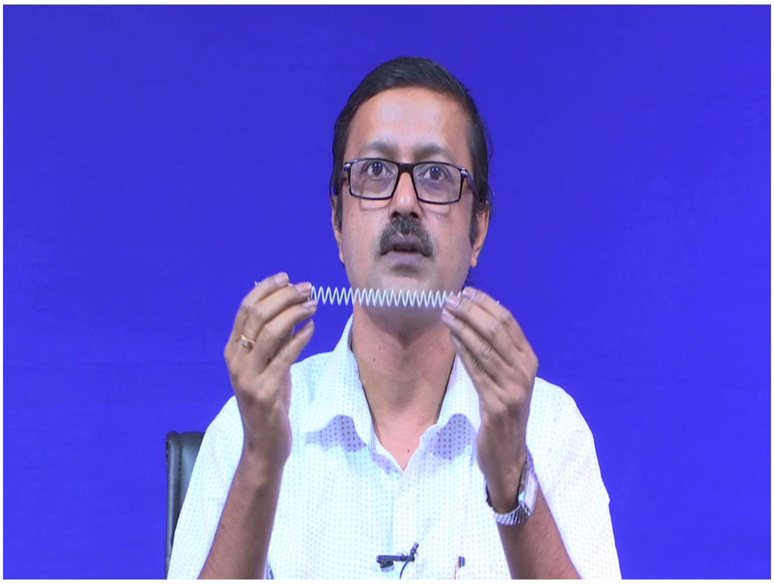

So, if you see this particulars compression and the stretching; so, you will see the particle displacement and the movement of this particular wave in a same direction which is actually the longitudinal wave motion. And the examples of the longitudinal wave motion is the motion of the spring as I described and also the sound wave is a another type of longitudinal motion P-wave.

P-wave is the primary wave which comes due to the is some seismic activity is also.

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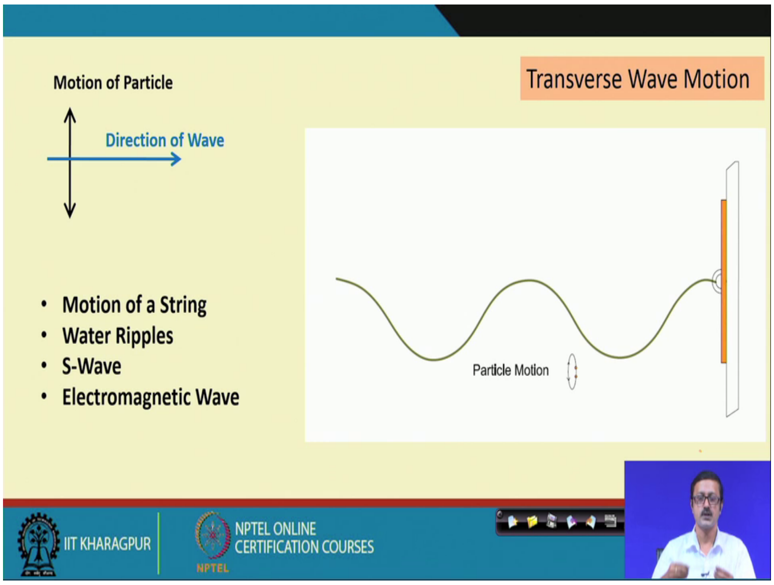

Now, next is the transverse wave motion where the motion of the wave is suppose in this direction and the particle we will displaced in the vertically like that. So, something like if I just swing; so, just try to make a kind of you wave we pattern in this string; so, this is some kind of the transverse motion which will take place or something like that.

So, here the examples are the motion of the string which I have just now described, the water ripples the S-wave; S-wave is the shear wave which is again a kind of the seismic wave and also the electromagnetic wave kind of a thing.

Here we are going to have some kind of the equation development now. Now, in the sine wave equation, if I go to the just 2 minute, if I go to the generation of some kind of assignments sound wave as we know.

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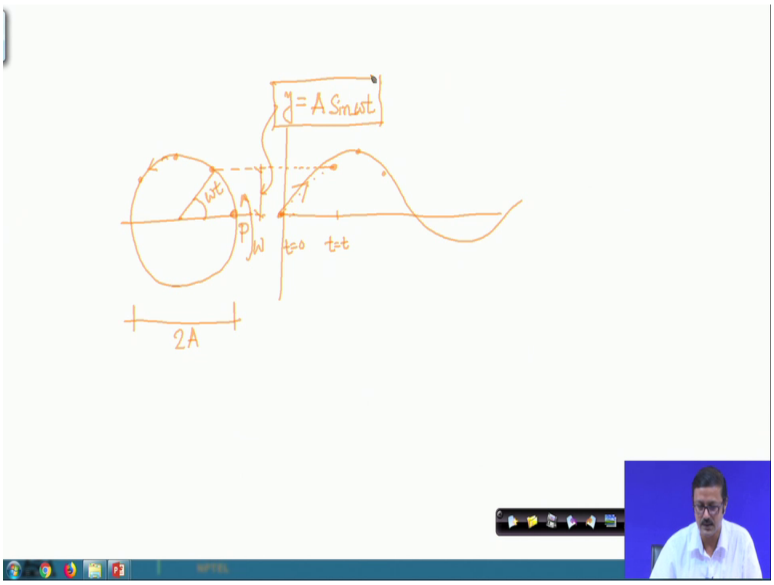

So, let us take some kind of the generation of the wave and as we know that a sound wave is generated by virtue of the motion, a motion of a particle motion of a particle in the circular fashion.

So, suppose this is the point P where this particular this thing this particular point is located. And if the point is move from with this in a some kind of angular velocity through this particular through this particular circle.

Then the projections of this line point in the vertical line we will give me the wave motion. So, suppose this particular circle has a diameter of twice of A that is the radius is almost about the A and it has a angular speed of the omega. So, by some time after a time t its moves a angle of omega t and after this is the t equal to 0 and after sometime t equal to t these moves to somewhere here.

So, the displacement is from basically from like this. This particular y intercept or y intercept is nothing, but the this y intercept is nothing, but the A times sin omega t because it is a sin intercept of that particular angle and the radius being the A.

So, when this moves here at the top its moves further up and when its moves again the point P come down again its goes down. So, something like a kind of a general wave motion we will going to create and whenever this particular wave motion is going to create and its take a particular equation of wave like y equal to a sin omega t.

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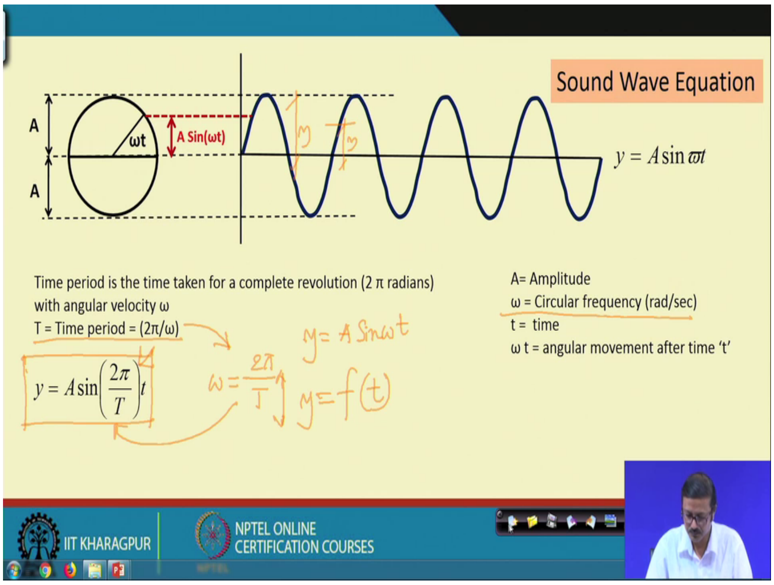

And so when it is now moves like this and this particular wave will propagate like a sinusoidal curve.

Now, here we let us find out some terms over here that omega is the circular a radiation or sorry very sorry the circular frequency which is gives in the radian per second. And because of this radian per second I must say that is the time period is 2 pi omega because it is with a time t, its moves 2 pi radian total angle and with a velocity of omega.

And we can replace this omega by because your omega is then your 2 pi by t which comes from here and we can replace this in this particular sin in wave equation which was your y equal to A sin omega t.

So, omega is replaced and we will get a general form of the equation of the motion which is y equal to A sin 2 pi by T into small t; small t is a variable. So, I again may say this y which is the displacement functions, which is this, this is y this is all are the y for different time is a function of time.

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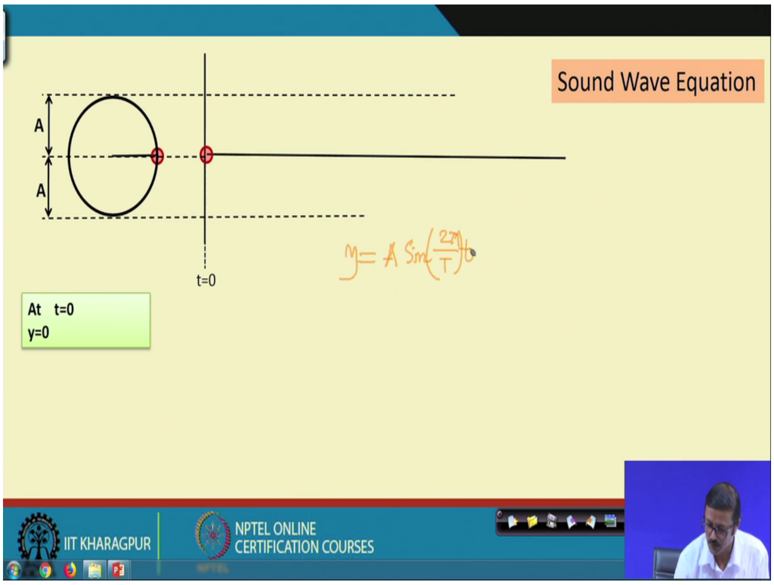

So, let us see how further we can move with this the wave equation and how can we gradually come into the sum of the parameters of this particular wave motion. Now, first of all we will let us give this particular rewrite this equation like y is equal to A sin 2 pi by T into small t.

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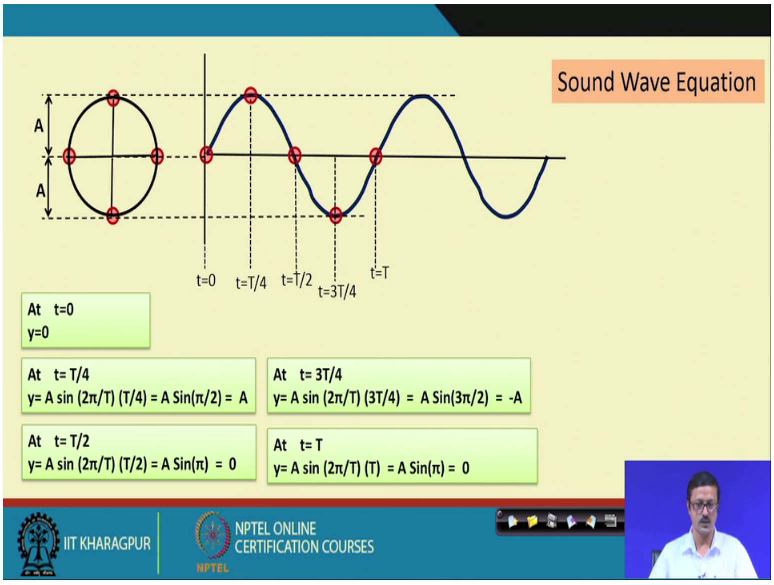

If I now going to have the t equal to t capital T by 2 that is the one fourth of the time period and I replace the small t by T by 4, then the y becomes capital A. So, after t by 4 it moves to this particular point; the highest point of the that particular the wave propagation. Next let us move another T by 4; so, when it is T by 2 that is the half of the time period then this y becomes again 0 because sin pi is equal to 0.

Let us move another T by 4; so, this is t by t equal to 3 it capital T by 4 that that is the 70 percent of the total amount of your time period. So, then again its comes, but its comes in a negative displacement that is below the midline and it is again minus A. And finally, if you go to the full cycle or that that when the t equal to capital T in the that is the full time period or the particular t, then it is again its 0 sin pi.

So, finally this particular wave will repeat this particular module will repeat from one point to the other point and this particular sin wave is created in a and that is the motion of the sound can be mapped with this particular that the equation.

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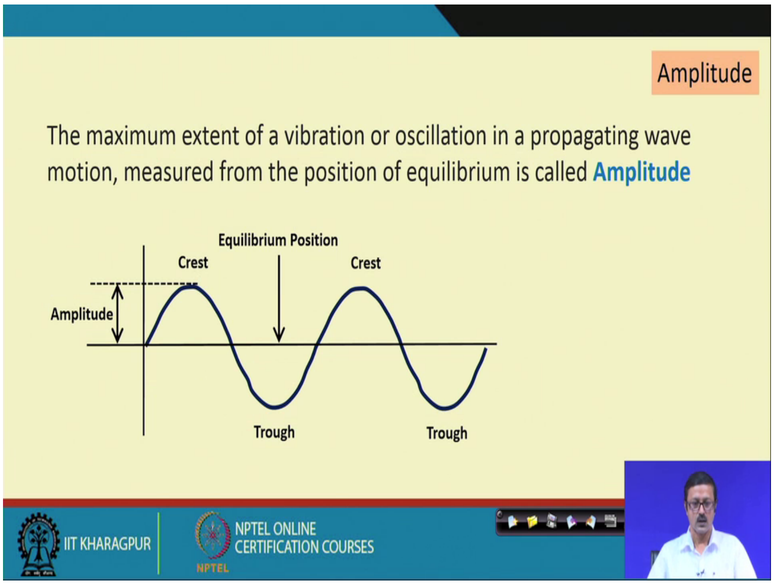

Here let us discuss some of the physical properties of those the equations or the motion. If you draw a this kind of the sound wave line; so we will get some kind of a some kind of a crest and some kind of a troughs, which are the top most point and the value point also.

So, here this particular line which is the midline; so, midline from the crest and this particular vertical axis is called the amplitude of the motion amplitude of the motion.

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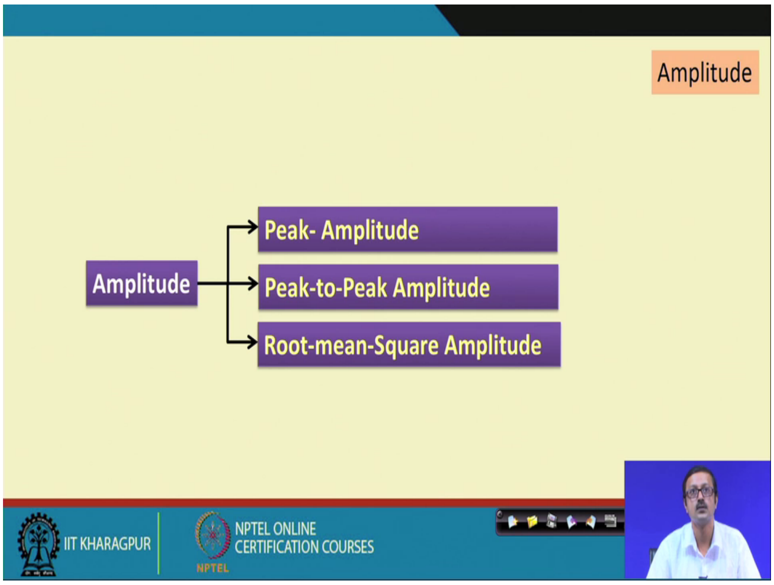

Now, this amplitude of the motion is also having 3 types, the one called the peak amplitude then another is the peak to peak amplitude and the root mean square amplitude.

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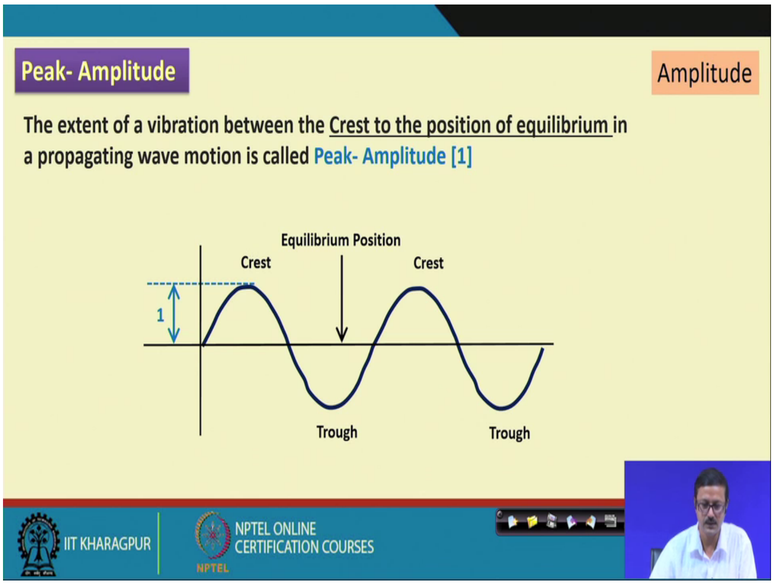

In the peak amplitude case, this whatever I have described in the last slide we will be remain as the peak amplitude; it is the crest to the mid equilibrium position the distance; the vertical distance.

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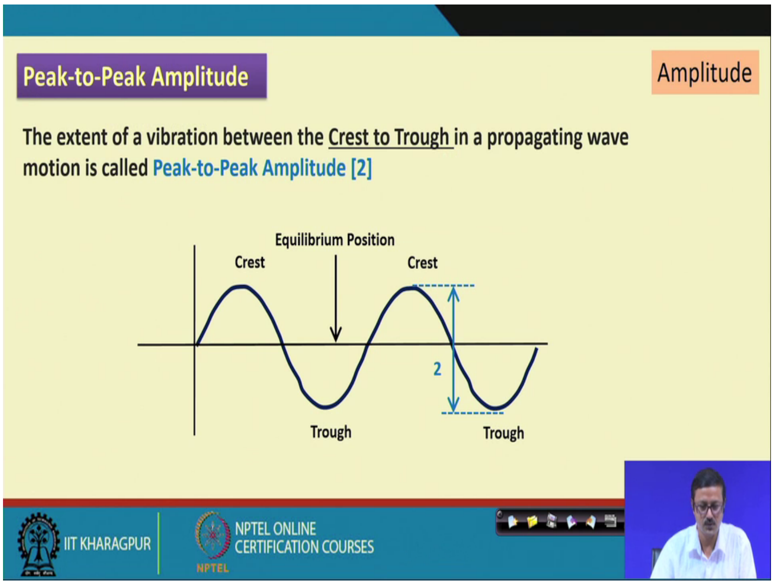

Next one is the peak to peak amplitude if add the crest to the trough, this particular total distance has to be taken into account which is look like the twice of that. But sometimes it may not may be n a complicated form when there is a mixed frequencies it may not be that that twice A trough maybe little bit nearer to the equilibrium positions or something like that.

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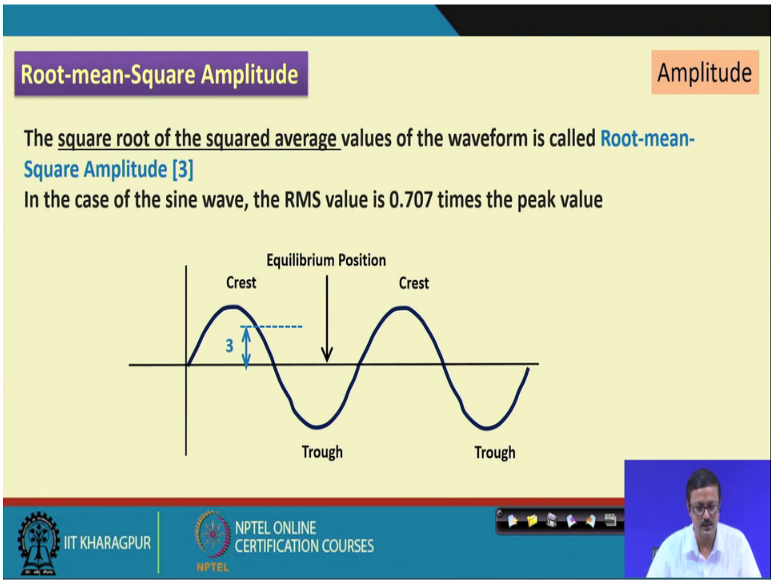

There will second; the third one is called the RMS amplitude or the root mean square amplitude where we take the RMS value; the root mean square value this the square root of the square average, squared average of the total propagation by integrating this particular in a period of time t and it comes about almost 1 upon root 2 times the actual amplitude or maybe the 0.707 times the peak amplitude which is given shown over here as a the 3.

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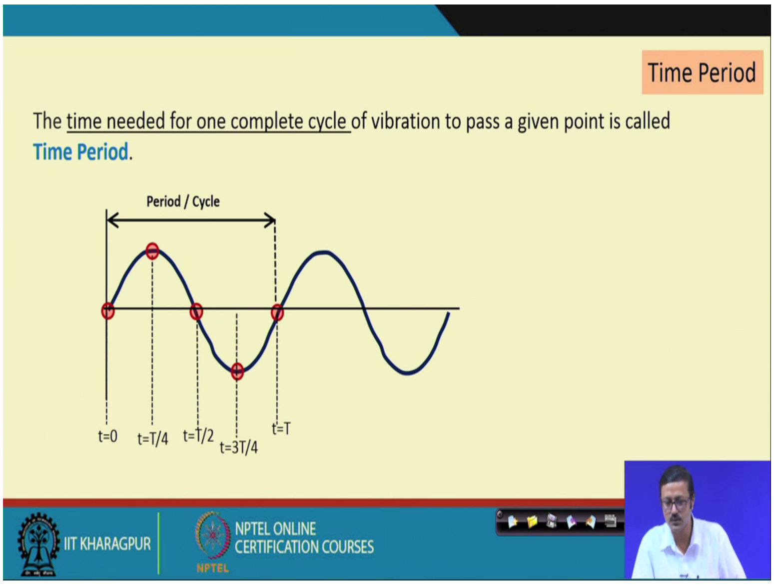

After the amplitude we will let us discuss about the time period; time period is the one full cycle the one full cycles actually starts from t equal to 0 to the t equal to capital T, when their full cycle is going to be happen.

And we as we know that t and this is can be related with the omega; omega is the angular velocity of the particle which moves in a circular orbit or circular the perimeter. And this particular T is also 1 upon f; the 1 upon frequency that we will discuss in the next slide.

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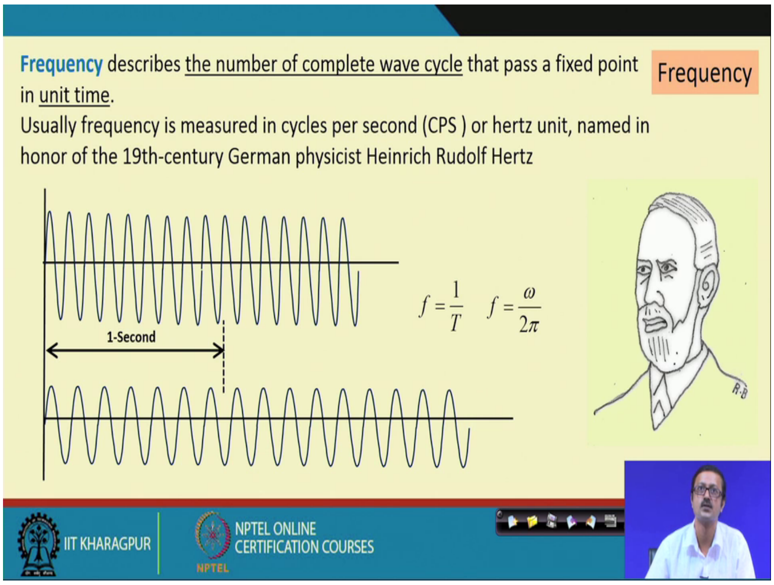

The frequency is the number of wave or the number of wave cycle that passes to a fixed point in unit time. So, in a unit time; that means, in the unit second, 1 second how many those number of cycles actually passes through a particular point? And that is the that is the frequency.

So, suppose if I take this particular 2 wavelength; so, I can be easily say the first wave that is the this wave this wave is having the high frequency because in 1 second, there are lot many many the cycles. The second diagram gives me the relatively less amount of frequency because the same 1 second there are 1 2 3 4 or 5 may be 5 such cycles passing through.

So, this particular second one may have a frequency of 5 this particular the wave may have a frequency of 12 or 13. So, the frequency is 1 upon T, 1 upon T is T is the time period and the frequency also can be rewritten as the omega by 2 pi.

And the German Physicist Heinrich Rudolf Hertz in 19 century has given lot of theories on the sound physics or so, so on the honor to him, we have kept that particular frequency the unit of the frequency as hertz in it is also sometimes called cycles per second or CPS.

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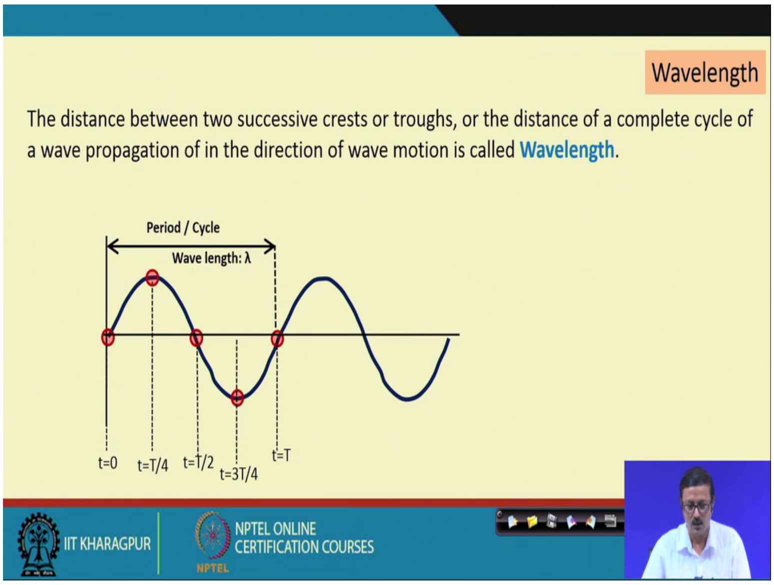

Wavelength another important parameter on the sound wave propagation, wavelength is a length it say in meter or centimeter or millimeter. It say it say it say length of the one period one full period of the wave. So, from t equal to 0 to t equal to capital T the total length of the wave is called the period or it is called the period and it is called the length is called that the wavelength.

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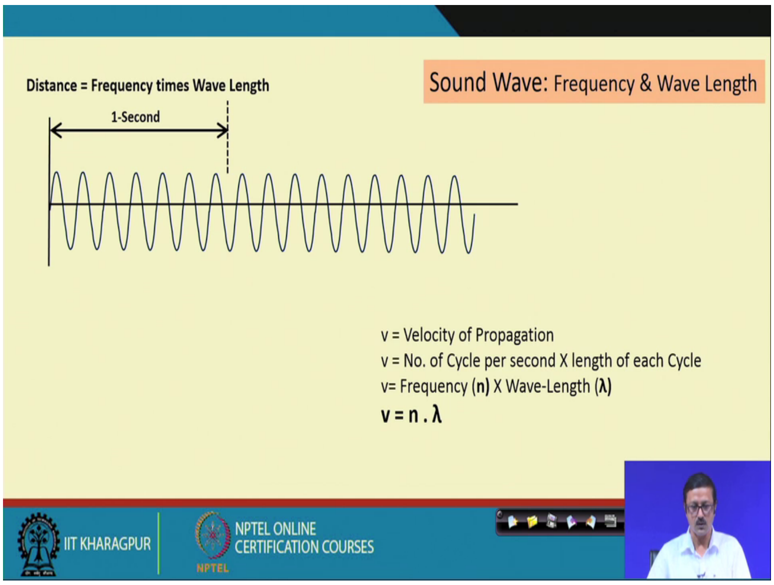

So, now let us in particular 1 second there are so, many frequency so that is your the frequency or so, so, many periods also. So, that is the frequency, so distance covered by the particular unit time is the frequency times the wavelength.

So, then the velocity of the sound or may maybe the velocity of the propagation of any kind of the wave is the in 1 second how much distance its covered? So, the distance is your frequency times the wavelength. So, the v equal to n into lambda where n is your frequency and lambda is your wavelength.

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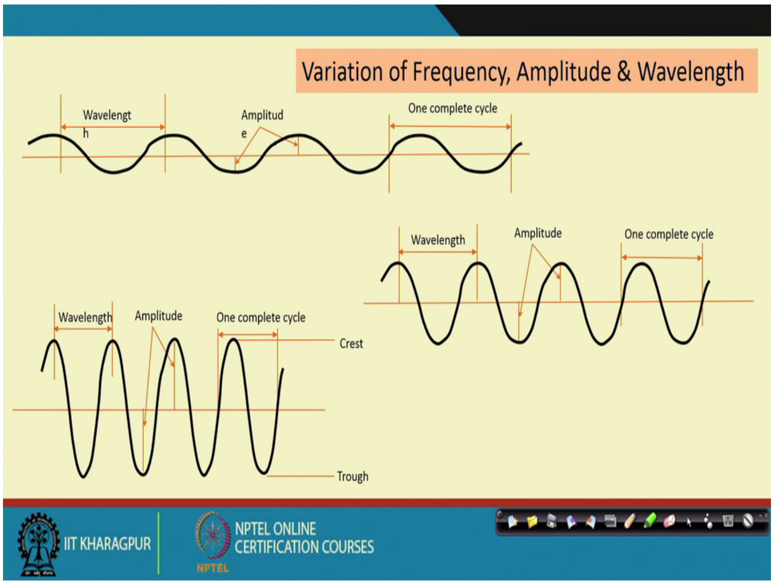

Now, the frequency amplitude and the wavelength may vary. So, I have some 3 diagrams where we can compare this particular things where if you see this is a the first figure which is having a very flat kind of a nature, which is having a less amount of amplitude which is given as the e over here; one complete cycle is very extended; so, the wavelength is very much extended.

If you compare the figure number 2 and the figure number 3 you see the variation in the amplitude; the amplitude peak is very high in this case, but the one cycle is very compressed. So, this is the wavelength is very much compressed over here whether this case second case wavelength is very much extended. So, by virtue of by virtue of this 3 parameters; that is the wavelength, the amplitude and the one cycle length that is the lambda or the wavelength, we may map we may actually mathematically calculate different type of frequencies or different type of frequencies and the different type of wave propagation.

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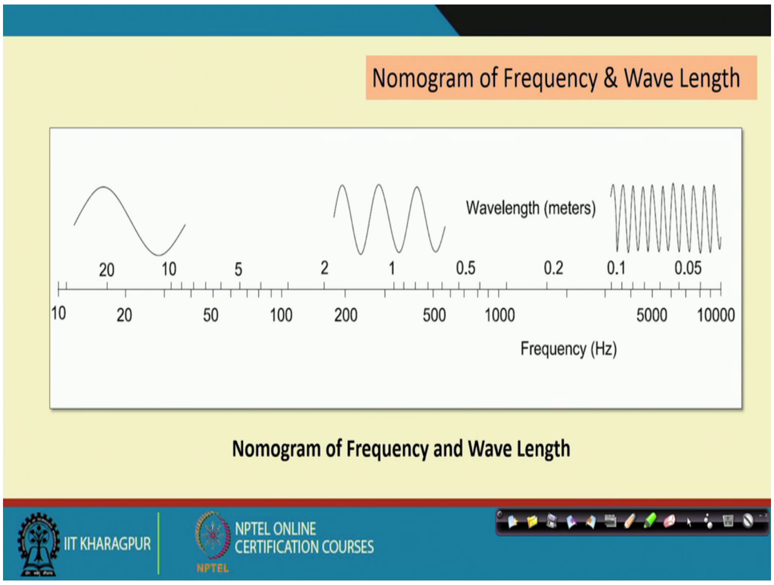

So, this is a nomogram where we can a extended version of the frequency in the lower axis of the x and the upper axis of the x is gives the wavelength. Because there is a in terms of the wavelength and the frequency is play the role of a kind of a 2, 2 this wavelength and this particular frequency can create a the velocity of the sound. Though this velocity of a sound is more or less fixed and from that background we can say that the frequency and the wavelength has the kind of a very intimate relation.

And this intimate relations is actually focused or the mapped over here when from 10 hertz in this that the left hand side to the 1000 hertz in the right hand side; if is goes, the wavelength is higher when the frequency is lower and gradually the wavelength is going to shorter and shorter and this 0.05 when the frequency is almost about the 10000 or. So, it is the very intimate kind of a relationship when you see and by virtue of the fixed parameter call the velocity of the sound.

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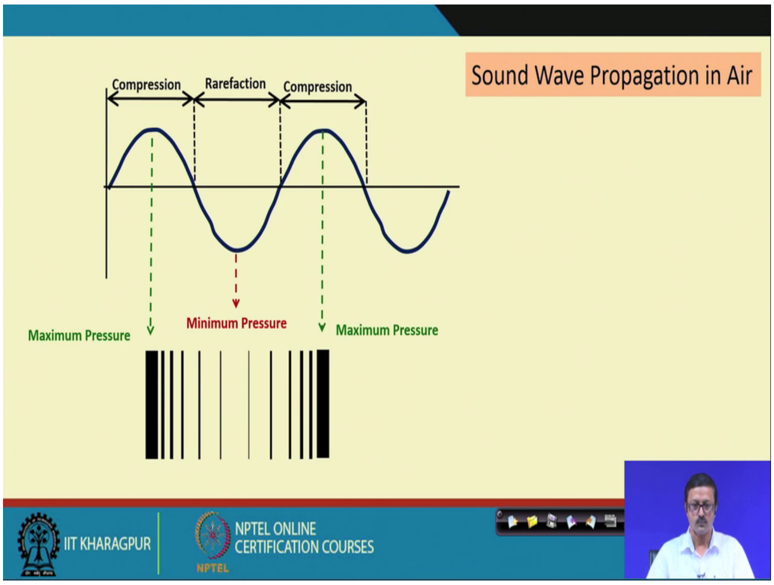

So, when sound in propagate in the air a pressure fluctuation will create because it is a it is a it is a longitudinal kind of a wave. So, the pressure fluctuations is also mapped like this when it is in the crest it is a maximum pressure, it is very very densified the air molecules are very very densified. And when it is a trough minimum pressure that is here been molecules are a stretchend.

So, a compression and the radar fraction will take place one after another and this fluctuation of the pressure we will take the sound from one point to the other point and the pressure in the particular fluctuate like compression and the radar fraction.

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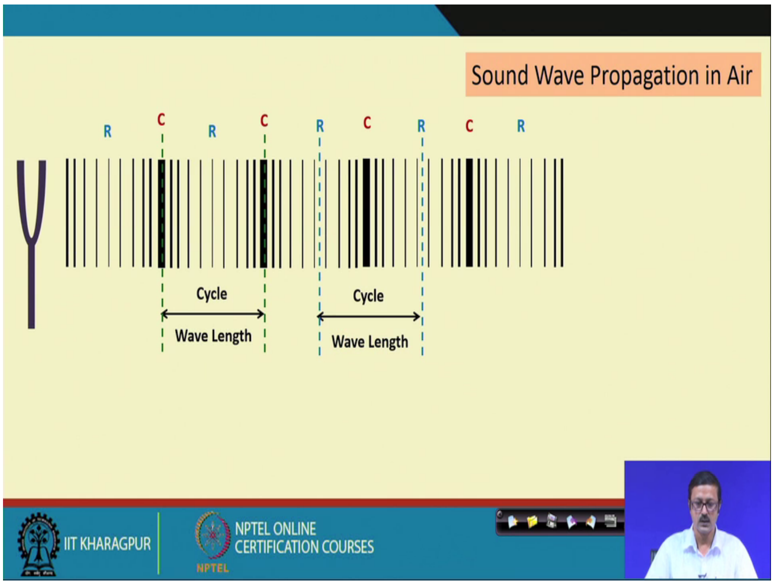

So, this will give in a in extended version of the format where in the blue R's are in the radar fraction zone and the red C or the compression zone. So, one cycle is actually the from the C to C or maybe a R to R.

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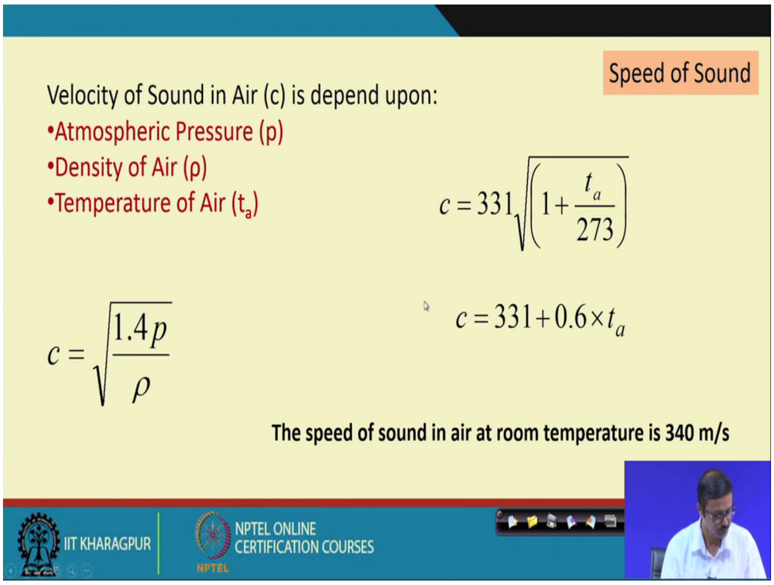

And that is the one cycle of the are the wavelength; it may be make creative for due to any kind of the sound source; I have shown over here a kind of a the tuning fork. The speed of the sound now is a another important criteria. So, we have seen the speed of the sound is based on the wavelength and the frequency.

But speed of the sound is also depend upon lot of physical parameters of the air, the first parameter will be the atmospheric pressure, second parameter may be the density of the air and also the third parameter may be the temperature of the air. By virtue of the atmospheric pressure and the density we can find out the velocity as c as with this particular formula where the small p is the pressure atmospheric pressure and the rho is the density.

We sometimes use this particular form second formula where the c is depend upon t a; t a is the temperature of the air which can be rewrite as with the form of this kind of a equation as c is equal to 331; 331 plus 0.6 t a. And this equation will be very much helpful for us when we will discuss the propagation of the air velocity of the air in the open air acoustics.

So, if you just put some value t a as 20 centigrade temperature room temperature. So, we will come around a velocity of 340 meter per second kind of a thing.

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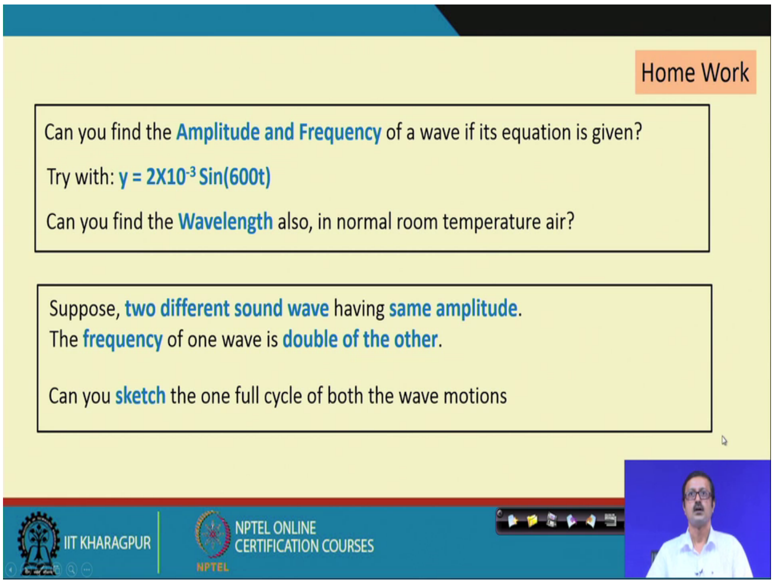

So, this is almost the end of this particular chapter and let us have some kind of a small homework for you. So, the first what I want to say that the suppose I have given the equation like y equal to 2 into 10 to the power minus 3 Sin 600 t.

So, can you find out the wavelength and of this particular propagation of the sound this with the wave with the normal room temperature or so?

Can you find out the amplitude all also the frequency of the sound? Now, in the second homework; suppose there are two different sound wave having the same amplitude or given same amplitude, but the frequency of the one is double of the other. So, can you sketch of a one full cycle of the wave motion? So, try it and if you have any kind of a doubt we can contact us through the NPTEL the web link and the all the way there we can. So, this is the end of it.

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And this is the some bibliography, this is the end of my the lecture number 2 hope you understand that one and we will move to the next lecture in the next half an hour with the frequency and the octave.

Thank you.