NOISE CONTROL IN MECHANICAL SYSTEMS

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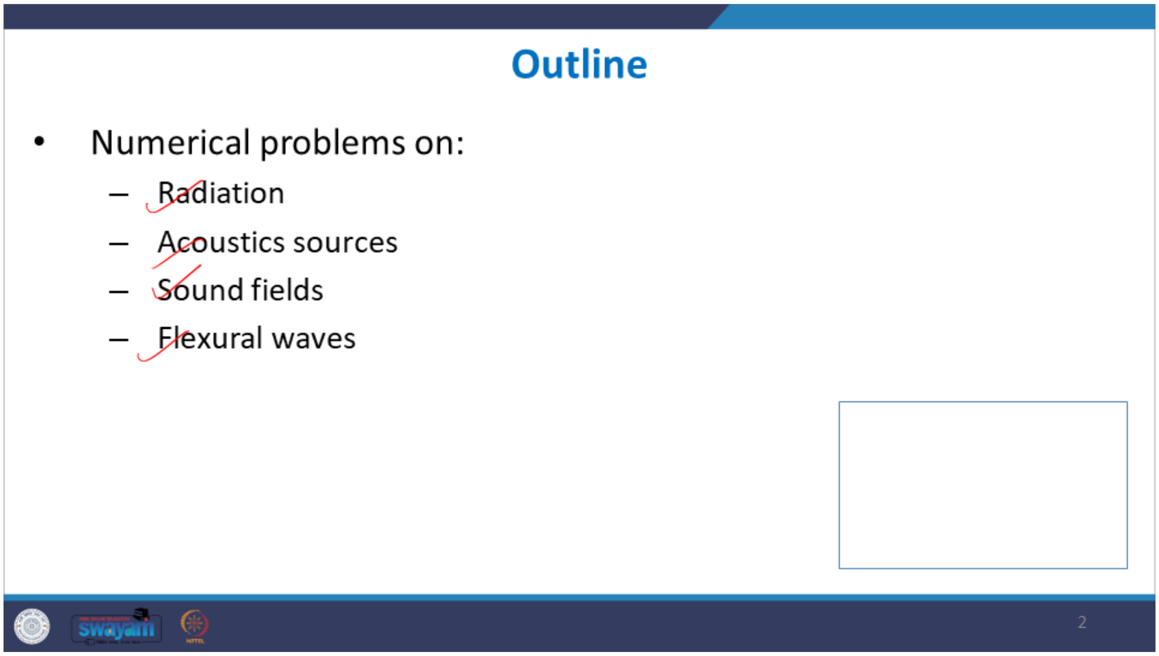
Week:03

Lecture:12

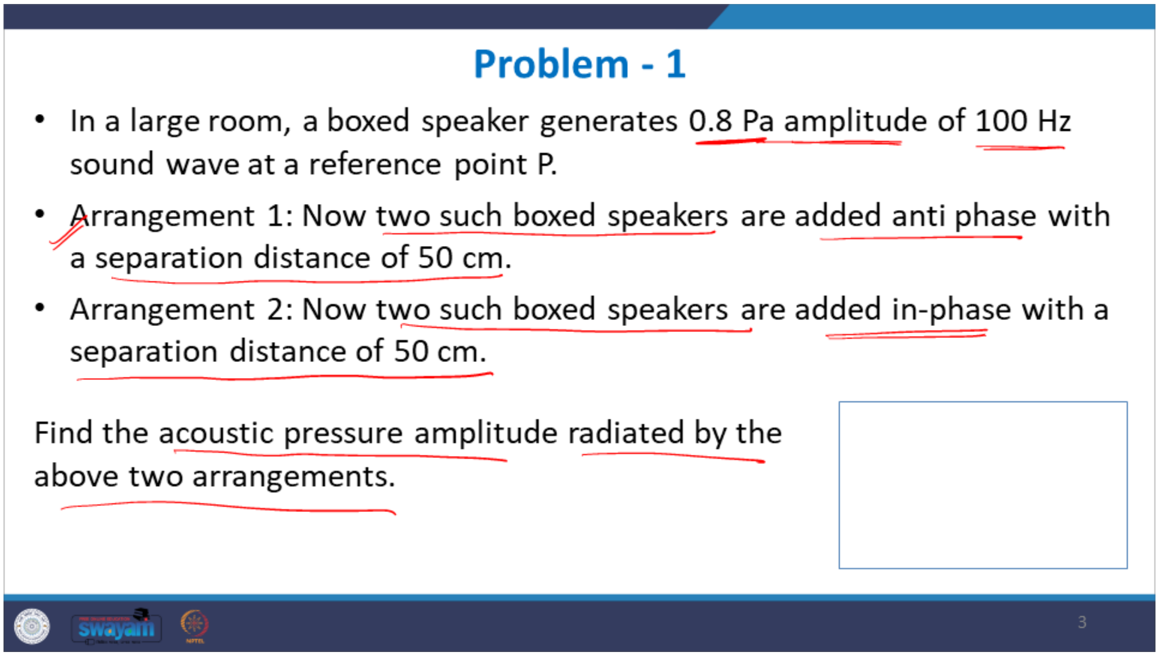
Lecture 12: Radiation: Numerical Problems

Hello and welcome to the lecture 12 in the series on Noise Control in Mechanical Systems. Today, we will solve some problems with respect to sound radiation that we have studied in the previous two lectures. So, that is the outline. So, we will study about radiation, acoustical sources, sound fields and flexural waves we have studied and their numerical problems we will be solving.



So, let us see the problem 1.

Suppose we have a large room and we have got a boxed speaker it's generating 0.8 pascals amplitude of sound wave at 100 hertz frequency at a particular reference point p in the room now so these kind of speakers we have brought from the market now we want to arrange them so we want to have different arrangement of the speakers so let's say in the first arrangement two such box speakers they are added anti-phase at a separation distance of 50 centimeter whereas in the second one same two box speakers added in phase at a separation distance of 50 centimeters now you have to find out what is the acoustic pressure amplitude radiated by the above two arrangements so let's see here



So if you think here the very first case boxed speaker behaves like an acoustic monopole and considering assumption that the room is much larger than the speaker dimensions, it is given a very large room. So, we can say that it is a free field propagation. So, here what we can say that you know typically you know when no other conditions are given we assume that it is a free field propagation at the point P at the reference point P. So, which means that spherical wave front is emitted and it's behaving like an acoustic monopole. Now let's start and see what happens in arrangement 1. Two speakers or two monopoles antiphase at a distance of 50 centimeters. So what does it behave like? It behaves like a dipole. This becomes a dipole. Okay. so it behaves like a dipole and in that case obviously If you have studied the previous lectures, the radiation efficiency of a dipole is less compared to a monopole. So, probably the acoustic pressure should go down, okay.

The same speaker should radiate not as efficiently as the case of a single speaker when they are in antiphase. So, let us see what would that be. Let us find out the radiation efficiency of this dipole with respect to the monopole. So,

$$\eta_{d/m} = \frac{W_d}{W_m} = \frac{k^2 {L_1}^2}{3}$$

This is what has been found in the previous lectures. So, which means the energy radiated by arrangement 1 with respect to the energy of a single speaker is given by this. okay So, let us find out what this is. k so here we have got the frequency is 100 Hz if you think ok and therefore

$$\mathbf{k = \frac{\omega}{c}}$$

which becomes

$$\mathbf{k = \frac{2\pi * 100}{c}}$$

and if nothing is given we stake it is an air at the room temperature and we take its corresponding speed of sound and when you solve this what you will get is 1.8212 as radians per meter as your wave number k and L_1 is 50 centimeters. So, let us see Now, let us put all the values in SI units. So, centimeters we convert to meters. So, we get 0.5 meters whole square by 3. If you solve you find this as the relative radiation efficiency.

$$\boldsymbol{\eta_{d/m} = \frac{k^2 {L_1}^2}{3}}$$

$$\boldsymbol{\eta_{d/m} = 0.2764}$$

So, what it means is that the

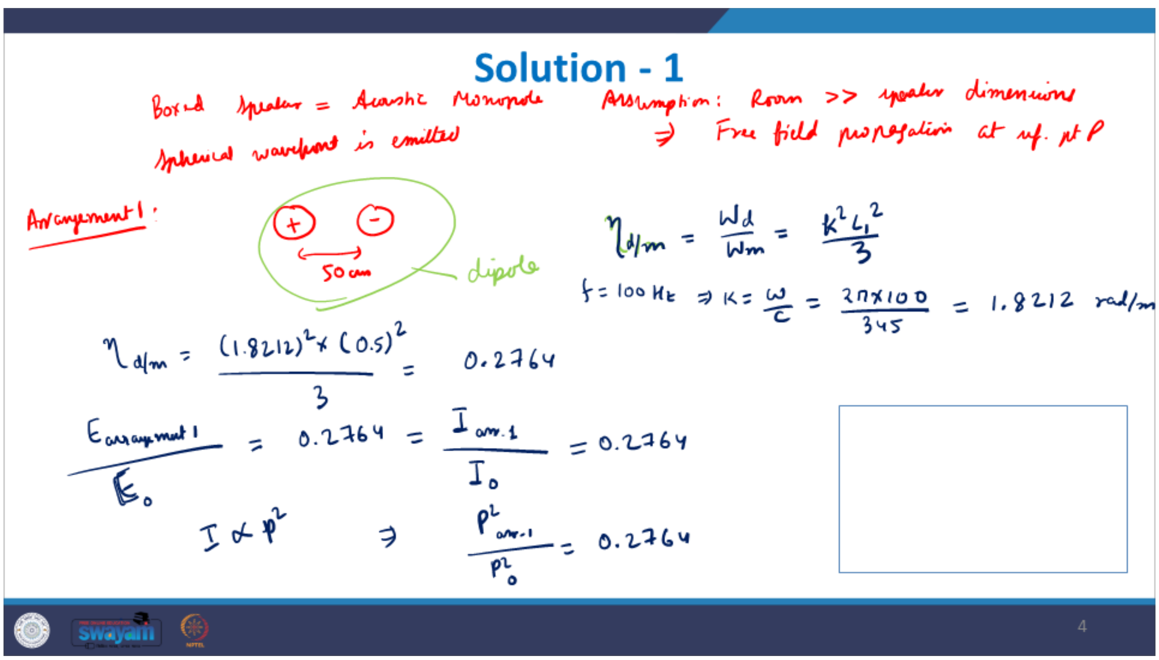
$$\mathbf{\frac{E1}{Eo} = 0.2764}$$

this thing and we know that.

$$\frac{I1}{Io} = 0.2764$$

intensity is directly proportional to P square.

$$\left(\frac{P1}{Po}\right)^2 = 0.2764$$



So, the acoustic pressure due to arrangement 1 should be square root of this, the ratio of this to be square root of their intensity or energy ratio which comes out to be this thing here.

$$\left(\frac{\mathbf{P1}}{\mathbf{Po}}\right) = \mathbf{0.526}$$

So, what would be the acoustic pressure that is has been asked here? Acoustic pressure due to arrangement 1 at the same reference point P is given by into P_0 and P_0 here was 0.8 so this comes out to be if you solve it 0.42 Pascal.

$$\mathbf{P_1 = 0.526 * 0.8 = 0.42\ pa}$$

so this becomes our answer for the first thing which we are supposed to find okay now let's solve for arrangement 2 okay again arrangement 2 is in phase so here now it will not act as a dipole but rather you can say a extended monopole that are separated by 50 centimeter now given that the room is very large let us first see how does this 50 centimeter stand in terms of the wavelength so the wavelength of the sound is

$$\boldsymbol{\lambda = \frac{c}{f} = \frac{345}{100} = 3.45\ m}$$

So, it is 3.45 meters. So, you see here that this separation distance d is very small compared to the wavelength. So, now overall at a far away point P we can assume it equivalent to a bigger sound source which is a because they are in phase. So, they behave like a bigger ball of mass pulsating and they are creating you know the sound waves. and following the principle each of them is individually generating sound waves that are in phase.

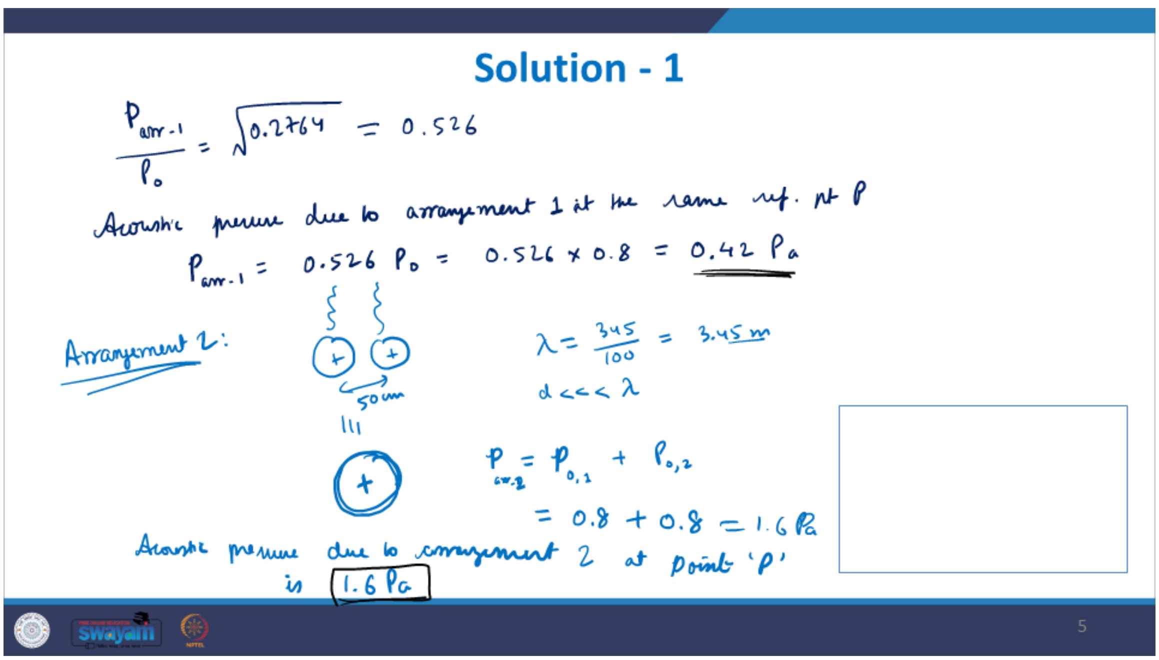
So, the in phase sounds. So, overall the pressure at point P should be P due to the speaker 1. So, P_0 due to speaker 1 and P_0 due to speaker 2 individual speakers. So, this becomes our pressure for arrangement 2 okay so we are simply superposition of these two wave fronts coming from the two speakers so here simply it is

$$P_{arrangement2} = P_{o1} + P_{o2}$$

0.8 plus 0.8 so the acoustic pressure which is asked due to arrangement to at point P is 1.6 pascals just double of what would be there fine.

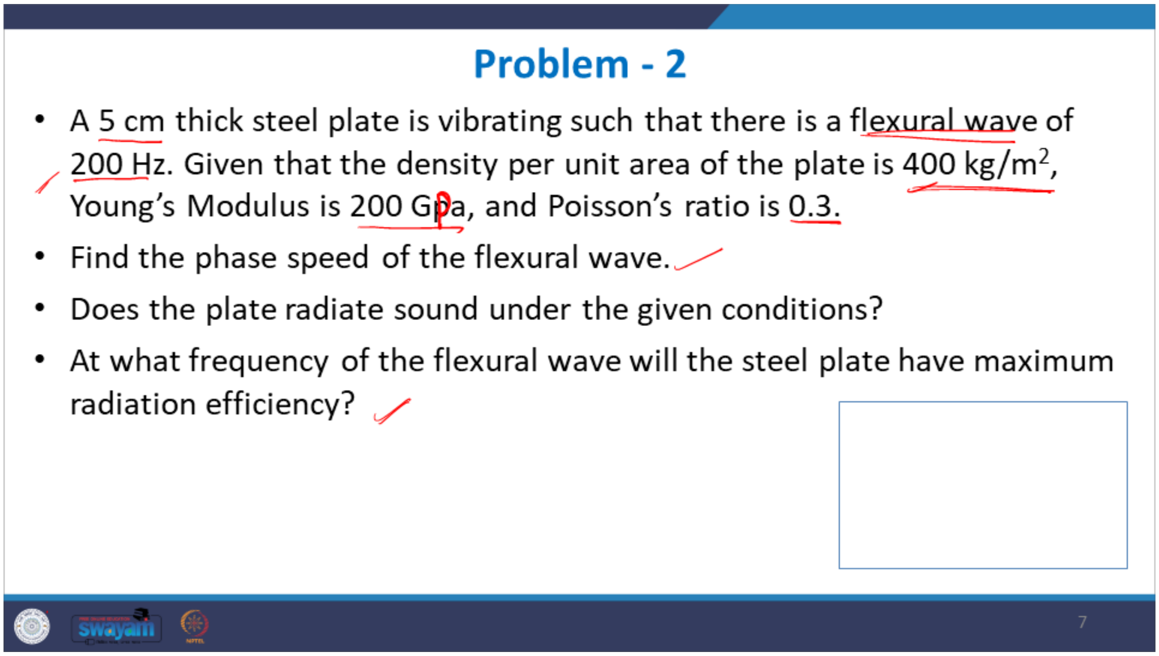
$$P_{arrangement2} = 0.8 + 0.8 = 1.6 \text{ pa}$$

So, I think that would be the acoustic pressure amplitude was asked for the two arrangements ok.



Let us go and see problem 2. Now, in this problem what is asked we have a 5 centimeter. So, let us underline and see what are the values that is given to us.

A 5-centimeter-thick steel plate vibrating such that we have a flexural wave in the steel plate. The density per unit area or the rho s is given as 400 kgs per meter square for that plate. The Young's modulus is given to us; Poisson's ratio is given to us. First of all, we have to find out the phase speed of the flexural wave that is created. answer the question that at this condition does the plate radiate sound and if so or if so not and then also answer what frequency of the flexural wave will give you the maximum radiation efficiency.



So, let us attempt this. So, over here the things that are this is the bending wave speed. The bending wave speed is given as

$$\mathbf{c_b} = \left(\frac{\boldsymbol{\omega}^2\mathbf{B}}{\boldsymbol{\rho}_s}\right)^{1/4}$$

Okay Now, let us find these individual quantities

$$\boldsymbol{\omega} = \mathbf{2\pi f}$$

which is for a 200 Hertz wave. This comes out to be 1256.6 radians per second. The bending speed is given as

$$\mathbf{B} = \frac{\boldsymbol{Eh^3}}{\mathbf{12(1-\boldsymbol{\mu}^2)}}$$

Here I will use a different symbol for Poisson's ratio to not confuse it with the frequency. So, let us use this symbol here, this is for the Poisson's ratio.

So, here all these values are given, the Young's modulus is given to be 200 gigapascals. and Poisson's ratio is 0.3. So, 200 gigapascals into the thickness of the plate which is 5 centimeter converted into SI units it becomes 0.05 whole cube divided by 12 into 1 minus 0.3 whole square. If you solve this entire thing hopefully you should get this answer. okay as the bending stiffness in the SI unit.

$$\mathbf{B = 2.2894 * 10^6}$$

So, let us find out what is the C_b for these conditions. So, C_b at 200 Hertz let us find out it is given as you put all these variables in this equation $\boldsymbol{\rho_s}$ is given to be 400 in the SI units. So, on solving what you get is the answer is probably this one,

$$\mathbf{C_b = 308.33\ m/s}$$

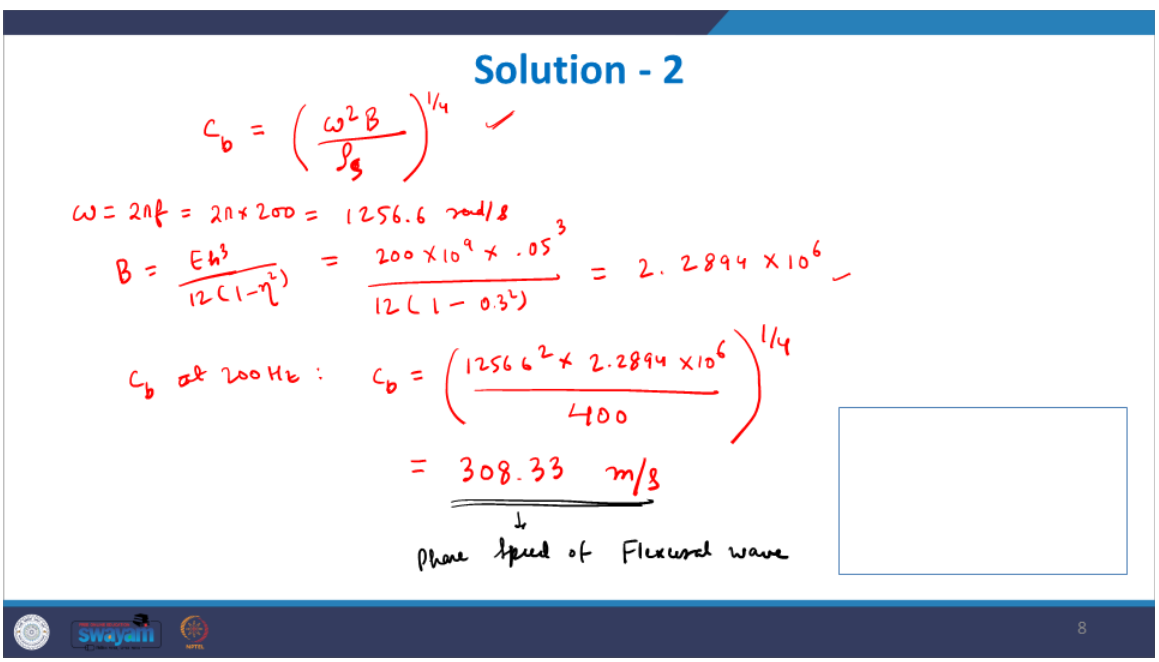
its speed it is in meters per second. So, that is what was asked, what is the speed of the flexural wave. This is the speed of the or the phase speed of the flexural wave that is generated in the flat plate under the given conditions. Now, will this plate radiate sound under the given conditions? So, what is the phase speed here? 308 and considering that the plate is surrounded by the air medium at room temperature which is you know the most common medium So, if nothing is given we say that the plate is in surrounded by air.

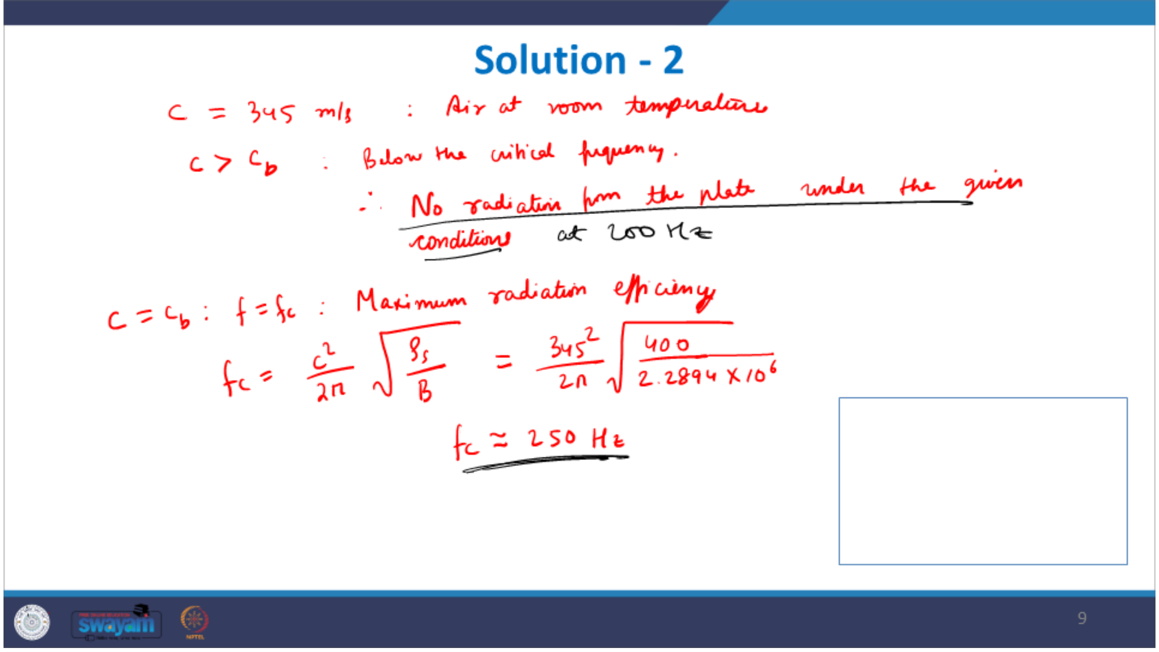
So, here for the medium the C is 345 meters per second for air at room temperature. So, this is the condition where C is greater than Cb okay. So, when C is greater than C_b what is happening? So, C_b has still not reached the critical frequency range. So, this is below the critical frequency.

This corresponds to below the critical frequency regime. Therefore, no radiation from the plate under these conditions. Now let us see what frequency will get maximum radiation efficiency. Well, you know that whenever C becomes equals to C_b or f becomes equals to the critical frequency at that region we get maximum radiation efficiency. for this particular plate you know fc is by this formula

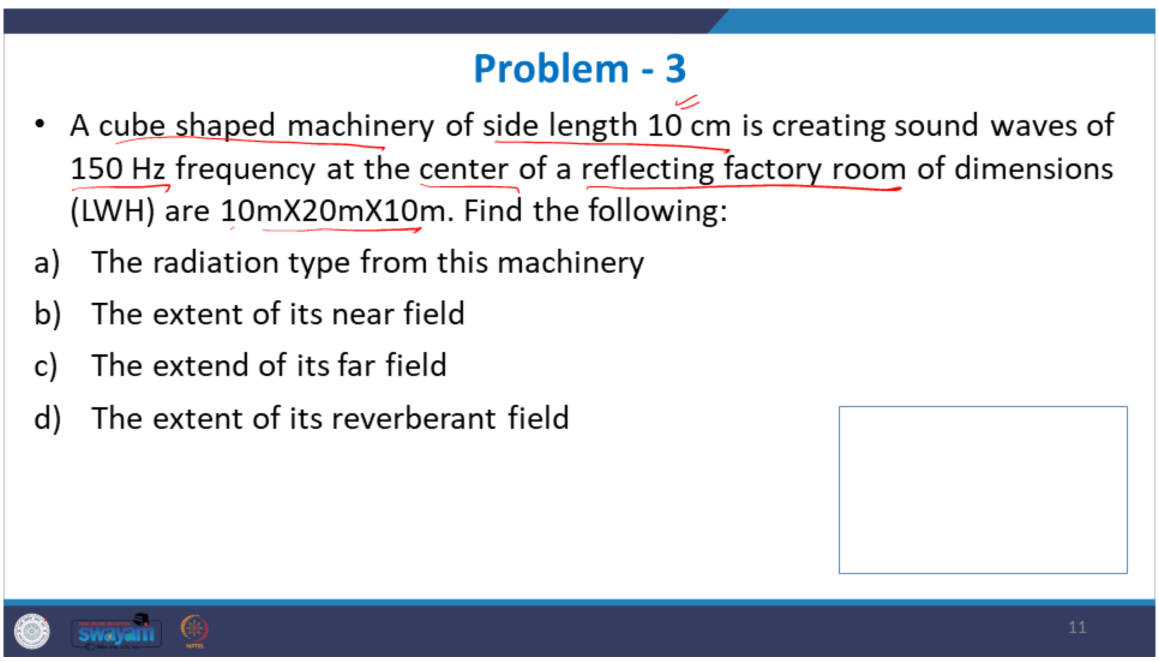
$$\mathbf{f = f_c = \frac{c^2}{2\pi}\sqrt{\frac{\rho_s}{B}}}$$

if you solve f_c comes out to be. So, let us put and find out this is 345 whole square by 2 π So, once you solve all of that hopefully what you should get is approximately 250 Hz, 250.4 Hz to be exact. So, here when the frequency is 250 Hz then you will reach the maximum radiation and as you can see you can cross check that initially the given condition was 200 Hz which was below the critical frequency and hence there was no radiation. at 200 Hz. Okay?





Fine. So, let us solve the problem 3. Now, here what we have is that we have a cube shaped machinery. Okay? We have got a cube shaped machinery. Side length is 10 cm. So, the dimensions are 10 cm. Create sound waves at 150 Hz at the center of a reflecting factory room. of dimensions given by 10 by 20 by 10 meters. Find the following, first of all what should be the radiation type from this machinery and then you find out what is the extent of the near field, the far field and the reverberant field in this machinery.

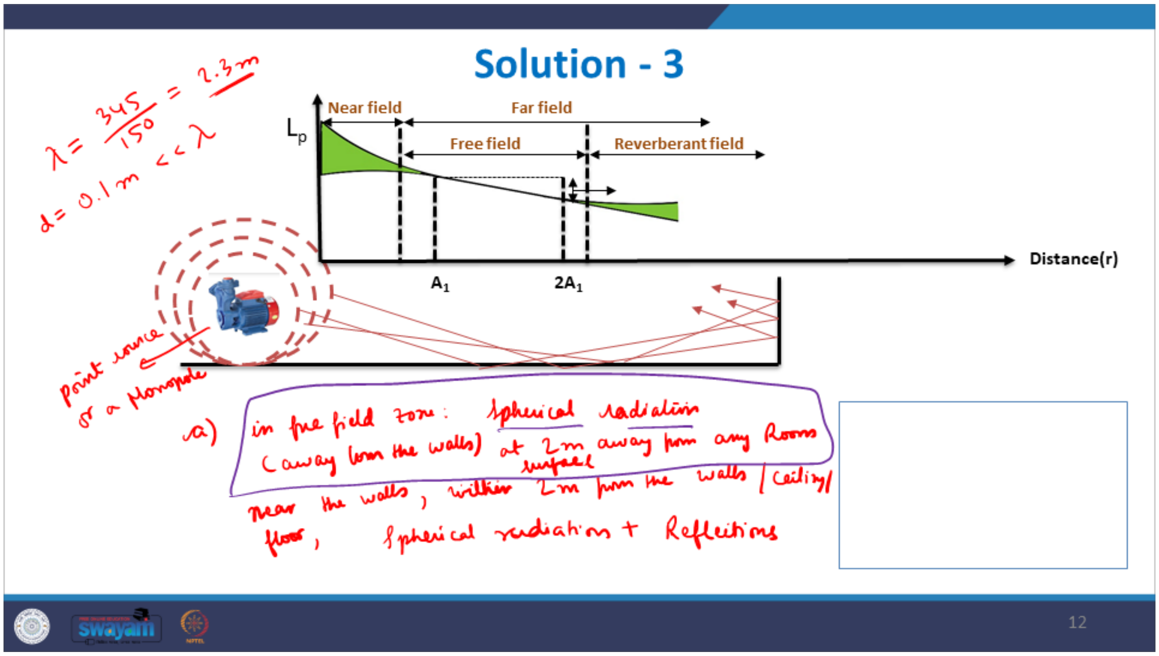


So, over here this represents very much our case which we have studied in the previous lecture. That is the case you have certain machinery which is placed somewhere in the center of the room and the room is pretty large compared to the dimensions of the machinery. So, the first thing is that this is 10 centimeters and the dimensions are where we are trying to measure are all in meters you know so much so these and the wavelength let us see what is the wavelength corresponding to 150 hertz so the wavelength.

$$\lambda = \frac{c}{f} = 2.3 \text{ m}$$

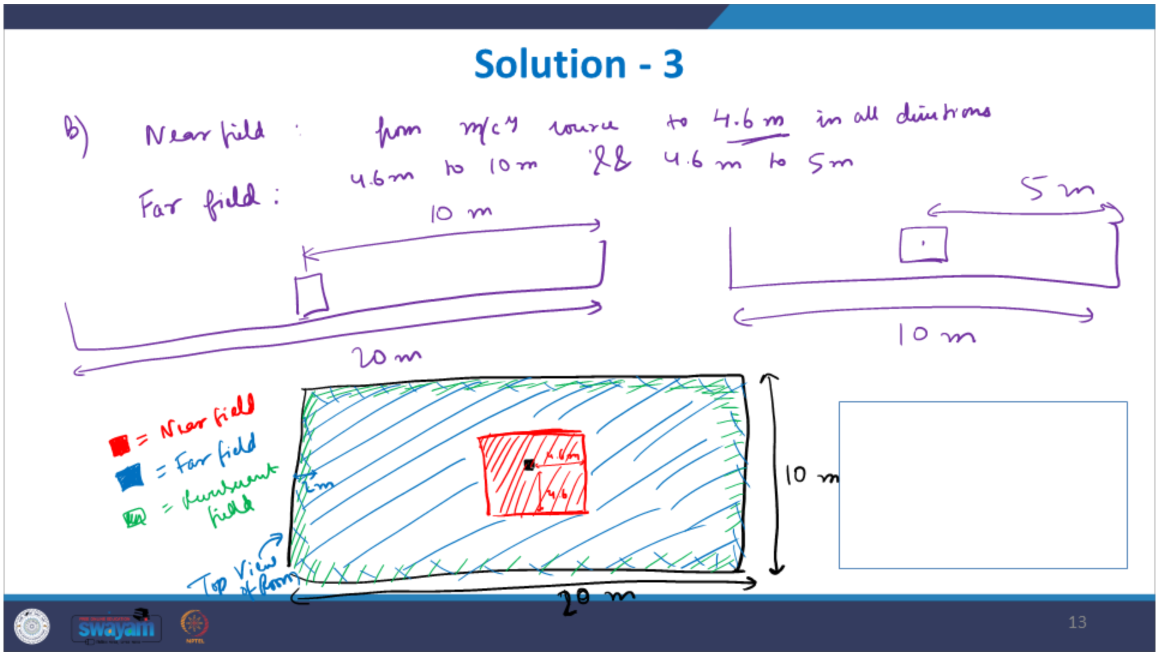
So, you see that the small d which is point, it is a 10 centimeters, so it would be 0.1 centimeters which is much smaller than λ.

So, the source behaves as a point source or a monopole. okay So, the source is behaving as a monopole. So, in the free field, it should be propagating spherical wave front. So, to answer what is the radiation type, we will say that in the large room in free field zone, we have spherical radiation and near field is always complicated. So, we do not deal with it. and then when it reaches in the free field spherical radiation. So, free field zone is when it is away from the walls, but near the walls. So, we will say that you know when the distance is roughly in the same magnitude as λ. So, near the walls, so roughly you know within the same magnitudes within 2 meters from the walls and ceiling and room, ceiling and floor all of them are reflectors. It becomes a reverberant so spherical radiation plus reflection. So again it becomes a complicated. field So, does not stay spherical near the walls. So, we get a bit of a riverberant field or a diffuse field or otherwise when it is near, so when it is away from the walls, so at least 2 meters away from. any room surface in that condition, in this particular condition you get a spherical radiation.

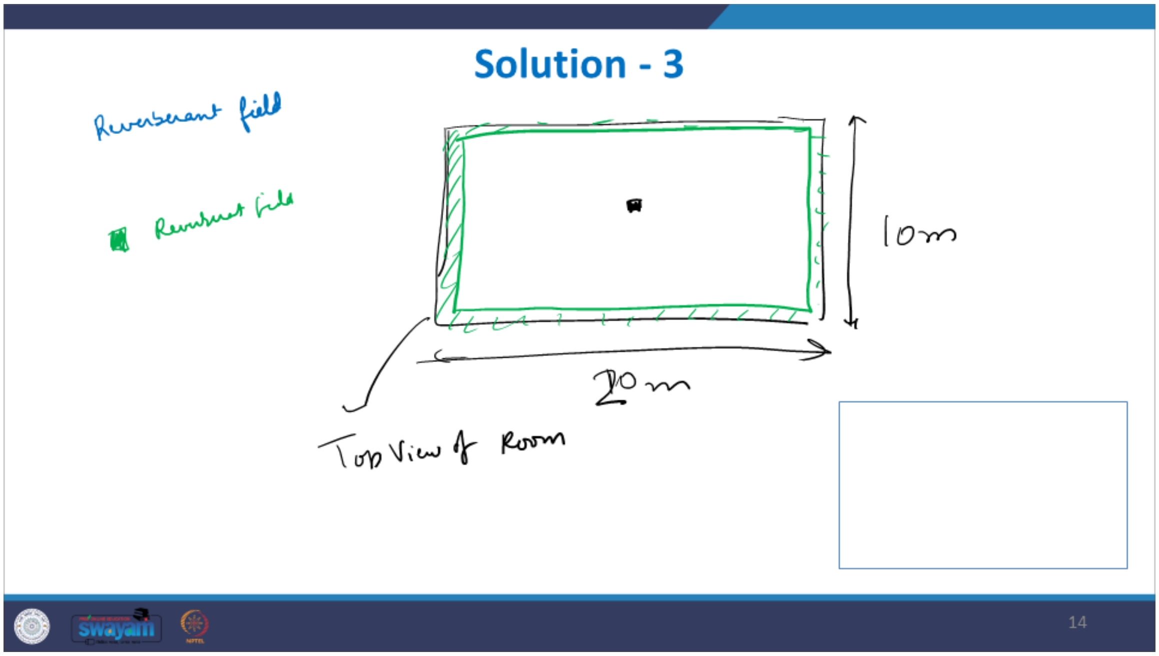


Now, let us see what is the extent of near field, the extent of far field and the reverberant field. So, near field would be from the machinery source that is there 2 up to up to let us say up to 2λ and the λ here is 2.3 meters. So, up to 4.6 meters in all directions ok. So, far field also includes a reverberant field by the way because it can have reflections and not reflections. So, it would be suppose this is your machinery here and let us consider the largest dimension which is given to be 20. So, here it is 20. So, this distance here is 10 meters. So, far field would be for largest dimension. from 4.6 meters to up to 10 meters till the room surface and for the smaller dimension which is 10 meters, it would be from and 4.6 meters to up to this would be 5 meters for the smaller dimension considering the machinery is placed at the center. So, up to 5 meters very small. So, if you think of the room layout let us take a top view of the room and how does the near field and the far field zone look like. Suppose this is your machinery let me draw a better layout 10 by 20 layout. This is your 10 meters, this is your 20 meters, this is your 10 meters. Let us draw the zone for near and far field. Let me indicate the near field. This is the legend.

So, near field with red and the far field with blue. and this is the top view. This is the top view of the room and how does it look like? We have the machinery here. So, somewhere in the centre we have this machinery. Okay, Now, what is happening is let us draw the near field and the far field. So, up to 4.6 roughly. So, let us draw a radius square 4.6 meters everywhere. so that becomes a near field and then we have the far field



Okay and what is the extent of the reverberant field field close to the walls so in that same room if i draw again that layout. this is the top view or layout of the room ok. So, and this is the small machine resource, then it should be roughly in the orders of magnitude of lambda away from all the surfaces. So, roughly 2 meters from everywhere ok. So, all of these are approximate dimensions ok. So, we will represent it using the green color, let us use a different color for this reverberant So, the reason why I am drawing the reverberant field separately is because the reverberant and the far field they are overlap. So, to make it more clear this is your reverberant field I can also show it here. so here it is both far field and reverberant field far field as well okay and this dimension here is 2 meters and so on ok.



So, with this you know we just solved some numerical problems on this topic and I would like to close this lecture. So, thank you for listening.