NOISE CONTROL IN MECHANICAL SYSTEMS

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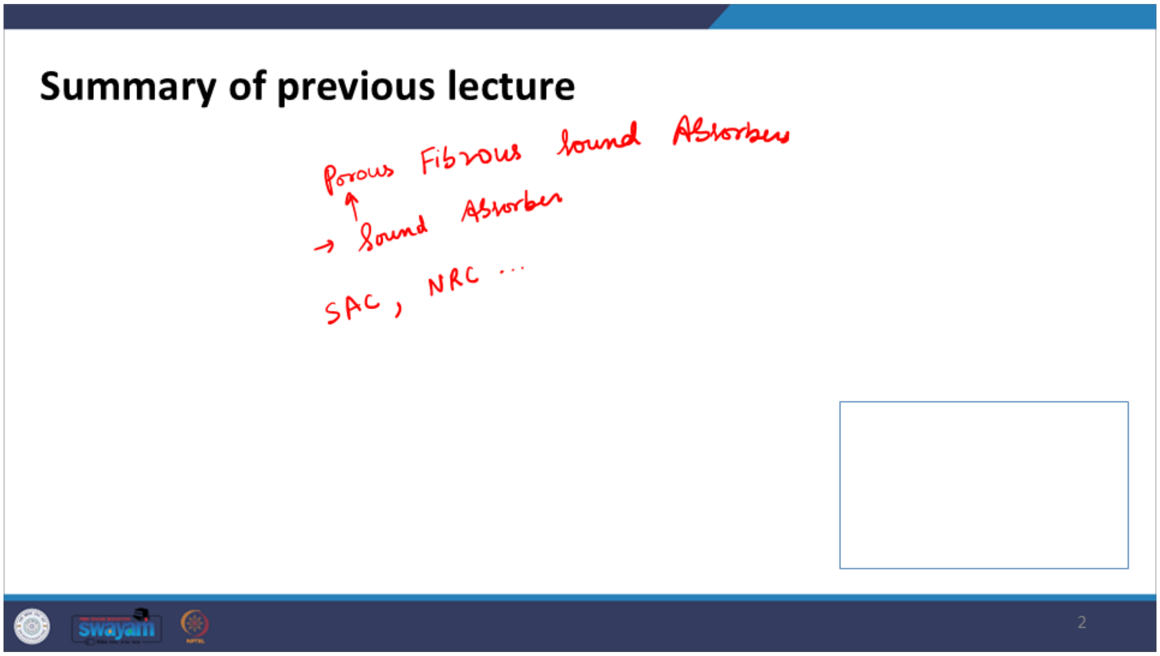
Week: 8

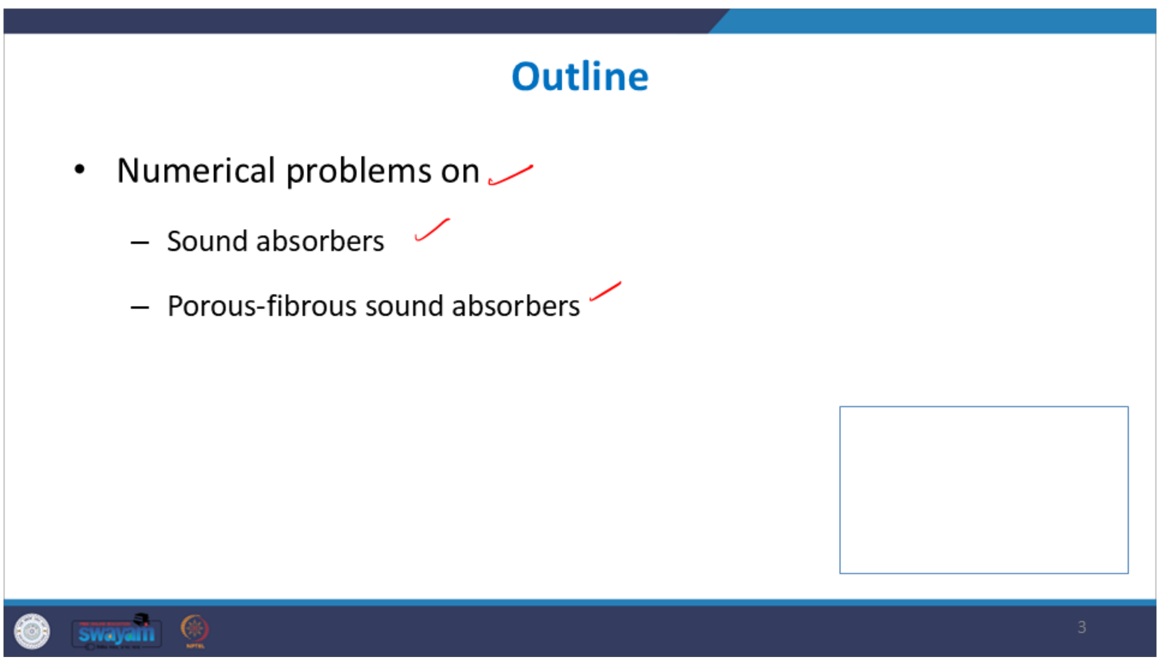
Lecture: 38

Lecture 38: Sound absorbers: Numerical

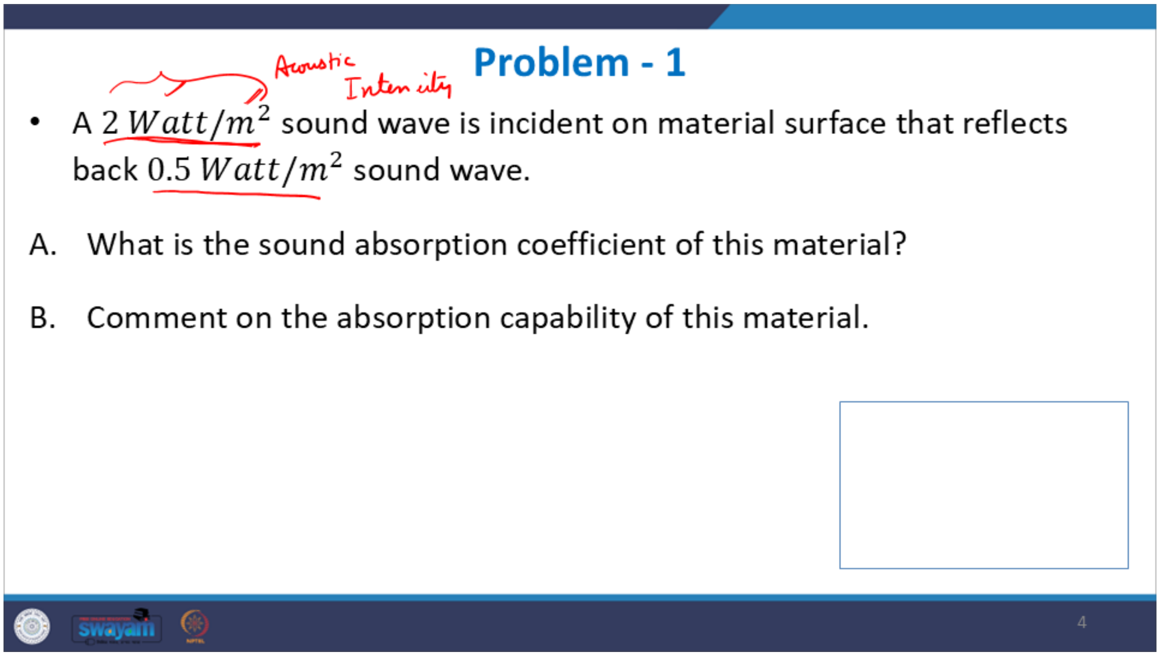
Hello and welcome to this lecture series on noise control in mechanical systems with me Professor Sneha Singh from IIT Roorkee and we have been discussing so far in our you know module on passive noise control we have discussed about the things such as you know absorbers and barriers and then in that we have discussed about you know porous, fibrous, sound absorbers and in general you know sound absorbers in general we have begin our discussion on you know and this is one type of them and what do you mean what are the performance measures such as sound absorption coefficient, noise reduction coefficient and so on.



So, let us solve a few mathematical problems based on the concepts learned. Ok, So, we will solve some mathematical problems based on the concepts of sound absorbers and porous fibrous sound absorbers.

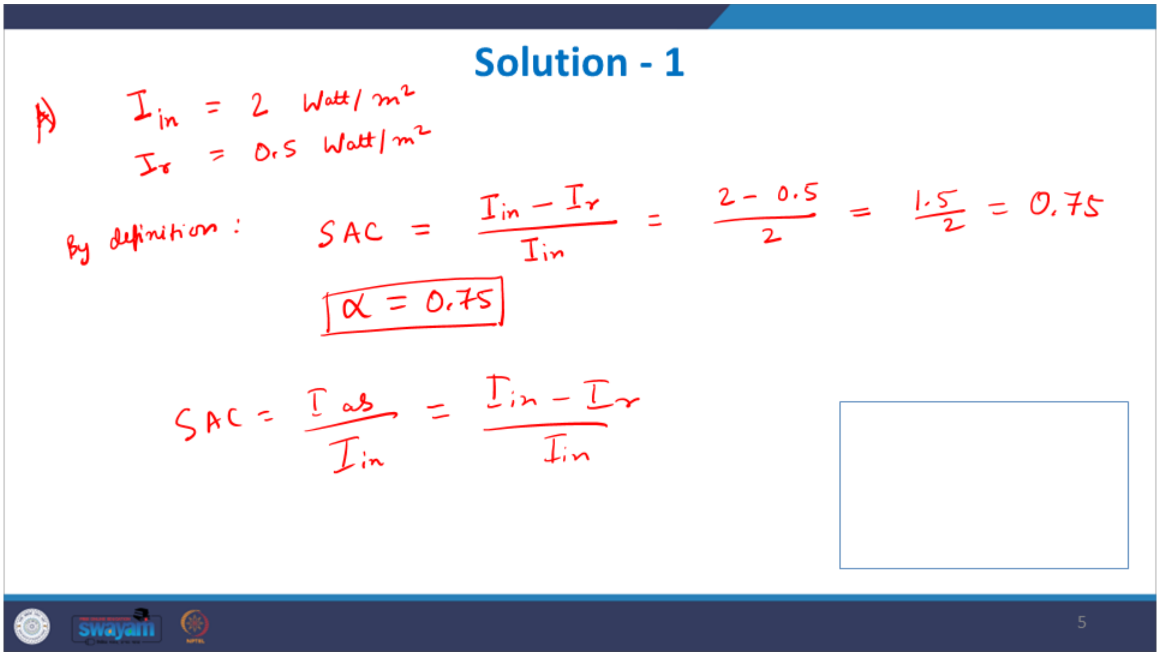


So, the very first problem you know a 2 watt per meter square sound wave is incident on a material surface that reflects back 0.5 watts per meter square of the sound wave. We have to find out what is the sound absorption coefficient of this material surface and also comment on the absorption capability of that material. So, as you can see here you know



it is not mentioned in whether it is the pressure intensity or energy, but from the unit itself you can guess ok watt is the unit for power and this is per meter square. So, this is the unit of intensity it is you know energy per unit time per you know per unit area. So, this becomes your acoustic intensity yeah or sound intensity.

So, that is given to us let us solve the two parts one by one. So, it is given that the intensity of the incident wave is 2 watts per meter square and out of that 2 watts that are being incident 0.5 watt per meter square is getting reflected back. Now, by the definition itself you know a sound absorption coefficient of the material is given by what is the intensity that is absorbed and you know that whatever is incident and whatever that is not

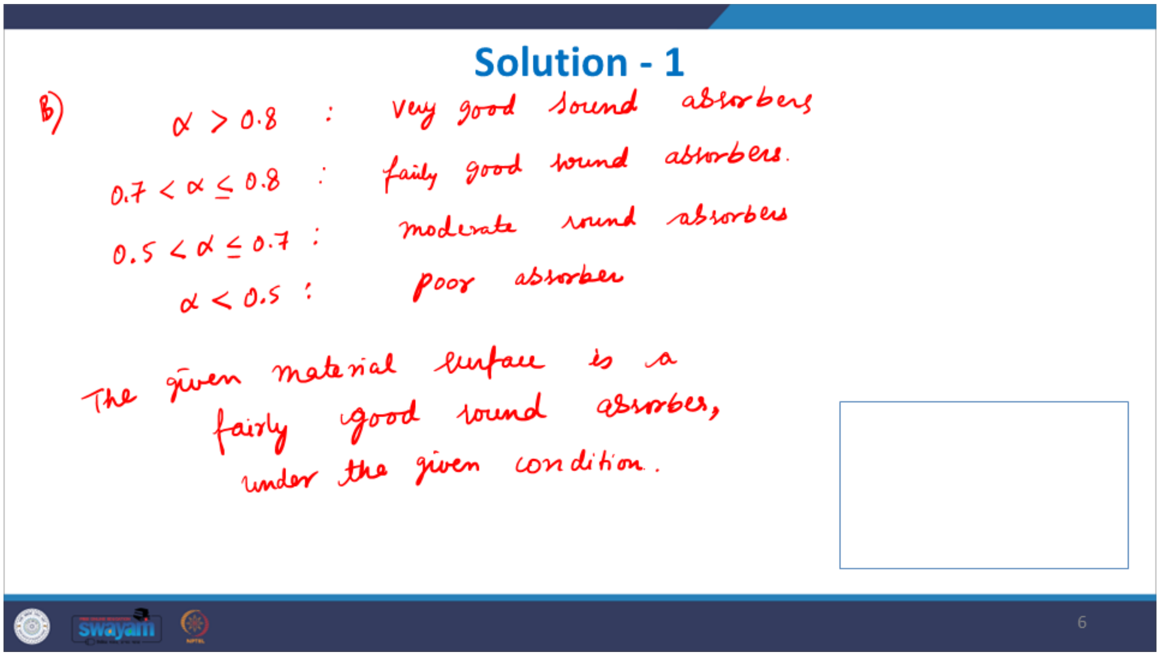


reflected back it is getting absorbed okay so either it gets reflected back or it enters into the material which means it gets absorbed so I absorbed is simply I incident by Ir divided by I incident. So, the fraction of energy that is getting absorbed is the fraction of energy or intensity that is being lost in the process of reflection. So, simply if we do that you will get the answer. So, let us solve this. So, the answer here is

$$SAC = \frac{I_{in} - I_r}{I_{in}}$$

So, here the alpha or the absorption coefficient for this particular material surface is 0.75. So, that solves the very first problem. Now, we have to comment on the absorption capability of this material.

So, typically you know in the noise control engineering the way we you know go about is that you know if alpha is you know greater than 0.8 we consider it as a very good absorber. These are again these you know these are not very hard and fast kind of border lines, but just a generic you know practice by the noise control engineers.

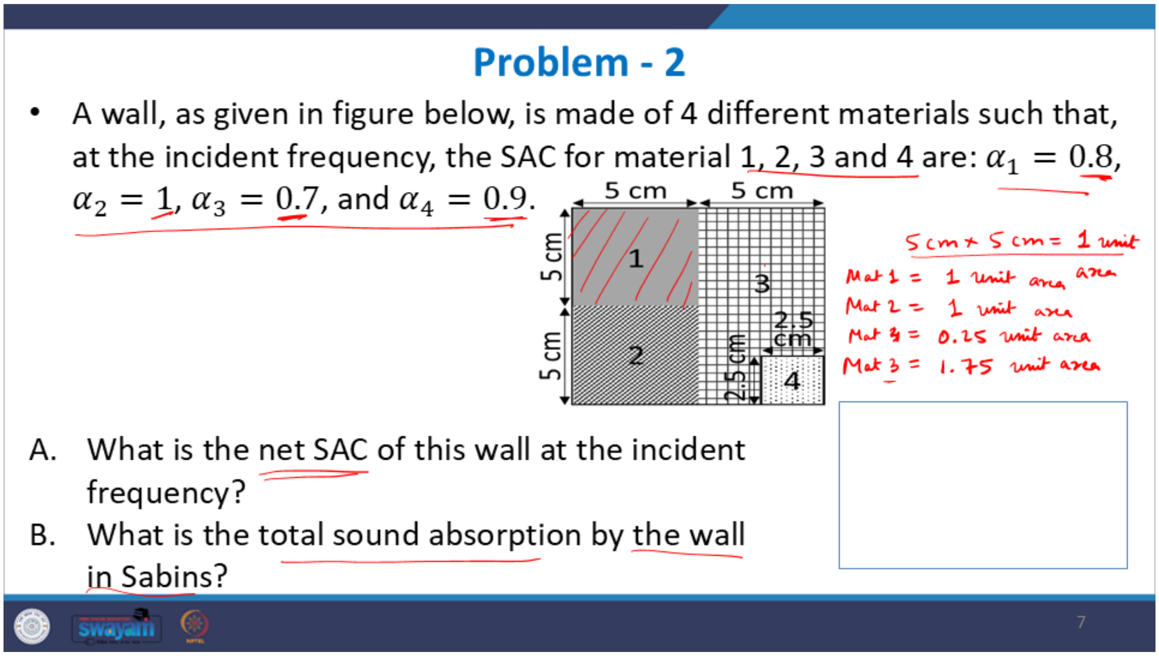


So, this is a very good sound absorber and roughly you can say between you know 0.7 to about 0.8 you can say that it is you know moderately good or fairly good you know fairly good. good sound absorber, then usually from 0.5 which means half of the energy is getting absorbed at least till 0.7, you can say it is you know a moderate sound absorber. So, it is somewhere between reflector and absorber, it is a moderate absorber. and below that obviously you know whenever alpha is smaller than 0.5 you can say that you know typically it is a very poor absorber it starts behaving as a reflector. So, here as you can see we have found our alpha as 0.75.

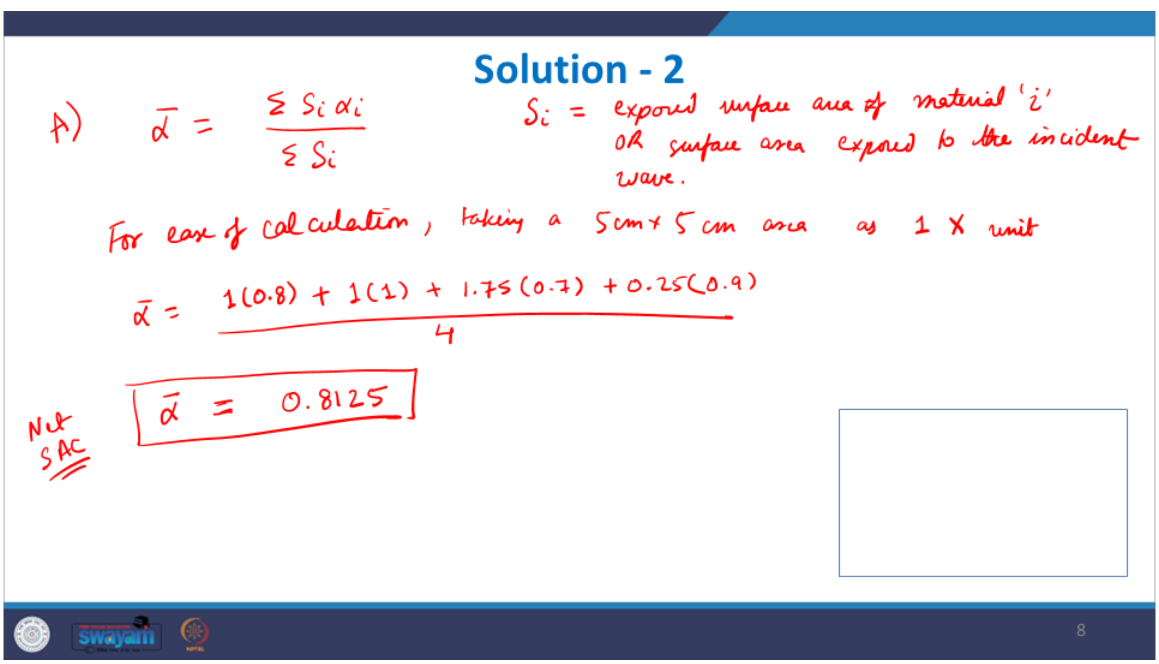
So, we can deduce that you know the given material, the given material surface. It is a fairly good sound absorber under the current given conditions, of course, because again, alpha will depend on your frequency and various other factors. So, it is a fairly good absorber under the given conditions. So, this was a slightly easy mathematical problem, very straightforward. If you know what the sound absorption coefficient is, you can solve any problem related to that, you know.

So, for example, here, if instead of this, what is SAC? It is I absorbed by I incident, which is then written as I incident minus Ir by I incident. So, if you know what you mean by SAC, you can relatively solve any kind of easy problems related to it. Okay, let us see problem 2.

So, what we have here is that we have a wall which is given. It is made up of, you know, not a single material, but it's combined with a lot of materials placed together to give a bigger wall. Each of these materials has a different sound absorption coefficient. So, this is a composite wall made of four different materials with four different exposed areas and having four different alpha values.



The net absorption coefficient, or the alpha bar for this wall, needs to be found at the given incident frequency, and also what would be the total sound absorption by this wall in Sabins. Let us start with the very first problem. Alpha bar, as we know, is what? If it is made of individual materials where each material has a particular alpha i and the surface



area of that material to which the incidence is happening, okay. So, here you have to remember that this Si is the exposed surface area, which is, you know, of the material i component, material i, which is, you know, the surface area.

Exposed to the incident wave, ok. So, suppose for example, we had a material some material component or any material of, let us say, 2 square meters, but then we, you know, covered it with tape. So, we had a material of 2 square meters in area, but we covered it in some way, or the way we had placed it, we were only bombarding it with sound waves not in the entire 2 square meters, but rather just in 1 square meter of its area. Then the surface area would be 1 square meter. So, this is not just the surface area of the material; it is actually the exposed surface area, i.e., the surface area that is available for absorption.

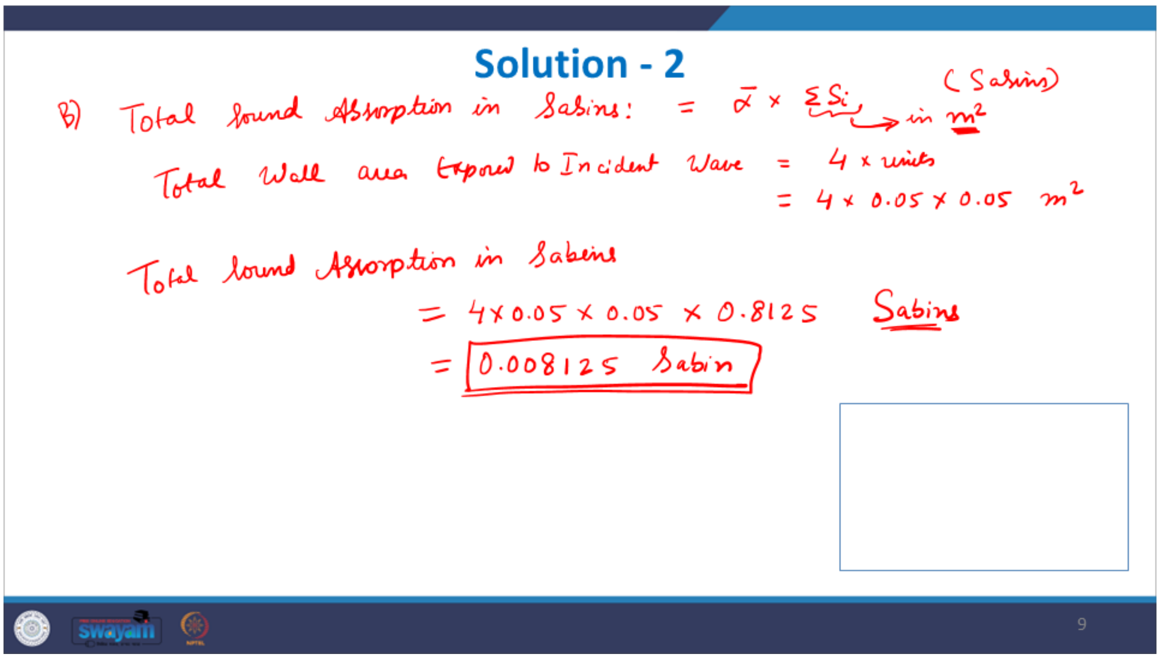
The surface area over which the incidence is happening. Even if you have a material of 5 square meters, but you expose only 1 meter or let us say you expose only 2 square meters of that material to the incident sound waves then the surface area would not be taken as 5 square meters, but the 2 square meters over which the sound waves are being incident. So, here we are assuming that the sound waves are bombarding the entire wall. So, this becomes your alpha bar. It is a weighted sum of the fraction of the surface areas each component applies, multiplied by their absorption coefficient.

So, let us quickly, you know, see. So, you know, here, if suppose here it is 5 centimeters by 5 centimeters. Why not we take, you know, just for ease of calculation, let us take this area. Over here as 1 unit. So, why not we take 5 centimeters by 5 centimeters as simply a 1-unit area, just for ease of calculation?

Then what you would see is that material 1, the area becomes 1 unit area, same as material 2, where the area is 1 unit area. This is just for our ease of calculation; you can do it otherwise also. Here, material 4, if you see, is one-fourth of the area of material 1 and 2. So, you can say it is 0.25 unit area, whatever you have assumed, where this is your unit, and material 3 is double of, you know, the material area of material 1 minus the material 4.

So, it is 2 minus 0.25. So, it is 1.75 unit area. So, let us use this and solve it because, anyways, the surface areas are going to get cancelled in the numerator and denominator. So, with that as an assumption, taking a 5-centimeter cross 5-centimeter area as 1 x unit, let us say.

Then what we will have is alpha bar would be given by 1 times 0.8, which is for the first material (alpha is 0.8), for the second it is 1, third it is 0.7, and then we have 0.9. So, respectively, that particular area of the material—so here it is 0.1, 0.75 for material 3, and alpha 3 is 0.7—and similarly, it is 0.25 as the area for material 4, and the alpha is 0.9, divided by the total area, which is, you know, obviously 1 plus 1 plus 1 plus 1, which is 4 units. If you solve this, this is the answer you are going to get, okay? So, this becomes your net SAC of the wall, okay? So, this was asked. Now, you have to find out what is the total sound absorption by the wall in Sabins, okay?

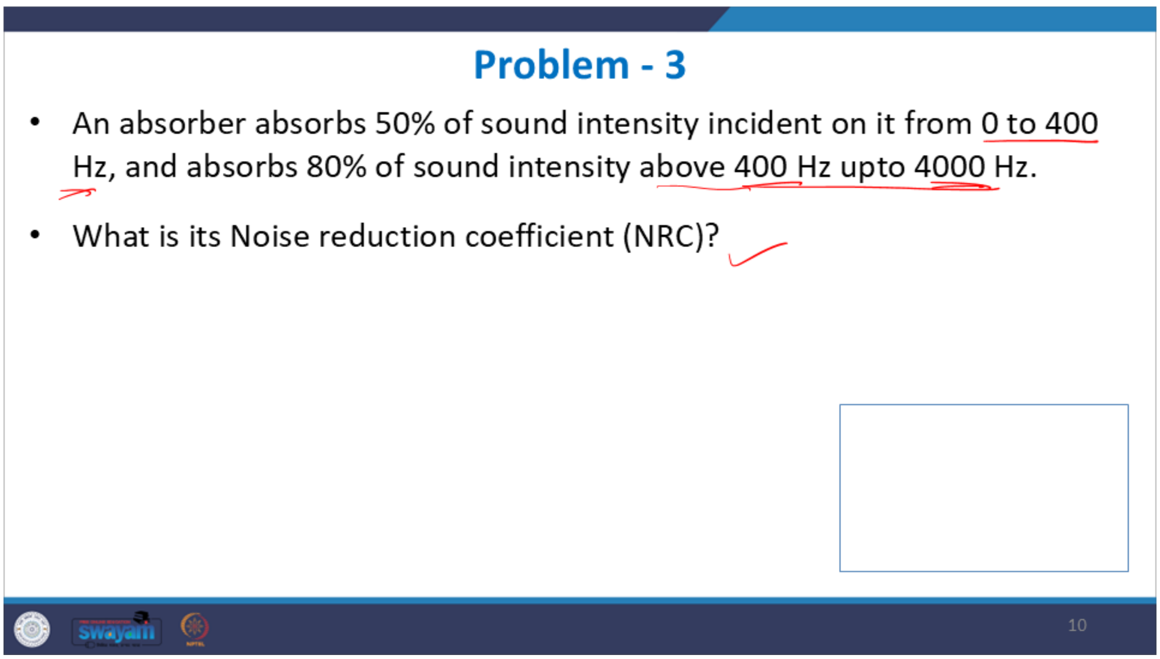


So, obviously, you know that the total sound absorption in Sabins is simply because absorption is a per-unit-area property. If you multiply that per-unit-area absorption or SAC with the total exposed area, you would get the total absorption.

So, the total absorption of the wall would be alpha bar multiplied by the sum of the whole areas of the entire wall. Ok, so, what you would get here is if you see what the total area of the wall is. So, the total wall area that is exposed to the incident wave, ok, is 4 units, and each unit is 5 centimeters by 5 centimeters.

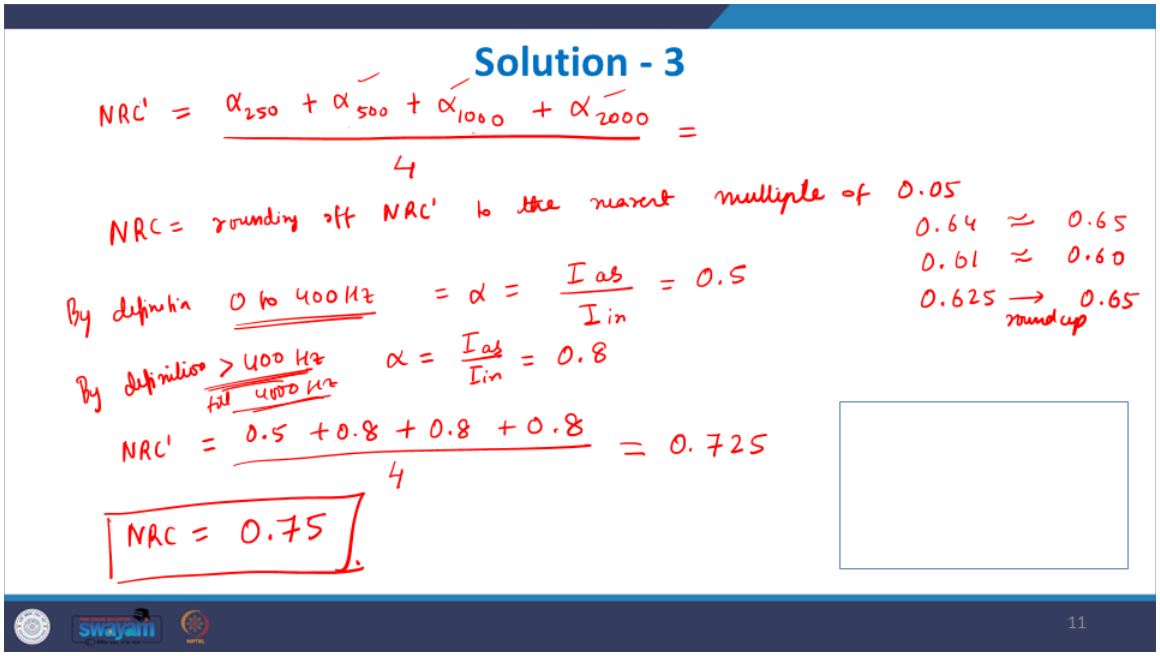
So, in SI units, because Sabin is for SI units where this is in meter square only, then you will get it is in Sabins, ok. So, the surface area we take it in SI unit meter square. So, I have found the total surface area. So, the total sound absorption in Sabins is given by the total surface area, which is this, multiplied by the average absorption for this whole area, which is 0.8125, and this would be in the units of Sabins, okay. So, if you do this math, what you will find is that this is your total surface area.

This is what you will find; this becomes your total absorption in Sabins. So, always remember, ok, that for total absorption in Sabins, you have to find the net absorption coefficient for that entire material surface that is multiplied by the total area which is being exposed to the incident wave in meter square, okay. Always remember to use meter square as the unit so that you can get the answer in Sabins. And always remember that it doesn't matter how big a wall is; the area that you take should be the exposed area. So, if suppose a wall is 10 meter square and only 5 meter square of it is being bombarded with incident waves, you will take the area as 5 meter square, okay. So, let's go to another problem.



So, here what we have is we have an absorber which is absorbing 50 percent of the sound intensity which is being incident on it in the range of 0 to 500 hertz. So, here, as you know, that absorption capability is frequency dependent. So, in the lower frequency range of 0 to 400, it is absorbing 50 percent of the sound intensity, and then from the range above 400 to 4000, above that, it is absorbing 80 percent of the sound intensity which is incident on it.

Now, the noise reduction coefficient needs to be found. So, here you know that the noise reduction coefficient is what you first find out. The arithmetic average of the absorption at 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz. Whatever value you get, the actual NRC



would be the rounding of the arithmetic average that you have found to the nearest multiple of 0.05, okay? In case the nearest multiple could either be a step below or a step above, you will take the larger value. So, you will round up, okay? You will take whatever is the nearest multiple of 0.05, which means that if it is something like 0.64, it will go up to 0.65.

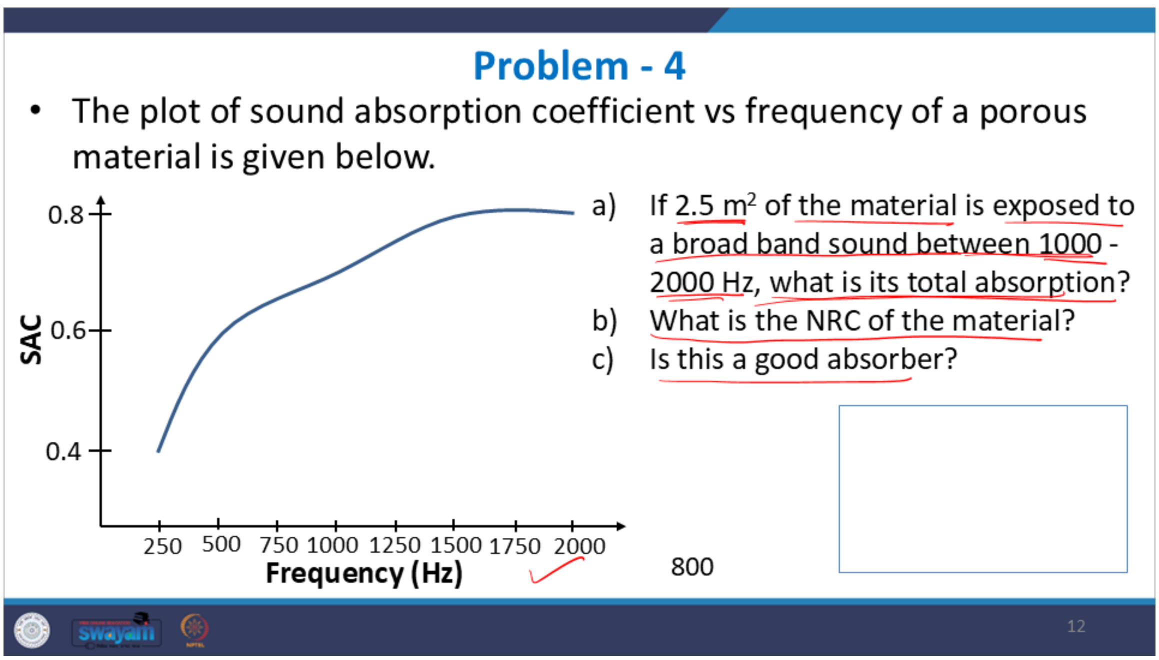
If it is 0.61, it will go down to 0.60. But if it is something like 0.625, it can go either way—0.60 or 0.65—because it is exactly at the midpoint of the two multiples of 0.05. So, in that case, you will round up. to 0.65. So, like that, you calculate it.

So, let us see here what we observe: in the range of 0 to 400 Hertz, 50 percent of the sound intensity that is incident is getting absorbed. So, by definition itself, from 0 to 400 Hertz, alpha is whatever is the intensity that is being absorbed. The fraction of the intensity being absorbed compared to the incident wave, and it already states straightforwardly that 50% of whatever is incident is getting absorbed. So, the fraction value would be 0.5. So, the intensity of the absorbed wave would be half of the intensity of the incident wave.

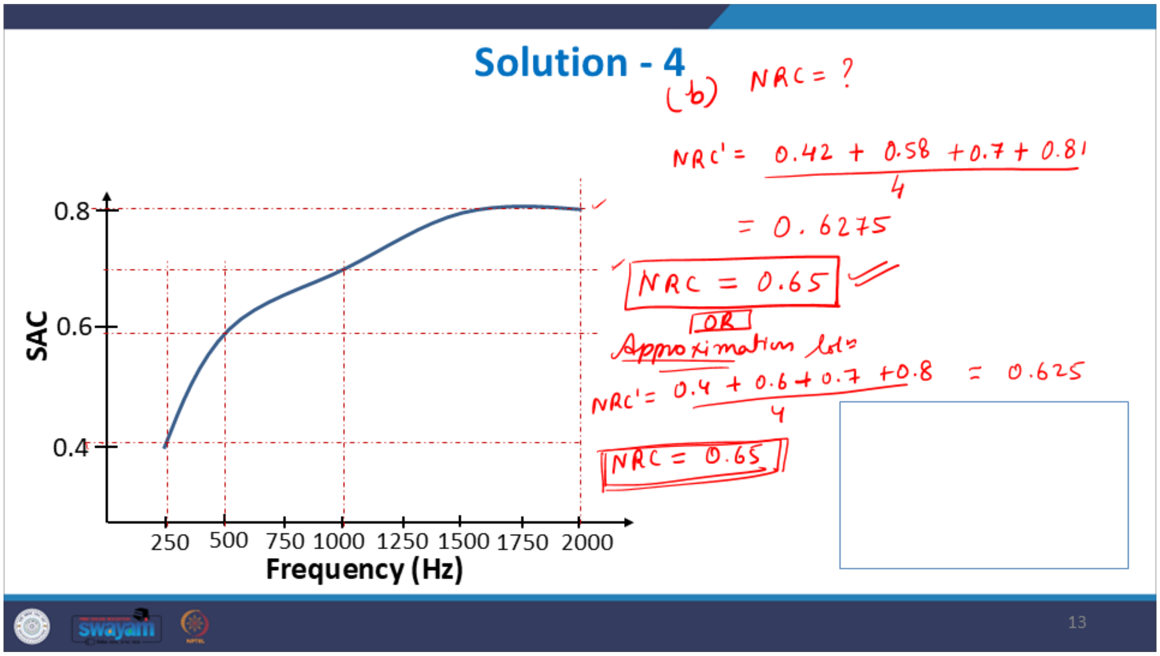
So, alpha is 0.5 for this range and, similarly, by definition. For greater than 400 Hertz, the alpha value is again 80 percent. The intensity of the absorbed wave is 80 percent of the intensity of the incident wave. So, the fractional value is 0.8, okay—80 by 100, which is 0.8. So, because alpha is not written in percentage, but rather in fraction. Not written in percentage but rather in fractions, you convert the 50 percent into a fraction, which is 0.5, and the 80 percent into a fraction, which is 0.8.

Now, you simply find this out: what is the arithmetic average? You will see that alpha at 250 would be 0.5, and alpha at 500 would now be in this range—it would be 0.8. Alpha at 1000 would also be 0.8 because, above 400 till 4000, it is like that—you know, in this range, it is always 0.8. So, all the other values—this, this, and this—would be 0.8, and you take the arithmetic average, okay? So, once you take the average, the value that you get is— Now, you see that this is somewhere midway—you know, the nearest multiple could be 0.70 or 0.75.

So, you will round up, okay. So, the NRC here would be the nearest 0.05 multiple, which is 0.75. Okay. This gives us the NRC of the material, which we had to find. Let us see the last problem for this particular lecture. You know, here, a graph has been given to you.



It is a graph of the sound absorption coefficient versus frequency for a porous material, and it is given that a 2.5-meter square of that material surface is being exposed to a broadband sound between 1000 to 2000 Hertz. You have to find out what its total absorption would be. You also have to find out what the NRC of the material is and then comment on whether it is a good absorber or not. Okay, so let us start and see. Okay, so over here, let us solve part B first, as it is a little more straightforward. So, we'll start with the solution for part B, where we have to find out the NRC. And you know that for NRC,



we need to find out the average of 250, 500, 1000, and 2000 Hertz alpha and then round it up to the nearest multiple of 0.05. So, let us see what these values are.

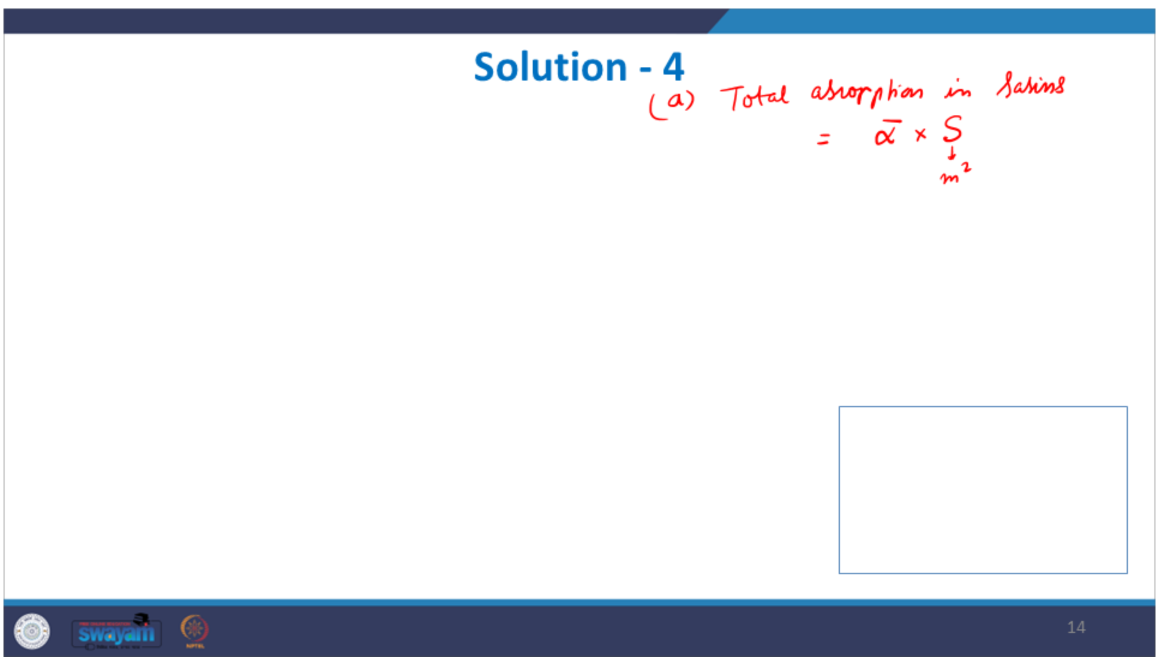
So, at 250, you know you have roughly above 0.4—you have got approximately 0.42 if you go by the divisions. If you solve these problems, you need to get a grasp of reading graphs, okay? So, you need to get a grasp of, you know— a grasp you need to have. So, it is roughly 0.42, and here it is just that unit below it.

So, it is 0.58, and this is exactly in the midway at 1000 Hertz. So, this is 0.7, and here it is just above half of this particular unit. So, it is 0.81. So, you can say first you can find this value— So, alpha at 250 is 0.42, then alpha at 500 is just below one big division below 0.6, which is a big subdivision.

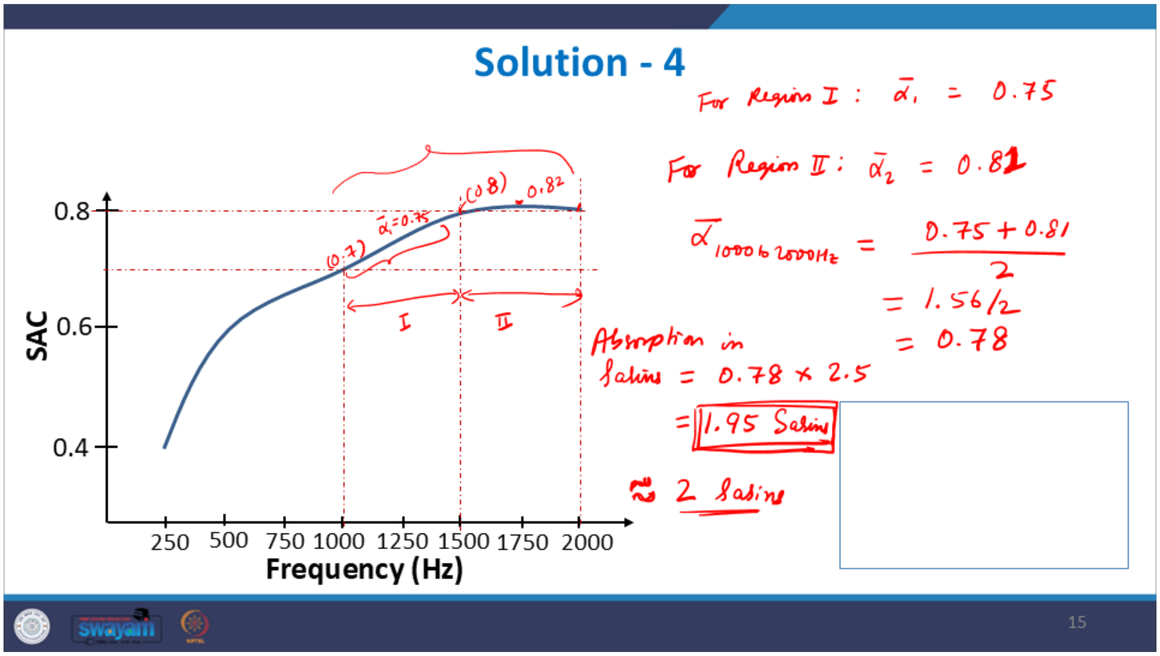
So, which is 0.58 and 1000 it is 0.7, and then at 2000 it is one small subdivision ahead of 0.8, which is 0.81 by 4. If you solve this, this is the answer you should get. Then NRC would be the nearest multiple of this, which would be 0.65. Now, if you look here, you know

even if you were not, this is the actual answer, but even if you did not read the graph properly or you said, 'Why not approximate?' because anyway, you have to do the multiple of 0.05, and if you had just gone by an approximation—okay, this is an alternate solution an approximate solution—then you would just have said, 'Why not find out first? It is closer to 0.4 plus closer to 0.6 plus closer to 0.7 plus closer to 0.8 by 4, okay.' And if you had solved it again, you would have gotten the value, which is approximately 0.625, and then the nearest multiple, you would still have gotten the same answer, but it is slightly risky. You have to have an engineering mind that, okay, if it's just a little bit above or below, I can take that approximation or not. Okay, now let us see the answer for part a, which is if 2.5 square meters of this material is exposed to broadband sound, which means a sound of the same intensity between 1000 to 2000 hertz, what will be the total absorption? So for that, what we can do is find out what the average absorption is between 1000 to 2000 hertz and then simply multiply it by the total exposed area. Okay, so you know that absorption in Sabins—the total

absorption in Sabins—is simply, for the given condition or the given material, whatever is the alpha bar multiplied by the total exposed area in square meters, that will give you the answer in Sabins.



So, let us see the same graph. Here, between 1000 to 2000, that is where the sound wave is being incident, and you have to find out the absorption for this condition, which means the exposure is only within this range, okay. Between 1000 to 2000 hertz is where our incident wave is coming and hitting, and in this range, what would be the overall absorption? So, you can make an approximation here.



so what you see is that between 1000 to 1500 it is approximately like a linear line starting from 0.7 here and ending here somewhere at 0.8 so for this zone 1 from here to here the alpha bar for the alpha 1 bar here would be 0.75 okay so if this is your zone 1 this is your zone 2 for region 1 the alpha bar is coming out to be because it seems like an approximately a linear line starting from 0.7 and ending at 0.8 we can say that it is roughly 0.75 okay and for region 2 You know if you go by this so the alpha 2 you can say that it starts from 0.8 ends at 0.8 it looks like a small kind of a parabola it is hitting its maximum somewhere around 0.82. So you can take that the midpoint of this which is 0.81 should be roughly your alpha bar for that region.

So, over from between here to here the average absorption is 0.75 and from this region to this region your average absorption ok is 0.81 actually it reaches from 0.8 to 0.82. So, it should be half of that should be your average absorption. So, 0.81. So, overall you know the net absorption between 1000 to 2000 hertz is what it is again you take the average of the two regions because they are equidistant in frequency you can directly take the midpoint of that if you do so what you end up with is you know so roughly 0.78 ok so over here you know

0.78 is what is your alpha bar. So, your absorption in Sebins that you have to find would be 0.78 multiplied by the total surface area which is 2.5 meters square. If you do that, you end up with this value 1.95 Sebins. And if you were doing some approximation, it is approximately 2 Sebins. Okay.

So, any answer is fine here. Okay. So, in this way, you can solve various problems related to absorption and porous fibrous absorbers. I would like to close this lecture with this note. Thank you for listening.