Noise Management & Its Control
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Lecture - 56
Reverberation Time

Hello. Welcome again to Noise Control and its Management. Today is the second day of this week and what we plan to do today is introduce you to the concept of reverb time, because in a lot of cases this particular parameter reverb time, if we manage it correctly it makes things in a room more pleasant and it also reduces the noise level in context of speech intelligibility.

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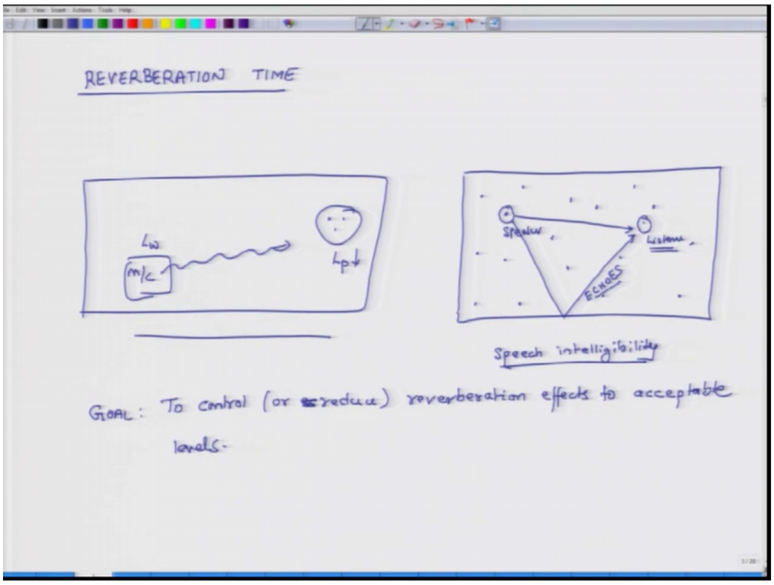

So, what we will discuss today is reverb time or it is in brief it is known as reverb time or the actual word is reverberation time; now we have been discussing about noise control in the context that suppose, you have a room and suppose there is a machine and it is generating noise and there is a person here and we are interested in reducing the noise level here, let say L p and the sound power level is L w. So, we want to ensure that this L p goes down that is the context which has been so far. I mean that has been the context that when we try to reduce noises, we are trying to reduce noise from some external source machine or something and because of that we want to reduce the noise level.

But there is another context in which we want to reduce noise and we will look at that and it is in that context this reverb time becomes important. So, suppose we have a very large room and there are lots of people in this room and there may be lots of people or even 1 individual. So, we it does it really does not matter, but essentially when a person speaks and there is another listener, so this is a speaker and there is a listener.

Some sound goes to the listener directly and then he also hears a lot of echoes or sound reflections. Now especially if the room is very large then he will he also he and if the room is very large and the walls of the room and the floor and the ceiling of the room are highly reflecting surfaces, then he will hear a lot of echoes and as a consequence this listener will not be able to clearly understand what the speaker is speaking. So, this is the problem known as speech intelligibility.

Here the speech of the speaker is not intelligible to that to the listener. So, we have a speech intelligibility problem and the reason for that as I mentioned earlier is because of the presence of a lot of echoes. So, whenever the speaker listens, he listens to the direct sound a little earlier and then while he is listening to the next word or the next letter echoes of the earlier letters also come and then he becomes confused as to what he is listening.

So, we have to ensure that the role played by echoes in such rooms is less because, these echoes are also creating are like noise. So, the first problem we will address is this type of a problem, where we have the problem of speech intelligibility and in this case we have our goal will be to reduce, actually to control and in lot of cases it is to actually reduce reverberation. So, these echo effects are also known as reverberation effects. So, that is why I will say so reverberation effects to acceptable levels. So, the goal is to reduce these reverberation effects to acceptable levels.

So, this is also a noise control problem, because whenever we do not we are hearing some sound, which is not desired that is noise. So, here these echoes are behaving as noise. So, this problem is fundamentally different from the problem which we have been discussing, but maybe later this week tomorrow onwards we will come back to this other problem which we have been discussing. So, this is the problem we are going to address, we have to control or reduce the effects of reverberations to acceptable level because if these reverberation effects become less then the speaker, will hear more direct sound and as he or she hears more of direct sound and the ratio of echoes to direct sound is less, he will be able to clearly understand what is being said and we encounter such problems in large rooms such as very large classrooms, auditoriums, conference rooms, gyms and places like that. So, to control this affect there is a parameter known as reverb time.

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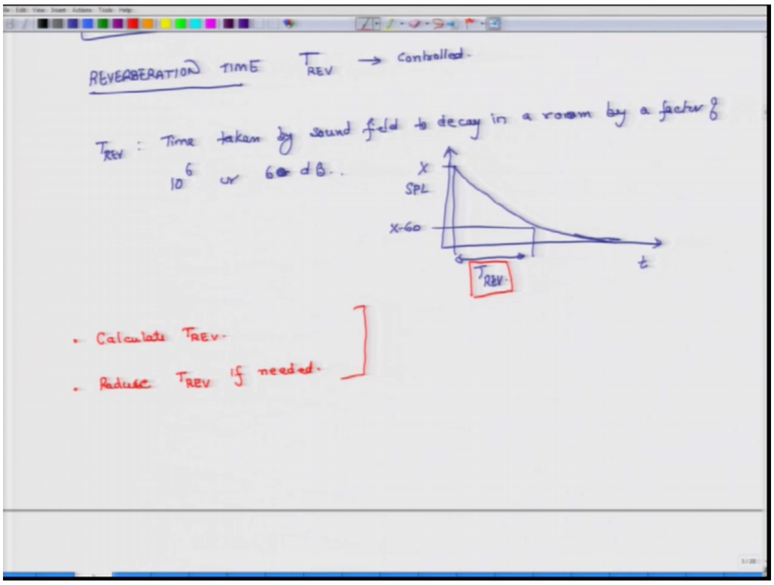

So, we will call it T REV this parameter has to be controlled, if this parameter so what does this parameter mean it means. So, T REV what is reverberation time we will first define it. It is time taken by sound field to decay, in a room by effect by a factor of 10 to the power of 6 or 60 decibels. So, what does this mean suppose I am in a very large room and I say hey and then I do not say anything. So, there is absolute silence after that, but in the room my sound will go and hit the walls and it will keep on bumping in the room and as it hits the walls, a little bit of it gets absorbed and then the remaining gets reflected.

So, after the first reflection sound level in the room comes down a little bit, then the same sound goes and hits another wall and then sound level again comes down a little bit further. So, the sound pressure level in the room after I just speak just 1 single word or 1 impulse and if I look at time and if I look at spl, the sound pressure level it goes down something like this because each time it the sound gets reflected, a little bit of it gets absorbed, but still it does not become 0.

So, it will take theoretically infinite amount of time for all the sound to die out, even though no new sound is being produced. So the time, so suppose this is x decibels and this is x minus 60 decibels, then this is the time it takes for the sound pressure level in the room to drop down by 60 decibels so this is called T rev. If the value of this T REV is very large what does it mean, that the walls are highly reflecting and they are not absorbing a lot of sound and because of that you have a long duration over which you keep on hearing echoes at stronger levels and if you are hearing echoes and reverberation at the stronger levels, then you will have this speech intelligibility problem.

So, our goal will be to somehow calculate T REV and then if we want we should be able to reduce the value of T REV to an acceptable level. So, that is what we are going to learn today. So, what we are going to learn is calculate T rev, so this is the first goal and the second thing is reduce T REV if needed and this is the first noise management problem we are going to address T REV and I am going to.

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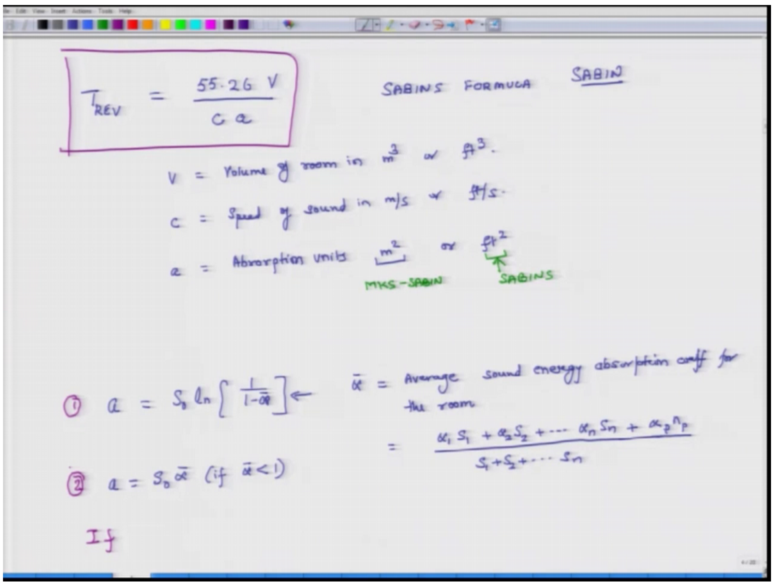

So, there is a person by the name of Sabin and in late 19 century, he actually developed the relation for reverberation time using a lot of statistics and empirical methods and of course, basics of acoustics or mix of these and based on his work this is the relation he came up with. So, it is 55.26 times v divided by c times a and so this is known as Sabin formula.

Here v is the volume of room in cubic metres or you can use cubic feet use 1 of these, c is the speed of sound in meters per second or feet per second and a is known as absorption units and we will not discuss too much about what this means, but this is kind of the internal surface area, but it also takes into account absorption coefficient and all those things. So, this is known as absorption units and here the units are either metre square or feet square and I will give you a relation for a.

In a lot of literature you will find that instead of metre square they call the absorption units, the unit of absorption unit they call as MKS sabins, in honour of Mr. Sabin and instead of feet square they just call it Sabin. So, dimensionally it is metre square or feet square, but in honour of the person Sabin they either call it Mk sabins or Sabins. So, you should be aware that this terminology is being used, now what is a?

So, a is equal to S naught times natural log of 1 over 1 minus alpha bar, where alpha bar is, what it is the average sound energy absorption coefficient for the room. And we have discussed this earlier and this was we. If you remember, if a room has n surfaces then it is alpha 1 absorption coefficient of the first surface times it is area plus alpha 2 times area alpha n times area of nth surface divided by total surfaces, sum of total surfaces. And then if there are also people sitting in the room then, they have their own surface absorption coefficient sound absorption coefficient.

So, let is call this alpha p and if there are p people then p times, if there are n people so it is alpha p times n p. So, this is something we have also covered earlier; now this is the general relation for a and but Mr. Sabin he made this a little simpler, so what he said is that he will not use log of 1 over 1 minus alpha, especially if alpha is small. So in that case if you do the mathematics, you will find out that a is equal to S naught times alpha bar.

This natural log of 1 over 1 minus alpha bar approximates to alpha bar, if alpha bar is small compared to 1. So, if the relation for T REV is this and it depends whether you want to use relation number 1 to compute a or relation number 2 to compute a.

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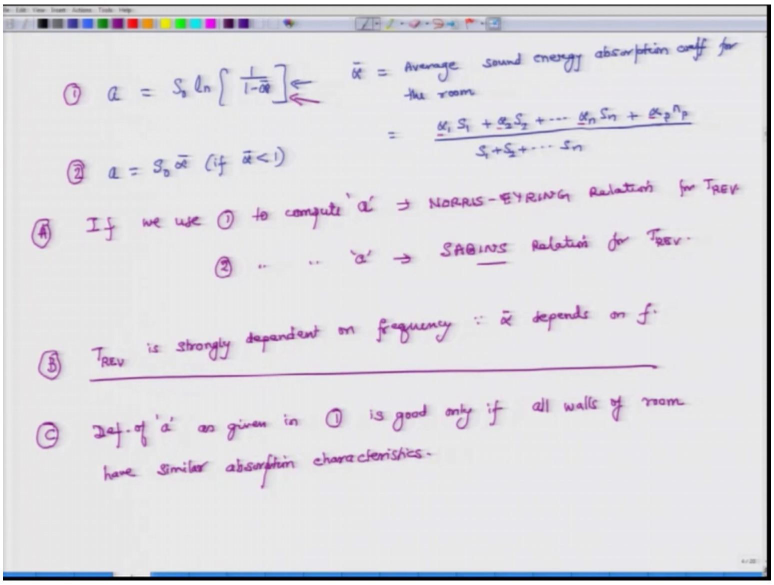

If you use 1 to compute a, then we say that we are using a different formula Norris, we are using NORRIS EYRING relation for computing T REV and if we use 2 to compute absorption units, then we say that we are using sabins relation.

The relation is the same, but the definition of a changes definition. So, initially people lot of people used to use this sabins relation, where they approximated log of natural log of 1 over 1 minus alpha bar, is alpha bar especially when computers were not much in vogue in early 19 early 20 century and things like that, but now there is no good reason why we cannot use a more accurate expression for computing a.

So, whatever calculations we will do today, we will use this Norris Eyring approach for computing reverberation time, now please remember that these alphas change with frequency; how much of an energy is absorbed by a material it depends on which frequency is hitting it. So, reverberation time this important to remember T REV is strongly dependent on frequency, because alpha power depends on frequency. So, if you are computing the reverberation time you should always remember that, you are computing it for a particular frequency.

So, this is the second thing, so these are some of the important comments. So, this is comment number 1, comment number 2 and then I will make a third comment and this is also very important, this definition of absorption units as given in 1 is good; only if all walls of room have similar absorption characteristics, what does that mean? What that means, is that suppose you have a room.

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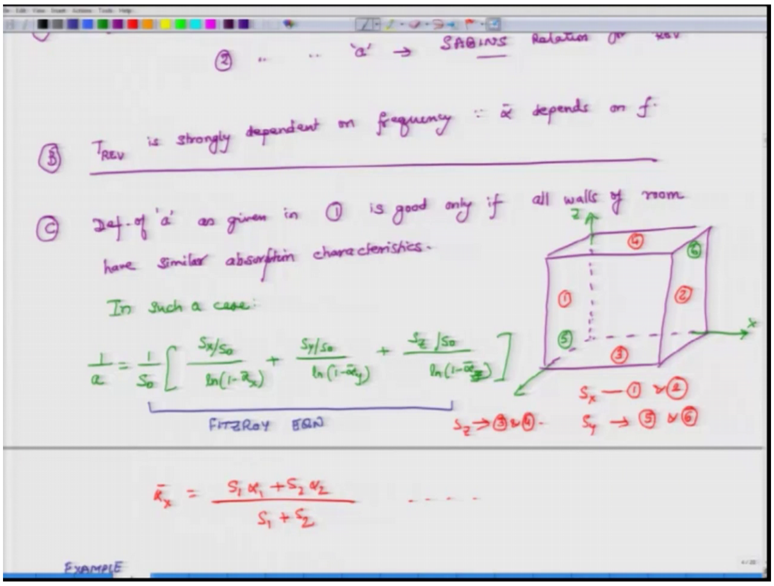

So, I will explain that suppose you have a room, so this particular room has 6 surfaces 1 and 2 are opposite each other, 3 and 4 are opposite each other and then I have 5 and 6 they are opposite each other. Now you can choose the materials of this room, in such a way that for instance your floor could be having carpet and the ceiling could be false ceiling and these all other walls could be made up of and the 4 walls, which is 1 2 and 5 and 6 they could be made up of some regular wall.

So, what will happen your floor is of ceiling of carpet and your roof or the ceiling is made up of it is a false ceiling and typically carpets are very good sound absorbers and similarly false ceilings are also very good sound absorbers. So, when the sound hits the floor or the ceiling a lot of it gets absorbed, but when it hits the walls it does not get observed that much. So, this condition that all walls of the room have similar absorption characters is not necessarily true in such a situation, ok.

Because your ceiling and the floor is absorbing a lot of sound, but the walls are not absorbing a lot of sound. So, they do not have similar they do not have to be exactly the same, but they do not have similar absorption characteristics. If that is the situation then you cannot have you cannot use this relation equation 1 to compute a. So, if that is then you cannot use equation 1, so in such a case what do we do we compute the value of a through a modified different relation.

What is this relation 1 over a equals 1 over S naught divided by multiplied by S x divided by S naught times S naught in 1 minus alpha bar x plus S y divided by S naught over actually excuse me; I should not have S naught here because I have already have it outside so this is log of 1 minus alpha bar z and what are the meanings of S x S y s, suppose you have a room and let is put a coordinate system here x y z, then S x is the total surface area in the x direction. So, that will be for you can compute S x by 1 and 2.

What will be the value for S y you can compute S y by computing. So, y is that directions 5 and 6 and S z can be calculated by accounting for z is the vertical direction. So, surface area for 3 and 4, similarly what is alpha x bar or alpha bar x you have to compute alpha bar by using this relation, but here you only include surfaces 1 and 2. So, what is alpha x bar it is equal to S 1 alpha 1 plus S 2 alpha 2 divided by S 1 plus S 2 and so and so far.

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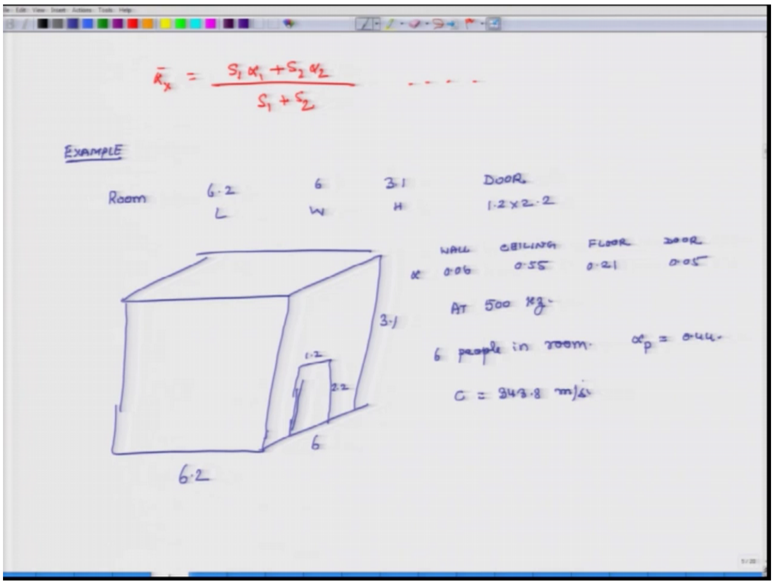

So let is quickly do an example, let say we have a room and the room is 6.2 meters long it is 6 metres wide and it is 3.1 meters tall high and so the room is like this. So, length is 6 meters, 6.2 width is 6 height is 3.1, then there is a door and the door is in this side and what are the dimensions of the door is 1.2 times 2.2.

So, this is 2.2 and the width is 1.2 meters and what we will also specify is the alphas for all these surfaces. So, alpha for all these excuse me. So, we are going to make a small table alpha for walls ceiling floor and door. So, door is made of wood and I will specify the values of walls are made up of some plaster and at 500 hertz the values are .06 ceiling is 0.55 floor is 0.21 and door is 0.05 and there are 6 people in the room. So, this is at 500 hertz and there also 6 people in the room ok and each person's alpha p is 0.44, so n p is 6 and we are given that c is equal to 343.8.

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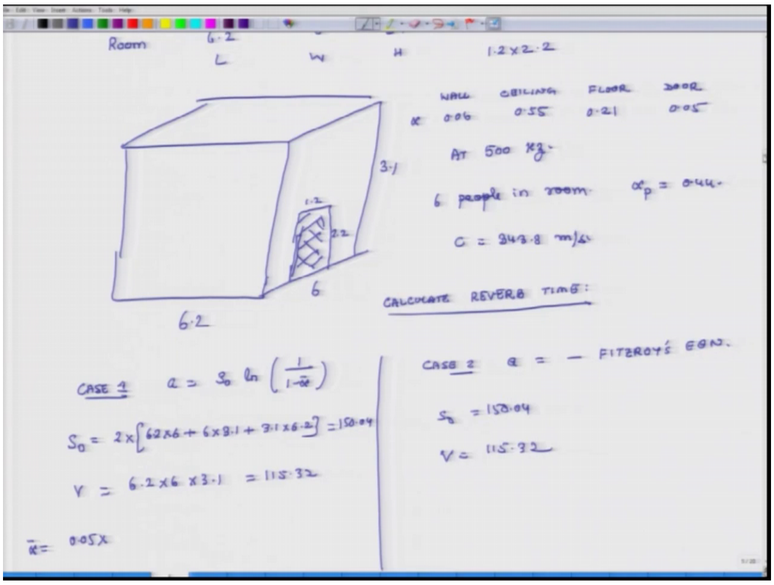

So, the question is that calculate reverb time for the room. So, we will calculate it using both methods, the first method is we will use actually this relation a is equal to S naught times natural lag of 1 over 1 minus alpha bar and the other method that a equals this complicate relation.

By the way this relation was given by a person known as Fitzroy. So, it is also known as Fitzroy equation. So, we will use Fitzroy equation to compute a in 1 case and the other equation, this equation 1 in the other case and using that then we will compute reverb time and see whether it makes a difference or not.

Remember this equation we have said to compute a will work only if all the walls and by walls I mean all the reflected surfaces. So, it should be more accurate is all reflecting surfaces of the room have similar absorption characteristics, look at this the ceiling and the floor have a very high alpha, but all the 4 walls including the door have .05

adsorption coefficient rights. So, this directly tells you that surfaces do not have similar absorption characteristics and we will see whether this makes a difference or not.

So, case 1 a is equal to S naught natural log of 1 over 1 minus alpha bar, this is the first one. So, first we will calculate a using this and then in the second case we will do a is equal to, we will use that Fitzroy equation. S naught you will find? So what is S naught it is the surface area internal surface area. So this is equal to, so these are the dimensions. So, 2 into 6 into plus 6 into 3.1 plus 3.1 into 6.2 this is the internal surface area of all the room. So, if you do all the math it comes to 73 and S naught is same here also ok.

What is the volume of the room volume is 6.2times 6 into 3.1 is equal to 115.32, now we compute alpha bar in this case. So, alpha bar is we have to look at every single area multiply that by it is absorption coefficient. So, oh I am sorry, this number is 150.04. So, here we do we consider the walls .04 times the surface area and then when we are computing the surface area, we have to reduce the surface of this door right because this is a separate surface which has a separate absorption coefficient.

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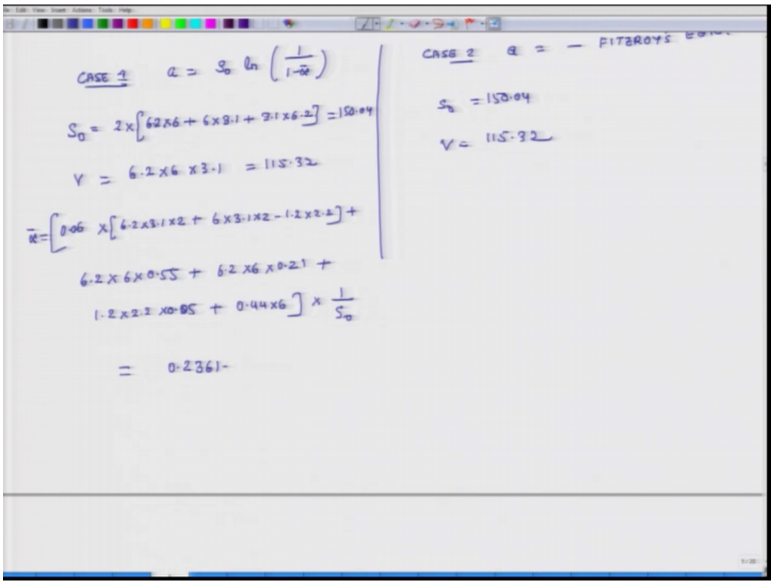

The walls have a surface area of .05 .06, but the door has of .05. So, it is .05into 6.2 times 3.1 into 2 plus 6 into 3.1 into 2 minus the area of the door, which is 1.1 times 2.2. So, this is for the walls plus, now I am just reducing the area of the walls ok.

So, this is the contribution of the walls plus the contribution of ceiling. So, that is 6.2 into 6 into and what is the thing for ceiling .55 plus the floor 6.2 times 6 into 0.21 right plus the contribution of door 1.2 into 2.2 into 0.05. So, divided by surface area and what is the surface area; excuse me I missed the contribution of people. So, times 0.44 into 6 and divided by surface area.

So, if you do all this math you get alpha to be 0.2361 and what we will do now is, we will do the competition for the other case also. So, but I think that time for today is over. And we will continue this discussion in the next class.

And in the next class we will actually compute both sides, in totality and see what kind of a difference it makes based on which kind of approach we use. So, that covers our discussion for today and then I look forward to seeing you tomorrow.

Thank you.