Fire Protection, Services and Maintenance Management of Building
B. Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture – 27
Numerical Problem on HVAC System

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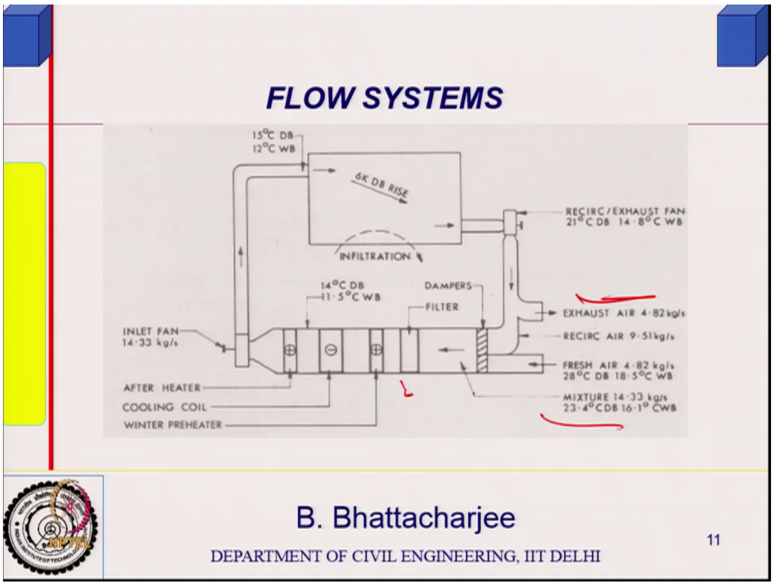

So, you know we are trying to look into an example problem for HVAC. So, this is our control space. And we said that part of the air is recirculated and mixed with fresh air. And fresh air how much fresh air we should be supply that is dependent by governed by hygienic ventilation. There is a minimamount of air flow fresh air flow you require that is governed by hygienic we are you know hygienic ventilation requirement.

So, if you look at this way, this is this is the exhaust, and all exhaust are collection of the recycle you know like already the air from room, and part of it would be recirculated, and rest all will be going out. So, here is the exhaust actually. So, this is a exhaust, this is recirculator, fresh air. So, given in this fresh air, then you have a damper; damper is essentially reduced on the velocity right so damper. Then there is a filter, filter would give the particulate system you know out that will not allow it to pass. And if you if the filter gets clogged in fact the fresh air you know we have combined mixed air supply tends to gets reduced obviously, so maintenance of this one is clean the filter from time to time

Then, you have got if you need a heating, then there is a preheater in case of winter, but in summer, this will not be you will be needing. Then there is a you know this these are cooling. So, cooling is through refrigeration as I said. This the you know evaporator will be here like which we discussed earlier, something like this if I if I recollect, if we just want to recollect from no sorry it is not here. But, we shall look into the cycle of refrigeration, and then cooling will be occurring you know this will be cooling, so cooling the coil would be here, where evaporation would take place, and it will cool this air here.

And then, you might need, you might cool it to a lower level in order to ensure some amount of condensation, because you want to control the amount of moisture content. Now, you want to reduce down the moisture content, then you have to go below the dew point, some moisture will condense, then you hit it back again, so that is the after heater. And then this fan directs this.

So, here the quantities are given. For example, in this one recirculated, it comes room temperature is 21 degree centigrade, and you know dry bulb temperature and 14.8 degree centigrade wet bulb temperature right. And here this is fresh air, outside is 28 degree centigrade, dry bulb temperature and 18.5 degree centigrade wet bulb temperature. Now, this difference governs the moisture content right of the air itself.

So, you mix them up. Depending upon the proportion you get you mix, it might be somewhere in between temperature. So, 28 and 21, depending upon the proportion of the mix you know the proportion of the fresh air and recirculated air. So, this is 28, this is 21 it means that you know already 21 plus 28, so proportion obviously you can see if it is coming to 23, it is linearly varying. So, proportion of the recirculated air here is more that is why it is close to the if it was 50-50, 50 percent of fresh, 50 percent of recirculated, then it would be 21 plus 28 divided by 2 right, it would been somewhere inside linearly varying. Since, more of the recirculated air we are using essentially fresh air is only, because it will make it you know cooling would be required will be more. So, therefore fresh air we would supply whatever is minimrequired to remove the carbon dioxide etcetera.

So, here 21 and 23 you can see that ratio correspondingly this is two difference, and this difference is 5. So, 2 is to 5 we know, you can see the mass flow rate would be. And then after that what is happening, this is cooling, and cooling to a temperature of cooling to a temperature of 14 degree centigrade with wet bulb temperature. Wet bulb temperature as shown, how much it is, one point 11.5 degree here five degree, so that is that is where it cools it. And then this fan, there will be some loss right there be some loss. So, its final rate would be stotal of this rate.

Now, if you look at it, the rate is also given, how much is the rate, because it is calculated and given we will do a calculation separately, this is as 14.33 kg per second mixture. But, before that, the fresh air you know the recirculated air was supplied at 9.51 kg per second, and fresh air is 4.82 kg per second you know, so 20 is to as I was saying 2 is to nearly 2 is to 5. And total stotal be the stotal of these two 9 plus 4 is 13 yes. So, it is adds up to fourteen point you know it is fourteen it is it is actually sorry ninefresh air is 4.3, and this is 9.51, stotal is making it 14.23, so 14.23. And if you see the moisture, of course wet bulb temperature does not give moisture content, directly you have go to psychrometric chart or use equation, so that is that is what normally the systems are.

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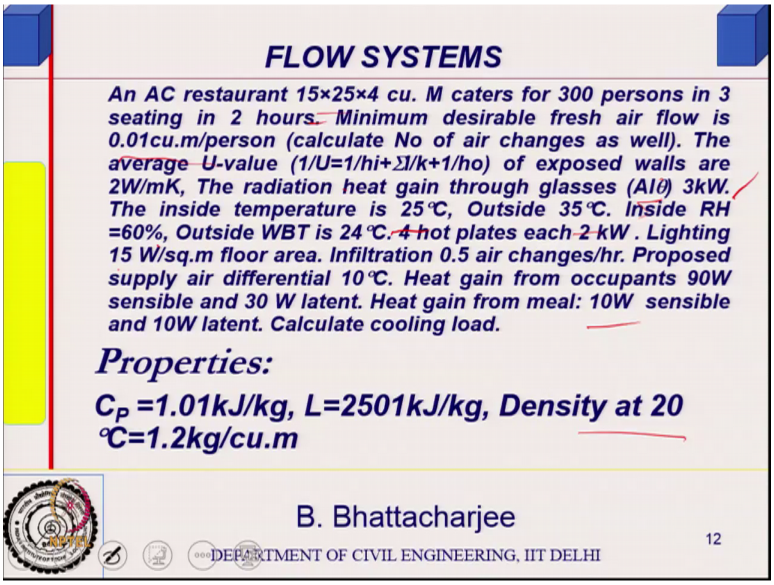

Let us look at an example problem. For example, (Refer Time: 06:23) AC restaurant of the size is given as 15 25 by 4 meter cube, and 300 persons in 3 seating in 2 hours. Well this is only to find out how many people are seating at a time right, 3 seating in 3 hour. Minimdesirable fresh air flow is 0.01 cubic meter per person right, because that is what is required to remove or some that much fresh air you must supply to remove carbon dioxide or for all hygienic requirement. So, you can calculate the number of air changes anyway, the average U-value of all the walls.

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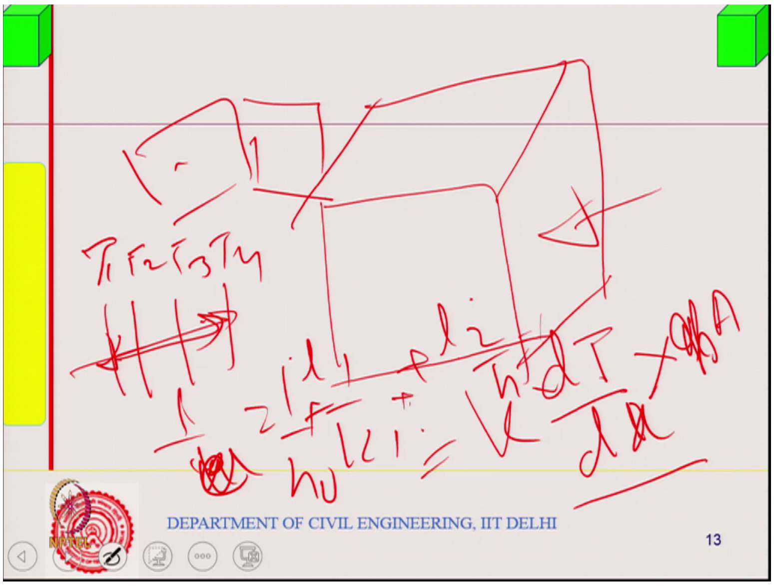

Now, you know the if when we have when we have walls, when we have walls roof etcetera, heat transfer takes place by conduction through this walls, and this is given in terms of you know if you if you if you if you remember what we discussed in terms of fire also. So, it is k thermal conductivity into temperature gradient multip[lied] dT dx let me call it multiplied by the thickness l or k or whatever it is q is equal to k into A; k you know q equals to k A dT dx sorry not l, there is no l multiplied by area, so that is the amount of heat will be, but then you have layered system.

So, when you have layered system, did I discussed this sometime earlier in this class maybe not. If you have a layered system, then under steady condition we assume the flow is same right, but temperature would be varying here T 1, T 2, T 3, T 4 etcetera. And if parallel if two walls are there, one wall, another wall, and they are subjected to same temperature difference, then heat will be stotal of the head heat flow like series and parallel model. So, under this condition, you can define equivalent, we call it conductance of all the layers. And the formula is given as 1 by u is equals to l 1 by k 1 by sorry 1 by conductance I am saying so far, l 1 plus k 1 plus l 2 plus k 2, where l 1, l 2 etcetera are the thickness of this ones; and k 1 is a k 1 is the thermal conductivity.

Now, this is but then there is a fine air layer on both the sides boundary air layer. And when you take care of their conductivity equivalent conductivity, there will be convection and radiation, which you can convert into equivalent conductivity. So, this is called surface conductivity. When you take that into account, so you write it like this 1 plus h o, where h o is the outside surface conductivity equivalent surface conductance of the you know surface layer plus surface, you know surface conductance no conductance, not conductivity or that is what you say. So, if you do that, and then you get what is called you get what is U-value. So, 1 over u is given like this. In other words, I am not going too, because going to details of this is not part of this course. So, I am not doing this.

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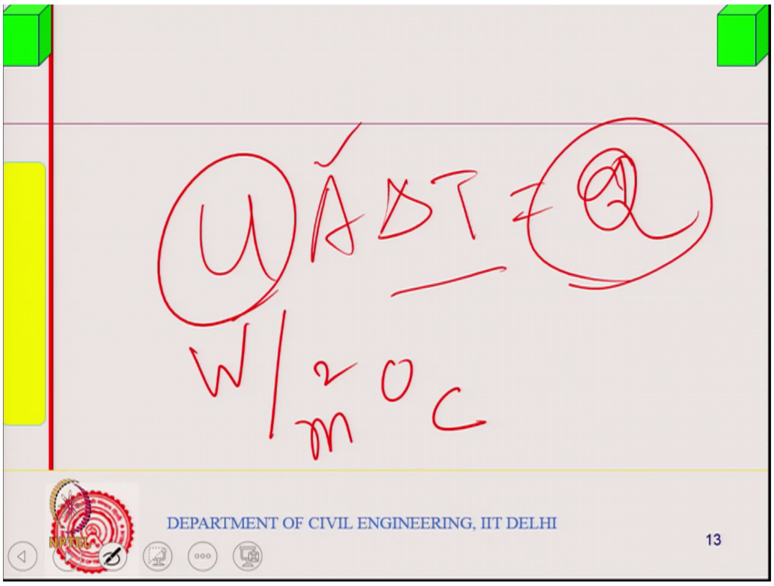

But, u a temperature difference gives you the amount of heat u a; u is what we call u value or transmittance value, which is units is watt per metre square per degree centigrade right into area of the wall into delta T temperature difference that will give me the amount of heat that will come in.

So, if I want to find out the amount of heat cooling load you know, so essentially I would like to know. So, this is U-value is average U-value is given 1 by u is equal to 1 by h i etcetera sigma l by k the formula is also given here of exposed walls are 2 watt per meter degree kelvin. The radiation heat gain through the glasses are given. If the radiation fall on to the glass, if I know intensity of radiation multi[plied]- because intensity of radiation is expressed in terms of watt per meter square, so that multiplied with the area of the window or the glass will give you the amount of heat that will come in multiplied by a factor, because glass will not transmit everything, only a fraction of it will come we call it solar gain factor, so that is why you have written A I theta. A is the area of the glass, I is the intensity of radiation, and theta is the solar gain factor the fraction, so that is also given as 3 kilowatt is already given to you, you do not have to calculate.

The inside temperature is 25 degrees centigrade, outside is 35 degree centigrade. Inside room temperature is 60 percent, outside WBT is 24 etcetera etcetera. And you have 4 hot plates, each 2 kilowatt are there inside, because the restaurant, so there should be generating heat. So, to simplify this whole affair, we said is 2 hot plate which straight away you can calculate the energy that is coming out of it.

Lighting is 15 watt per square meter. For this kind of you know area generally national building you give could gives you the area req[uirement] amount of lighting per meter square for different types of occupancies right. So, the 15 watt per square meter of course will have been based on the earlier days type of lamps modern lamps might require much less actually, but whatever it is here it is given as this. Infiltration is 0.5 air changes per hour. In other words, there is a leakages you know all windows will not be sealed properly. So, there will be air gaps, so through which fresh air will come in, and that is we call as infiltration, because that is not by design that by default, because the construction is not good. So, 0.5 air changes per hour is given.

Now, what is air changes, air changes per hour is the number of volume number of times you know room air gets exchanged, for example fresh air comes from outside, it will displace the room air.

Student: Room air.

Now, if the total volume through the total air you know volume of the air which is equivalent to the volume of the room, if it gets changed three times in an hour, then we call it three air changes. Six air changes means in 1 hour six times whole volume you know air equivalent to whole volume of the room will be exchanged fresh air will come. So, you can find out the flow rate 6 into volume of the room or number of air changes into volume of the room that is the flow rate will be given by number of air changes multiplied by volume of the room in meter cube per hour. If you want to convert it into second, then divide by 3600, because flow rate if you want to find out. So, this is given as three air you know 0.5 air changes per hour infiltration.

And proposed supply air differential is 10 degree. So, as I said that this is this is pre-decided differential between room temperature and supplied temperature right, this is pre-decided. Because, we do not want to keep it too high right, we do not want to keep it too high and again too low; if it is too high, then the insulation required will be because room temperature is fixed because of from your comfort condition. So, supply air temperature is too high it would mean?

Student: Insulation.

That insulation required cost will increase, because you are at much lower temperature you will be differential is high. So, supply temperature will be lower, we will require more insulation cost. And if supply temperature is high, then you go to increase the flow rate, because you want to remove the heat. And flow rate increase means size of the piping will increase. And if you lower the size, then velocity will increase which means that noise might increase. So, therefore this is a kind of a compromise between all these. So, we keep it at this case, we have been proposed to keep it at 10 degree.

Heat gain from each occupant is 90 watt right that is sensible heat gain means temperature related. And then there is some latent heat gain, because there will be perspiration even our you know through our respiration, we generally exhale some amount of moisture as well along with the carbon dioxide. So, this is 30 watt latent. And heat gain from meal, because the restaurant is 10 watt sensible, and 10 watt latent, now because the meal has served usually moist form, so the moisture will evaporate, so that is what it is right.

The properties of the air is given; specific heat of air is 1.01 kilo joules per kg, latent heat is given as on an average basis 2501 kg per kilo joules per kg, and density at 20 degree centigrade is 1.2 kg per cubic metre. So, we are going to look into this problem.

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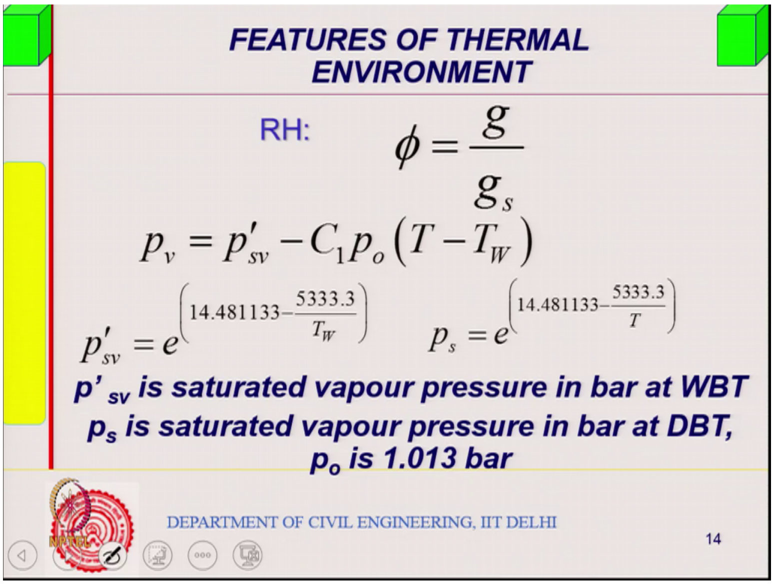

So, first thing we calculate out how much is the sensible heat gain right. This is this I think, this is the formula related to I will come back to this g s and all. This is the formula related to how you calculate out; we will come back to this later on, but let us is it given here. Now, the problem solve solution of the problem is not given ok. So, let us let us solve it straight away here itself. We will come back to this, how we calculate the relative humidity.

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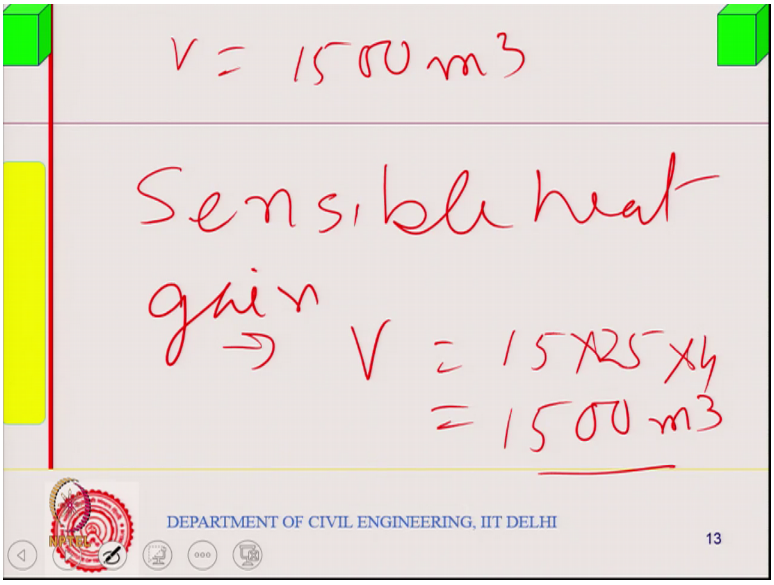

So, if I want to calculate this out right, so first thing is I find out how much is the sensible heat gain, how much will be the sensible heat gain, I have first is a the average U-value of exposed walls are 2 watt metre. So, room size let me first calculate out. Room size is to find out the volume of the room volume of the room is 25, 15 into 25 by 4 right 15 into 25 15 into 25 by 4, so that is how much 1500 metre cube that is the volume of the room ok.

Sensible heat gain will have component that is first thing, now this will be required. Now, if it is because this information I will require, so I will keep this volume as the room volume is 1500 metre cube. I want to find out the sensible heat. It will have a component of heat gain through the walls, walls and you know all surfaces. So, it is said that heat gain you know the average U-value of exposed walls are this. And you know total so total heat gain. So, what is the wall area wall area, 15 wall area is 15 plus 25 into 2 into 4 right.

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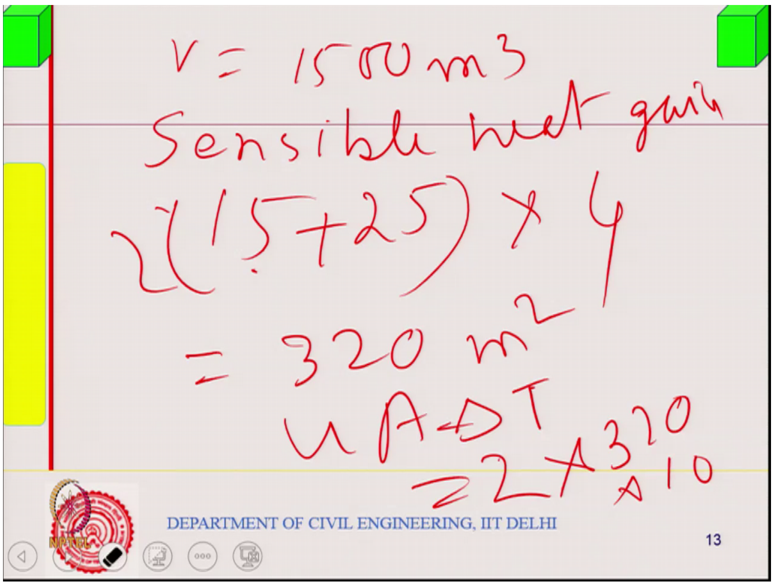

So, this would make it how much 40 into 2, this should be 8 into 40, 320 metre square, and how much is the heat gain through this. Actually, we are assuming the room below and room above is at same temperature, air condition. There is no heat exchange between, so only wall I am taking right. So, it is in some floor in between, so you know top level and bottom level are same temperature. So, roof and floor I am not taken any heat exchange.

So, area is 320 metre square, what will be the heat flow. The amount of outside temperature is given outside temperature is 35 degree, inside is 25 right. So, temperature difference, so U A delta T. So, U is it is given 2 right, it is given 2 it is given as 2 me[tre]- watt metre degree centigrade. So, this is 2 into 320 into 10. So, this is part of the sensible heat gain this part of the sensible heat gain right, this is part of the sensible heat gain. So, this will be so sensible heat gain if I calculate out, component of sensible heat gain sensible heat gain ok.

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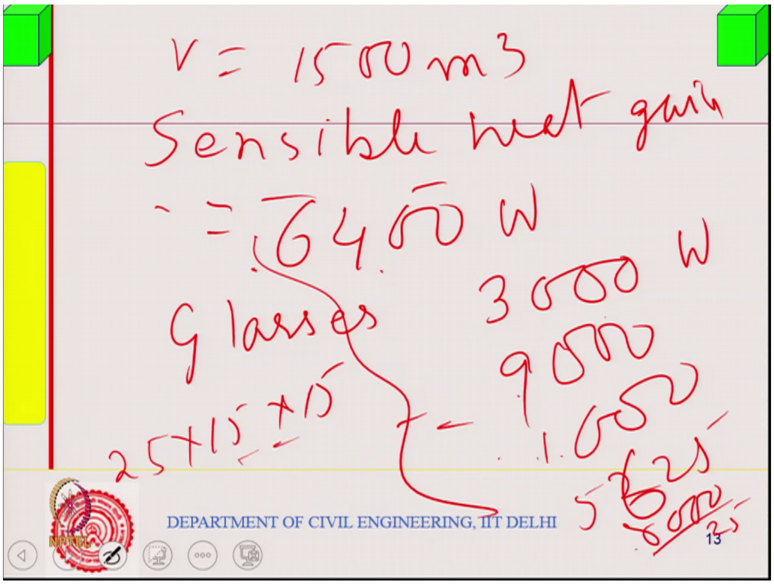

So, this is first is 320 into 20, 320 into that is 64 yeah. 320 into 10, 6000 this is first one is 6400 watt this is one. Then, let us see what is the other one? Next this is A I theta, so is there a glass area given. The amount of the heat flow is given also; amount of heat flow is 3 kilowatt. So, the glasses the heat that is coming is 3 kilowatt, you know the radiation heat gain through glasses is 3 kilowatt. So, I just add that. So, glasses through glasses 3000 watt 3000 watt, 3 kilowatt is already given.

Then from each person, now almost find out how many persons seating there, 300 persons in 3 seating in 2 hours that means in each seating, how many person will be there 100, and they sit for 2 hours. So, if I want to calculate out how much heat they are generating, that they 100 people will generate 90 watt is given I suppose. Something like that you know 90 watt where is it 90 watt each person actually generates heat of 90 watt right. So, 90 into 100 people, because at any time 100 I am designing for 100 people seating right anytime 100 people seating. So, this will be?

Student: (Refer Time: 21:42).

No.

Student: instead of 2.

Threes 3 hours 3 hours it makes any no difference, because I am calculating the rate of heat flow, 2 hours has got, no way. Now, I keep it open for the restaurant is open let us say for 2 hours, peak hours is 2 hours, at the time it will be less. I am designing for the 2 hours period. And where (Refer Time: 22:03) people will be seating in one seating, 300 people in you know 2 hours 3 in 3 seating, so 100 people.

So, 9000 right, 9000 that is sensible heat, what else is a sensible heat? And from each meal, so I will have 100 meals. Let me assume the extreme the 100 meals, each meal will have 10 watt sensible and 10 watt latent. So, let me take only the sensible heat. So, from mean again I will have 1000. So, anything else anything else heat you know anything else casual heat gain is if there is appliance is lighting, lighting how much is one point 15 watt per square metre. So, I have got how much area 320, you know how much area floor area 25 into 15, so that would be 25 into 15 into 15, 15 watt per metre square know lighting, so that would make it 15 into 25, 225 you know into how much it is some value.

Student: 5 6 2 5.

5 2.

Student: 5 6 2 5.

5 6 2 5 let us say this is that. And then I will have some from the heaters you know it is there is there some heater, what is that heater 4 hot plates 2 kilowatts that means, 8 kilowatts 8000. So, I add another 8000, I can sthis up all and I will get the total sensible heat, but there is one more thing remaining infiltration.

Student: yes.

Infiltration is remaining. Now, infiltration heat flow will be 0.5, where changes if I look at this, so therefore so for if I sit up, how much does it come 6400, 3000, 9000, so 12000, 13000 you know how much it comes to 52.

Student: (Refer Time: 24:24).

We will calculate separately, just I am trying to calculate the sI do not want to put this down 6000 is 9400, 18400, 19400, 19400 plus 5000 20 19 you know 24 plus 25000, 25, 25000, 25 plus 8, 25000, 25 plus 8 is 25 33500 so far I have got. I have got 33 percent 500. So far 37500 so far I have got right. So, sensible heat gain sof all plus this of course, I have to find it out from for from infiltration.

Student: 33025.

Ok 33025 yeah, so that is how it is coming to so let me write it down sensible heat gain.

Student: sensible heat gain.

It is all sensible heat gain yeah.

Student: all components of sensible heat gain

All components of sensible heat gain.

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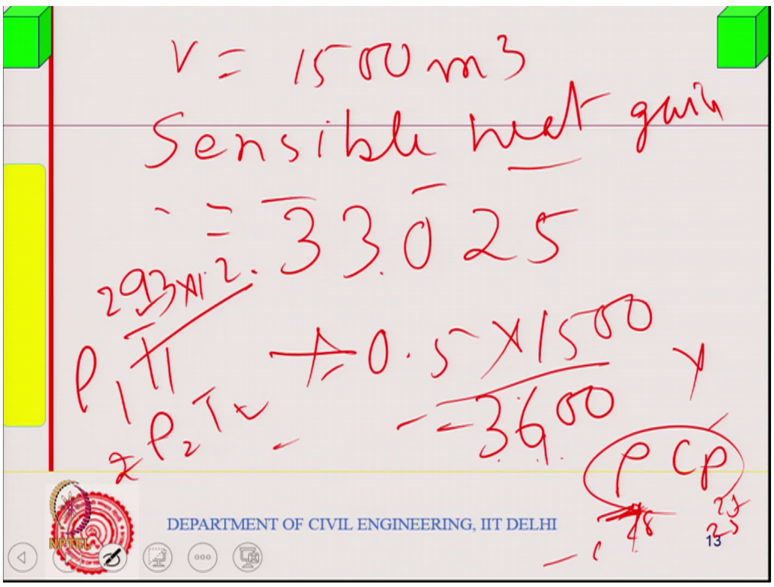

So, for it is thirty 33025 watts, plus the infiltration. Now, to find out the infiltration what is the information given to me, 0.5 air changes per hour, you know that is the information given to me. Infiltration is 0.5 air changes per hour, which means that 0.5 into volume of the room which was 1500 right. A lighting we have not calculated, no we calculated everything yeah that much would be change in 1 hour, so that if I want to convert it into watts, number of air changes multiplied by volume of the room divided by 3600, so that is the rate of flow multiplied by the density of air multiplied by density of air into specific heat multiplied by density of air and specific. Now, how much will be the density of air, density of air at this temperature at which it is coming?

Student: 20 degree.

20.

Student: 20 degree Celsius temperature.

That is to known to us 1.2, but this air is entering at you know how much heat it is bringing I want to find out. So, it is coming at 28 degree the heat that is bringing is. It would be actually the one that is going out at 21, because room temperature is 21 that is coming out is at 28. So, the density difference rho C p difference between these two temperatures I must calculate out. And rho is given by we know that rho 1 T 1 is equals to rho 2 T 2.

Student: rho 2 t 2.

This is for 273 plus 22 93 into 1.2 divided by the temperature at which I want to find out the density. So, if you are finding out at 28 degree centigrade, this will be you know so and C p given. Average C p value is given 101 kilojoules, which means 1010 joules per kg, so that has to be multiplied. So, if you multiply that, then you will get the amount of sensible heat gain right amount of sensible heat gain. Rho 1 C you know C p on[e]- 28 is entering at 28 and going out at 21 the going out. So, there is a density difference, specific heat I will keep it as constant right. And you can you can you can find it out, how much you know the sensible heat gain.

Student: 25.

Because outside air temperature is given as how much? 35 sorry.

Student: 25.

Thirty 25 was earlier problem, 35 degree centigrade and inside is 25.

Student: 25.

So, it is entering at 35 going out at 25. So, we can calculate out the difference in densities, you know multiplied by the specific heat which is given. So, you can calculate this out. So, let us say it comes out to be another 1000 or something of that order you know. Roughly it is actually one-third 1 by 3 roughly. So, this should be N into V, so it would be somewhere around not much large value, it will 750 or something, so that is how we can calculate out the total sensible heat gain that is how we can calculate out the total sensible heat gain right.

Now, I can calculate out the latent heat gain then. You do this you complete this problem yourself rest of the thing. So, then I can do the latent heat gain, how much will be the latent heat gain, only two sources. One is the number of persons, other is the?

Student: meal.

Other is the meal. So, from the meal, it comes 100 into 10.

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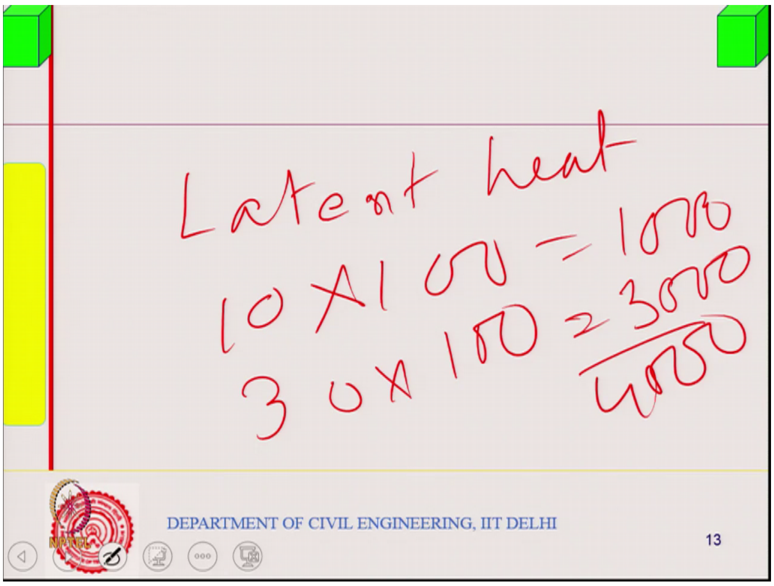

So, latent heat gain will be latent heat gain will be latent 10 into 100, because 100 persons are seating at a time. So, 1000 and every person 30 watts right is given. So, 30 into?

Student: (Refer Time: 29:47)

Right that is it only, so it is only 4000 watts. So, usually this is (Refer Time: 29:55) sensible heat is much higher than the latent heat gain, you know latent heat you will know. So, what we do, next step we find out the flow required mass flow required to remove this sensible heat gain ma[ss]- you know mass flow required flow required flow of supply air required to remove the sensible heat gain.