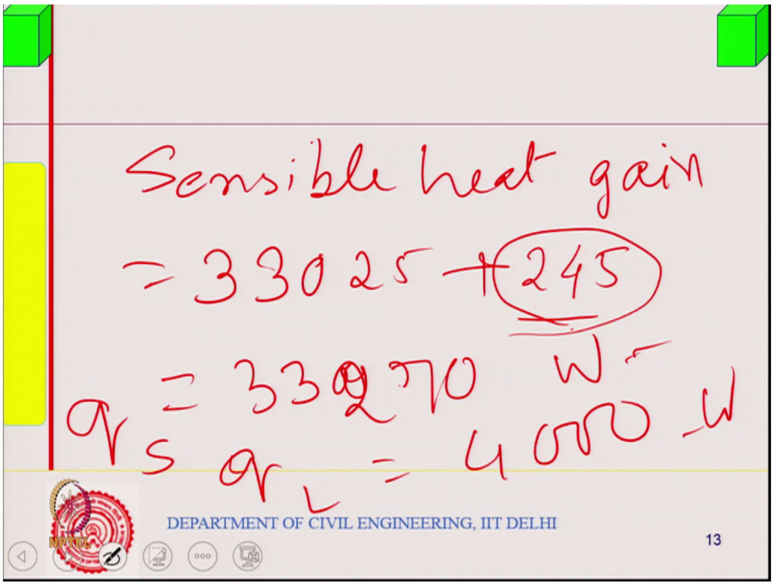
Fire Protection, Services and Maintenance Management of Building
Prof. B.Bhattacharjee
Department of Civil Engineering
Indian Institute of Technology, Delhi

Lecture – 28
Numerical Problem on HVAC System Continued

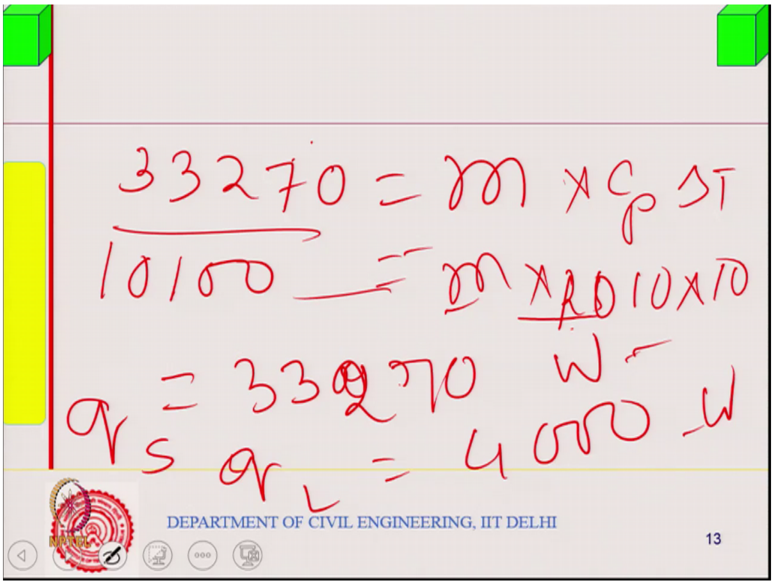
(Refer Slide Time: 00:20)



So, sensible heat gain that infiltration one comes out to be 245 say total is 33270 right. 270 watts and latent heat we have seen. So, q this is q, we call it q S and q L is equals to 4000 watts. Next step I want to find out the mass flow rate right, mass flow rate. So, this mass flow the heat remove sensible whichever is higher we take that this is usually much higher. So, this much what should sensible heat to be removed is this. And if my mass flow rate of supply air, let us say is a m into specific heat into delta t that will be the mass specification with delta t that is the amount of heat it will remove.

So, we can now what to do is we can find out the because temperature differential we have already said that will keep it at 10 degree. We have keep it 10 degree. So, a specific it is known to us m we can find out; specific heat is known to us. So, let us calculate this out; let us calculate this out. So, therefore, we take it to be q L q you know, we are taking the here keeping is there right.

(Refer Slide Time: 01:39)



So, 33270 must be equal to mass flow rate; combined mass flow rate fresh air and you circulated there because finally, you know that is the total air. So, multiplied by C p into.

Student: (Refer Time: 01:54).

That is there is I said there is delta t. Let me call it and we have decided that will keep it at 10 and m and C p is 2000; 1000 1 0.

Student: 1010.

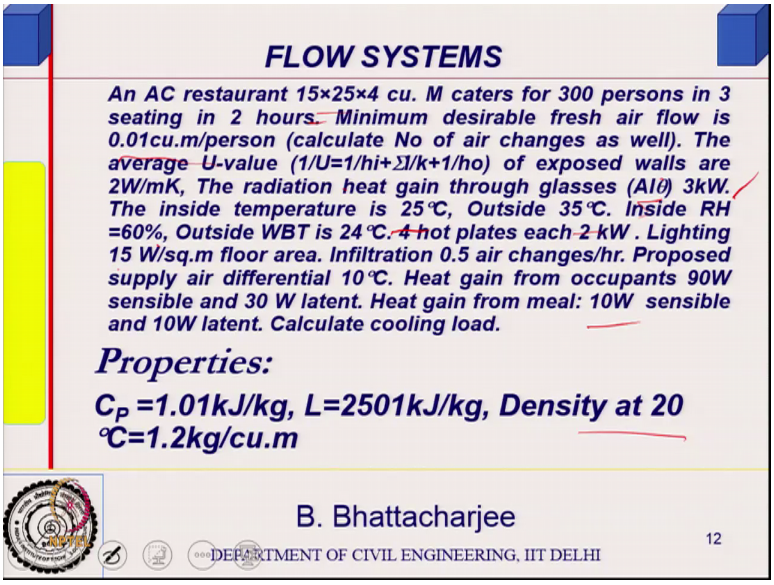
1010 into 10 so, you cannot find out what is a m.

Student: 3.3.

3.3 kg per second; this comes out to be 3.3. So, this comes out to be so, if we divide by this one 0 1 0 1 0 1 0 1 0 1 0 0 that is right because that will be equals to your m. So, that will be equals to your m. So, m will be equals to this and right m will be equals to and this comes out to be 3.3 whatever it is right. So, that is your mass flow rate.

Now, out of which you require minimum fresh air supply right for hygienic requirement and that is given us 0.01 cubic metre per person you know, this given in the problem this given in the problem.

(Refer Slide Time: 02:57)

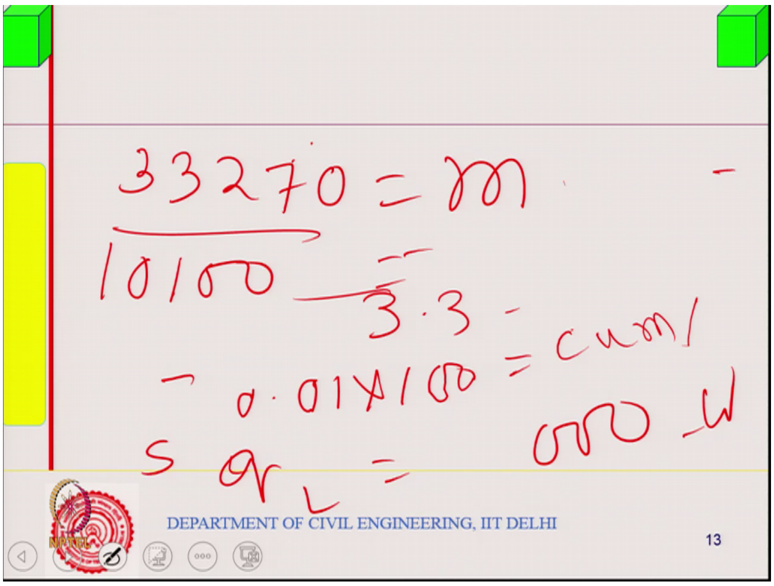


For hygienic requirement there some value is given.

Student: (Refer Time: 03:01).

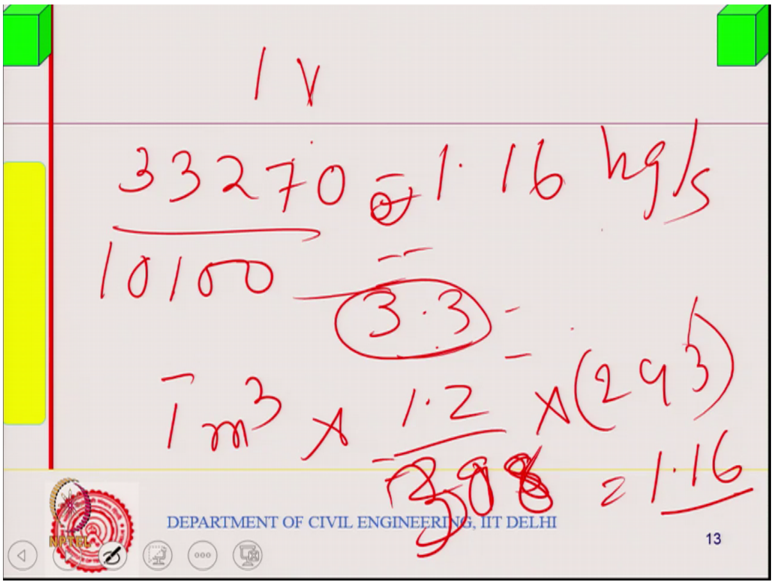
0.01 cubic metre per person.

(Refer Slide Time: 03:09)



So, if I have 100 persons then this will be 0.01 multiplied by 100, that much cubic metre per second actually I mean cubic thus you know per hour or per second is given.

(Refer Slide Time: 03:26)



Fresh air required was coming fresh air required is 0.1 meter cube per 1 meter cube multiplied by 1.2 divided by 293 into, no multiplied by 293.

Student: Multiplied by 293.

3 divided by 298 yeah.

Student: 308, it was 35 degree.

Yeah 308; so, 308; so, you can find out this is this comes out to be 1 point.

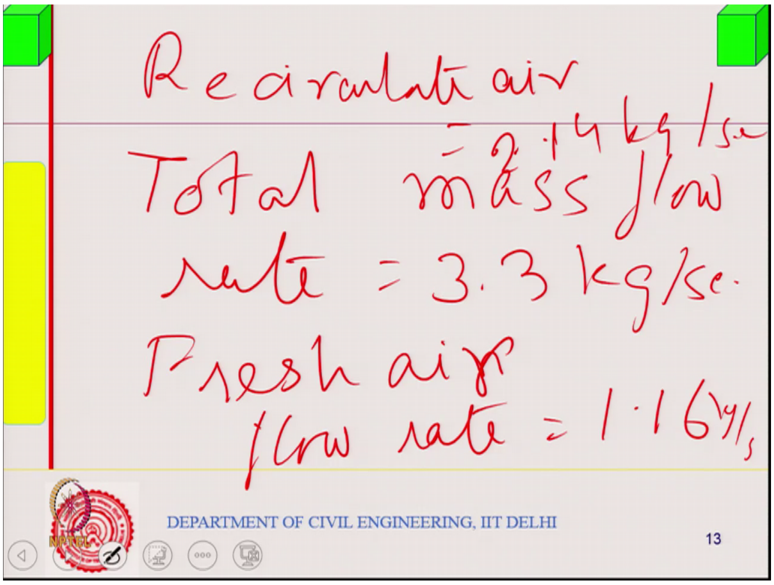
Student: 1.16.

1.16. So, 1.16.

Student: kg 2 second.

Kg per second is a fresh air. Let me just write it now all some it happen clearly write it.

(Refer Slide Time: 04:08)



So, total mass flow rate is 3.3 kg per second, fresh air flow rate.

Student: 1.16 kg

1.16 kg per.

Student: Second.

Second. So, then remaining is.

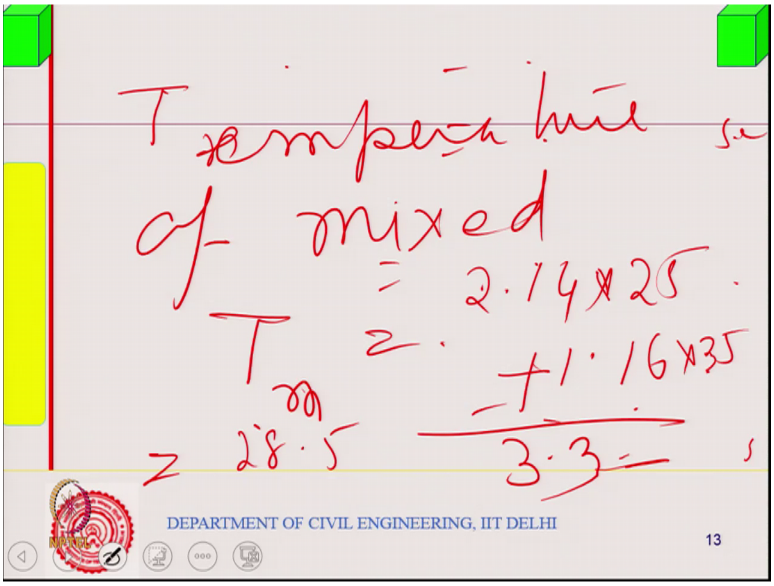
Student: Recirculated air.

Recirculated air. So, recirculated air will be 41 2.14 kg per second, recirculated air will be this much. Now one thing still remain to be found out the moisture content of the supply air, moisture content of the supply air and also you know the amount of cooling that I want to do. Because 25 degrees centigrade maintaining, no there is a mistake supply air temperature is 15 actually room temperature is 25, supply air temperature is 15 because 10 degree differential, I will keep it all right.

So, as far as so far calculation wise I think there is no problem because 35 degrees the outside temperature we have calculated based on this. I think we did not make any distance an mistakes over, but supply air temperature could be 15 degree and corresponding moisture content we would like to find out and how much is the cooling required. Actual cooling maybe the energy required to be somewhat different because the efficiency etcetera will come in.

So, first two step we have done is we have found out the right. Now, this is the re circulated air and this is of fresh required total air is 3.3. What will be the temperature of this air? What is the temperature of this air? That I can find out. How can I find out? What will be the temperature of this air it would be some you know 32.14 into this is this re-circulate 25, 2.14 into 25 plus 1.16 into let me just do this calculation. So, eraser, erase this we have seen that 2.14 and 16, total mixture temperature of the mixture.

(Refer Slide Time: 06:56)



T of the mixture, mixed you know T temperature of mixed air. I have now re circulated air and fresh air and mix them together and would be given by say let me call it T m right. This should be how much? This should be 2 point how much was it 2.14.

Student: (Refer Time: 07:27).

Into what was the temperature of the re circulated 25 degree centigrade plus fresh air is 1.16 into 35 divided by 3.3, divided by 3.4. Because is simply linear relationship; so, law of mixture. So, that you can find out what is the mixture temperature mixture, temperature would be how much it is mixture temperature would be somewhere in between the 225.

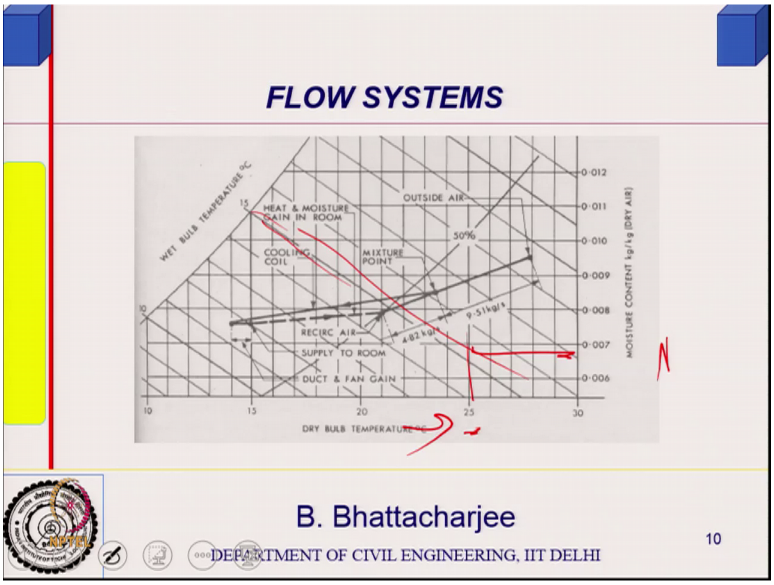
Student: 28.5.

28.5 so, that is the mixture temperature. Now I also want to find out the moisture content of the mixture, for that I have to go to the.

Student: Latent heat.

Yes latent. Now first have to go to the because moisture content of the outside air is known to me, how? From psychometric chart; from psychometric chart; if I have a psychometric chart quickly, I will show you.

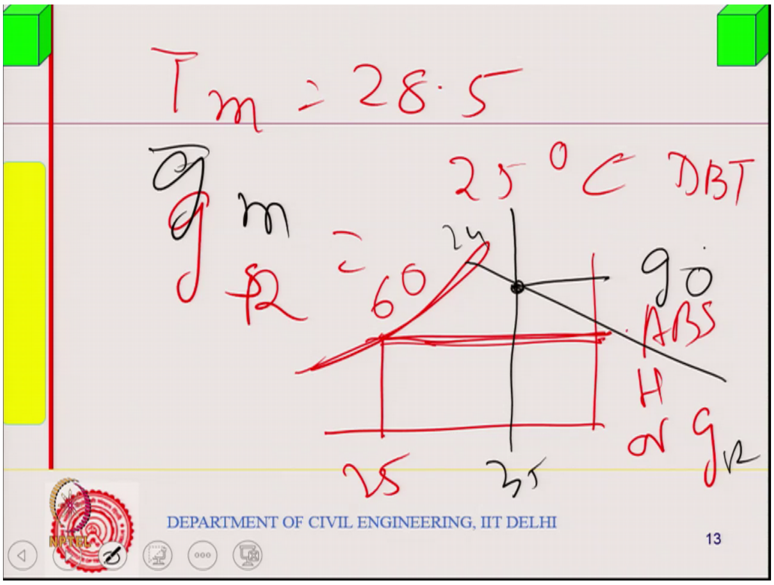
(Refer Slide Time: 08:24)



Because in psychometric chart you have got dry bulb temperature here and what is given? Wet bulb temperature is wet bulb line. Wet bulb temperature lines, I will given like this wet bulb temperature lines are given like this. So, look at the dry bulb temperature and here wet bulb temperature the moisture content is here right. This I absolute moisture content, in this case our temperatures are given 25 and some relative you know wet bulb temperature is given 12 or something. So, you do get 12 and find out what is the moisture content.

So, this one it may not have this on may not have any way, you can complete this problem; I am just telling you the procedure. So, basically then you find out the wet bulb you know moisture, basically moisture content you can find out from psychometric chart. So, temperature of the mixture we have found what will keep this in record for a while or erase everything in way erase.

(Refer Slide Time: 09:27)



So, temperature of the mixture we have seen that T m is equals to 28.5, g of the supply g of the, you know mixture I have to find out. But first groom room moisture content of the room will correspond to DBT 25, DBT sorry 25 degree centigrade DBT. And how much is a wet bulb temperature? Is given or.

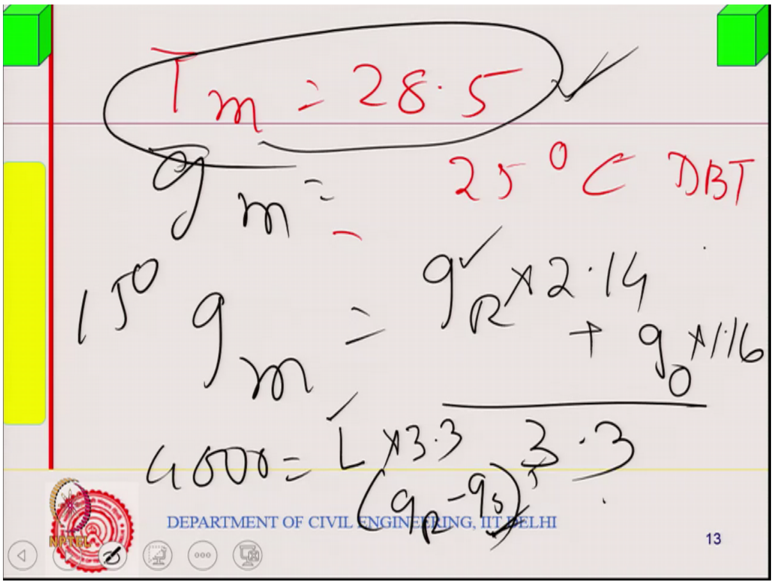
Student: 24 degree Celsius outside (Refer Time: 10:01)

Now, inside 60 percent relative memory something like that, room should be the average u value is given the radiation is given the inside relative humidity is 60 percent. Inside relative humidity is 60 percent right is given right, inside 35, outside temperature is inside relative humidity is a outside DBT is 24. So, g room if you want to find out you have to go to the psychometric chart. Look for the 60 percent curve; relative humidity 60 percent curve, 25 degree centigrade. And then from this curve exchange this horizontal point, this will be the absolute humidity or moisture content h or g. You will get the g room from this for 25 and 60. So, if you look psychometric chart is this you can find out right.

Similarly, for outside, what is given? Outside is given 35 degree and WBT is 24. So, in case of outside you go here outside you can go; outside you can go here, outside somewhere 35 and WBT line of you know 24 we will check. This will cut here and you come here, you get the g outside, you know g outside. So, this you find it out from the chart, did you find it out from the chart quickly that there would be order would be very small 0 0 something 0 0 7 and 0 7 and something that kind or 0 1 4 and things like that you can find out that.

Now, if you once you have found out that g outside and g R, g outside and g R, then you can find out g of the mixture by similar formula; g of the mixture by similar formula right; g of the mixture by similar formula right. But I will give you the equations now; obviously, I will not do you know I will give the equations next slides actually gives you the equation for calculating relative humidity values. Next slides set of slide gives you because chart is one thing, but the today and hardly anybody uses chart, one put in an excel sheet and get it straight away.

(Refer Slide Time: 12:30)



So, g of the mixture will be given as; g of the mixture will be given as g of the mixture will be given as g room multiplied by 2.14 slash g outside into 1.16 divided by 3.3 because 2.14 is a re circulated air and its room moisture content is g R. So, second law of mixture. So, once I mix I will get something in between. So, g of the outside some you know multiplied by 1.16. So, I am mixing 1.16 kg per second with 2.14 kg per second. What will be the, if I mix the two air with different moisture content? Moisture content will be the average moisture content per unit mass, you know per kg of air, if I calculate of this is the average.

So, divide by 3.3 per second which was the overall mass flow rate, you will get the moisture content of the mixture; moisture content of the mixture. So, you have got T m you get g m. So, gm values how much? Any idea gm value coming out to be how much is the g m value? Once we have found out this g m value mixture temperature I got, but then I have to cool it to a lower temperature right. I have cool it to a lower temperature you know to remove the amount of; to remove the amount air amount of heat to remove the amount of heat. So, any idea about the value gm?

Student: (Refer Time: 14:11).

It is does not matter. So, we would see the chart and you complete this problem yeah chart. So, you have to you have to find out from the chart. So, once you have found out from the chart, you have found out the moisture content of the mixture. Now, I got to actually you know this same air. First of all I see whether, what is the you know like supply air temperature, we have decided that is that should be 10 degree lower than the; 10 degree lower than the. This mixture I will have too cool it to 15 degree centigrade, this mixture I was got now a temperature of 28.5 and 15 degree centigrade. Now, the moisture content of the supply air that I can find out from latent heat removal because I want to remove 4000 watts of latent heat, room moisture content is known to me. This you know this must be equals to, the latent heat of evaporation which was 2500 01 kilo joules per kg multiplied by the mass flow rate I know that will be 3.3 into g R minus g S into g R minus g S.

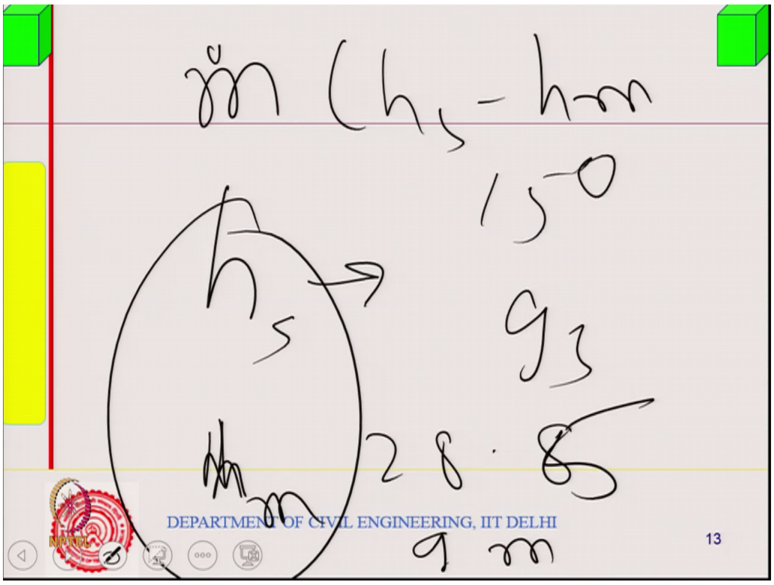
So, supply airs, this I can find out from this equation. Now L is known to me 3.3 is given because that is the supply rate g R, I found out. So, g R minus g S, I can find out g R minus g S, I can find out.

So, supply air temperature that is entering into the room will be at 10 15 degree centigrade. The moisture content must be given by g S. Now if there are some loss in the, you know lose in the pipes etcetera, you might take that into account and actual temperature how much loss is possible percentage loss that you can find out. And from that you can decide on how much temperature you know, temperature of the actual cooling how much what up to what temperature it should be done, up to actual cooling should be done up to what temperature.

Now, if you know the temperature of the, you know the 15 degree, we shall maybe it is it comes up to 13 or 12. So, this mixture at 28.5 3.3 kg per meter second kg per second and the moisture content of g S. This should be brought to now 15 degree or slightly less whatever, now let us say for our class. Let us take it to be 15 degree because you said 10 degree differential and loss let us neglect that. So, you will have to bring it to 15 degree and how much enthalpy change corresponding to that? That I should find out.

If you 3.3; so, specific enthalpy is given, you remember I give you a formula earlier last some class some class. So, specific enthalpy is given as that is I just C p into T plus L into g S moisture content because we said all evaporation will take place as 0 degree centigrade plus g L plus c w into g S; L plus c w specific heat of water. So, these values are given to me what is the enthalpy of the supply air. If it is at 15 degree, I can calculate out, specific enthalpy of supply air that will be corresponding to 15 degree and g S.

(Refer Slide Time: 17:49)



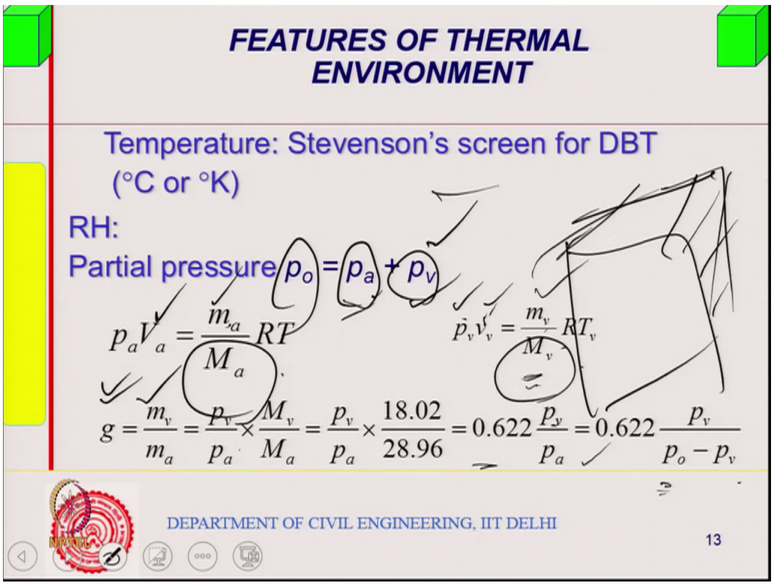
So, specific enthalpy corresponding to so, h corresponding to 15 degree and g S, I can calculate out and h corresponding to, you know h corresponding to mixture. That I can calculate out because this is at 28.5 and g of the mixture is known to me. This difference is the amount of cooling air or heat you know, internal heat change I require in the air right. Internal heat change I require for the air for unit mass. This multiplied by so, m multiplied by m dot multiplied by h s minus h m. That is actually the energy that I am I got to you know remove or I got to basically I have to cool it to that level; so, that much of energy I got to do.

Student: This is the cooling rule.

This is the cooling rule; this is the cooling rule; this is the cooling rule. So, this is the cooling rule, but this is a cooling I am doing the refrigerator will do much more warm. The amount of watt required from the refrigerator, you use what that I am not interested in, but this will be the cooling rule finally, because that will depend upon the machine system mechanical system that is a.

So, I think that discuss you know that ends up our discussion on this problem itself right. So, that is how we find out. Now I have not done full calculation, I leave it for you to do the rest of the calculation. Look at the psychometric chart or use the equation to find them out right, using the equation to find them out. So, let us look at the equation then, let us look at those equation then, if rather than you know psychometric chart is there.

(Refer Slide Time: 19:29)



So, the equation if you look at it, drywall temperature will measure you know; this course I am just repeating this we do this in some other course. Temperature will measure in Stevenson's screen. Drywall temperature is measured you know, you going to seen outside temperature we measured kind of a there are there is a box which will have loop box. So, that air moment is not there, so it is a calm air. So, you measure this called dry wall temperature and we know the partial pressure or you know pressure would be given as part of the dry air pressure plus moisture vapour pressure.

Total pressure is a sum total of partial pressure. What is partial pressure? Partial pressure is a pressure of the gas when it occupies the same volume as the mixture. If you have a container, I is hope I have the diagram, I do not have a diagram here. Supposing I have a container and fill in one gas there; some mass of the gas. It will exert some pressure. Now I fill in another gas some mass of another gas, it will exert some pressure. If you mix these two masses together and put it in the same container, pressure will now increase. This pressure is a sum total of those pressures individual pressures. Individual pressures are called partial pressures right.

When you have put the mass into that volume, you got some pressure. There is a partial pressure of that gas and when you put the another one is a pressure. So, if you have one vapour and dryer which is again a mixture, but you are not going to that carbon etcetera carbon dioxide and oxygen nitrogen I told you. So, sum total these are moisture vapour pressure plus the pressure of the dry air in the total pressure. So, subtotal of partial pressure would give you the pressure and I can now I apply ideal gas law.

So, if it is only one gas, then p a V a into mass of that gas divided by the molecular weight into R T. They are at same temperature let us say then similarly for the vapour p v v v, volume of the vapour is equals to mass weight mass of the vapour molecular weight of the vapour into R into T v. Now T v and T temperatures are same; T v and T temperatures are same because you are dealing with the same temperature, then the moisture content we define as mass of the moisture vapour divided by.

Student: Mass of the air.

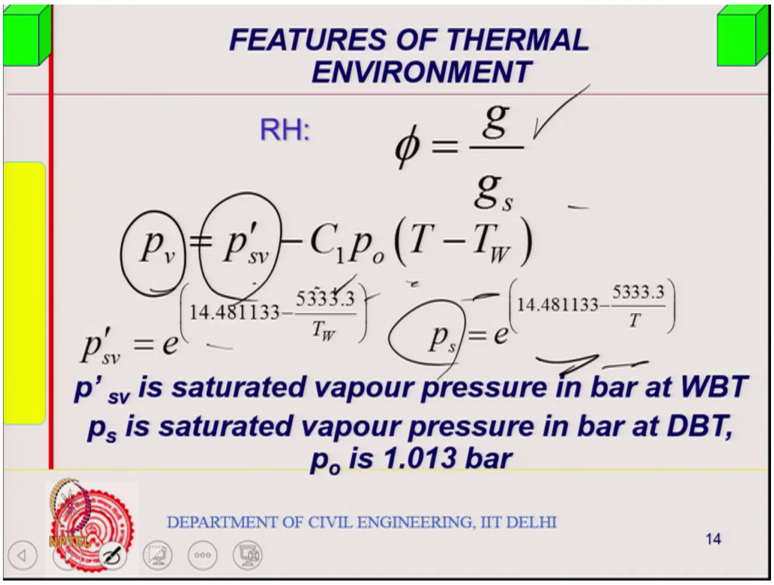
Mass of the air. So, this can be written as from this it follows mass of the vapour divided by the mass of the air. Only thing that is you know p a and p b will be same because we are talking of the same volume terms. So, these are same a T R is same temperature is same. Only thing there is different is difference is M v and p. So, I put it in M v by m a, I can write it in p v by p a little bit of algebra that comes out to be 0.622 partial pressure of vapour divided by.

Student: pressure.

Pressure of dry air and p v is nothing, but p 0 atmospheric pressure minus vapour pressure.

So, if you can calculate out the moisture content in terms of partial pressure themselves; provided you know partial pressure right. So, psychometric chart therefore, gives you partial pressures also corresponding to moisture content. You get partial pressures also right.

(Refer Slide Time: 23:05)



Relative humidity, how it is related? G by saturated g s g by saturated g s that is by definition. And we now have some empirical formula to calculate out the relative humidity right. So, partial vapour pressure of the vapour is given at saturation vapour pressure minus some constant into atmospheric pressure T minus T wet bulb temperature.

So, if you know wet bulb temperature, you should be able to calculate out the partial pressure from such an empirical formula. The values of C 1 atmospheric pressure you might, if you know it will depend upon what unit you are taking. Supposing you take it in one atmosphere, then these value is 1. So, you can find out in this manner and p sv is given; p p sv is given. This value saturation is given in terms of this kind of an empirical equation and you know saturation yes p. So, at a at any moisture content the saturation vapour pressure is given by this formula this you know this there is formula likes empirical formula like this maybe you should calculate out.

P sv is a saturated vapour pressure in bar in WBT. At WBT and p s is a saturated vapour pressure in bar; 1 bar is 1 atmosphere or you know p 0 is 1.103 bar it is taken nearly 1;

so, at DBT. So, p v is a saturation vapour pressure at the WBT and p s is a saturation vapour pressure at.

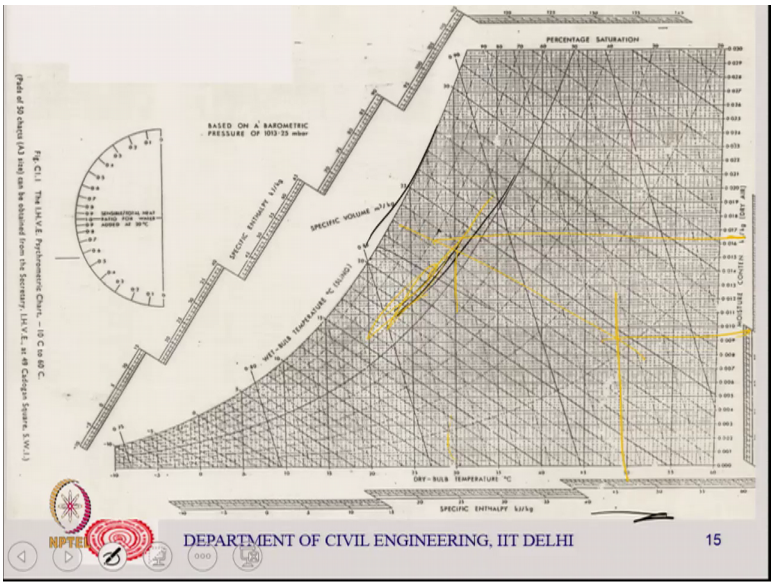
Student: G.

Dry wall temperature. So, g you know now you can you have got p v. You have got p v you can calculate out because if you know the wet bulb temperature. You should be able to calculate out p sv first and then p v and g is basically 0.622 p v divided by p 0 minus p v. So, you can actually calculate out g s from this empirical equation right g s from this; so, g sorry g from this empirical equation. And g s you can find out instead of using T w if you use T, then you get p s.

Student: So, in that question g R eater humidity is given to us.

Yeah so, if it is relative humidity is given? Yeah that is right relative humidity is given then straight away you can find out because saturation humidity units. So, you can find out moisture content corresponding to that and if it is wet bulb temperature is given, you can then also find out right. So, such only thing that you have to find out is at 100 percent you know, like for the dry wall temperature what is the saturation. So, using this equation you can find out the relative humidity value rather than going to the psychometric chart. You can try this out.

(Refer Slide Time: 26:02)

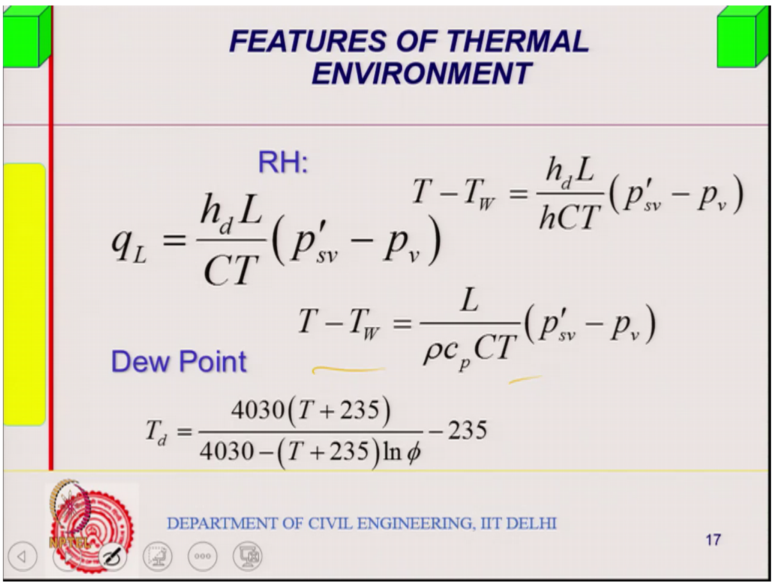


Psychometric chart is also here anyway is there right sorry psychometric chart. So, if you look at it I am just repeating psychometric chart. Earlier I showed you right. So, if I repeat it this is the dry wall temperature, these are the relative humidities and wet bulb temperature inclined ones enthalpy lines are also there. So, we need not look into the enthalpy line, we will can straight calculate from the formula. And if you know that relative humidity let us say 60 percent somewhere there; 60 percent somewhere there right. If you know relative humidity 90, 80 70 60, 60 percent relative humidity and how much was the 25 degree centigrade? So, go there, go here, we will get the absolute humidity moisture content you will get.

Student: (Refer Time: 26:48) 00.

Something like 0.0014 or some such thing it comes out be and you can calculate some formula also. And if it is a wet bulb temperature at 35 is given, 24 degree wet bulb temperature. You can take in corresponding moisture content, you can find out. It might be higher or lower depending upon the situation. If it is higher, whatever the value is you know if it is higher and finally, then you have to do that condensation. So, you to see how much moisture you go to remove corresponding to that you know, what is a dry bulb temperature, the dew point. So, corresponding that you have to find out, but I think then this problem I did not complicate this issue. So, that is how we can find out right.

(Refer Slide Time: 27:33)



So, that is how we can find out; that is how we can find out this. This I think at the moment I think I may not look into next class you might look into. So, you can actually wet bulb depression can be related to all these dew point temperature can be relate because if you have to do cooling beyond dew point, you might have to go to this temperature. So, this and we will see later on. We will see later on in the next class. So, at the moment if you have some questions, I think I will be able to answer. So, the problem you can do the rest of the problem yourself either might use the equation or might use the psychometric chart whichever you would like and complete this part.