Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 17
Heat flow in buildings

So, we start from where we stopped. So, we are looking at fluctuating heat again in the last class that we had.

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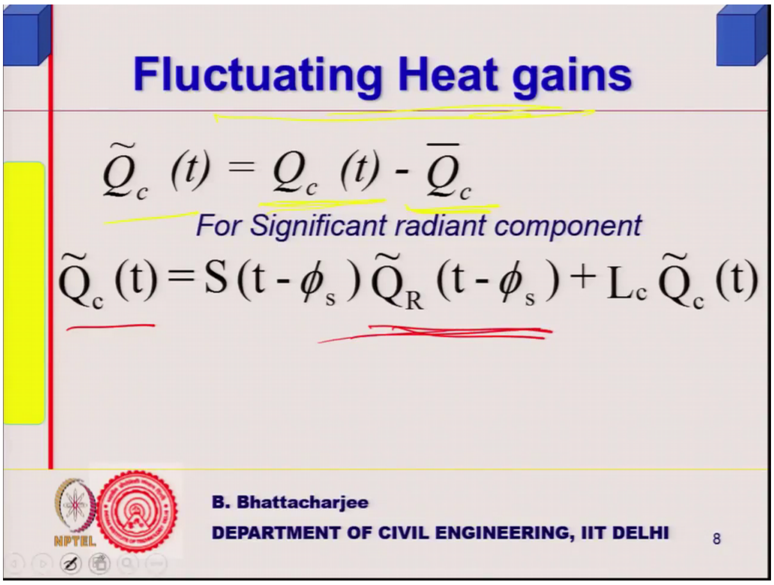

You know fluctuating heat gain. So, we continue from there. This is casual heat gain. Casual heat again you will have a mean casual heat gain here and this is at any instant. So, the difference gives you the fluctuating component of the casual heat gain.

So, Q c t, if there is a radius significant radiant component of the casual heat gain for example, if it is coming from some sources and goes to the wall part of it and then comes back then there can be a time lag associated with that also, but we generally neglect this. We generally neglect this for our purpose and I think this we looked into yesterday last class we looked into yesterday we did look into that and then we said that ventilation heat again is the one that we are supposed to look into.

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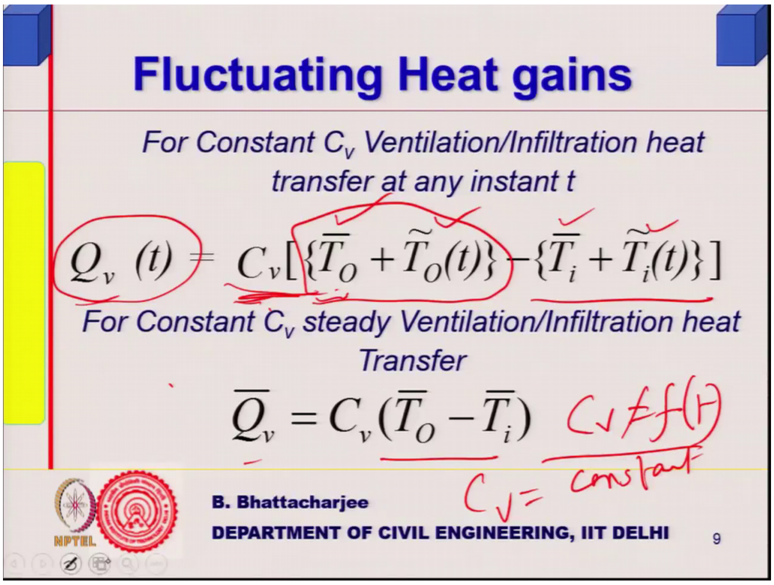

Ventilation heat gain where we, so, this is what we looked into you know C v we are taking care of constant air change at the moment. We are not assuming C v as a function of time, we are not considering this. We are assuming C v is constant; that means, we have fixed rate of air changes. So, in that case if it is C v, so, at any instant the amount of heat transferred due to ventilation should be C v into outside temperature minus inside temperature.

Now, outside temperature has got 2 components; one is the mean and other is a fluctuating and inside has got a mean and the fluctuating. Now, out of this this C v into T o bar minus T i bar we have taken care of in case of steady heat gain, you know mean heat calculation.

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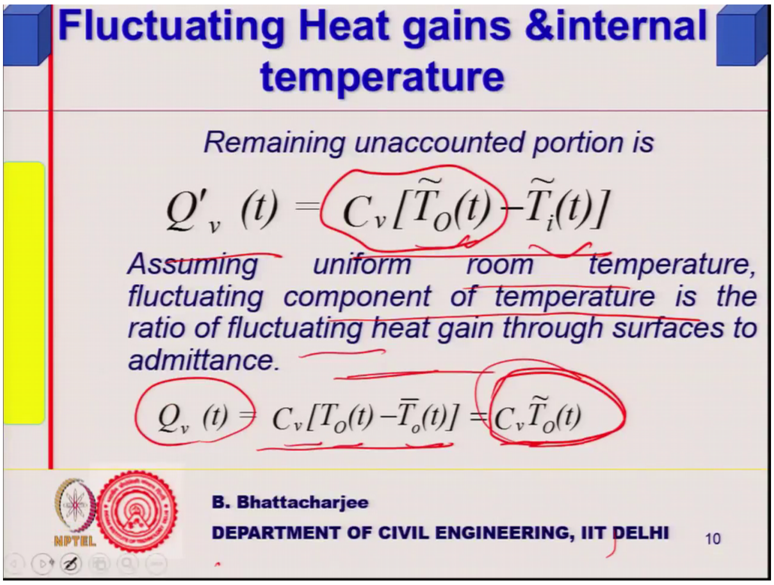

So, followed from this would be then the fluctuating part how it to you remaining unaccounted portion is this remaining unaccounted portion is this Q v dash I think that is where we stopped yesterday, C v this is a fluctuating component of outside temperature and fluctuating component of inside temperature this we did not take care of in the last mean calculation.

So, assuming uniform room temperature, fluctuating component temperature is the ratio of fluctuating heat gained through all the surfaces to admittance. So, this is what I think is a statement is fine, but let us explain what it is, let us understand what it is. As far as this is concerned Q v t I can write it like C v T o t minus only the fluctuating part you know this out of this I can separate this out this is the fluctuating portion of temperature and corresponding ventilation heat gain.

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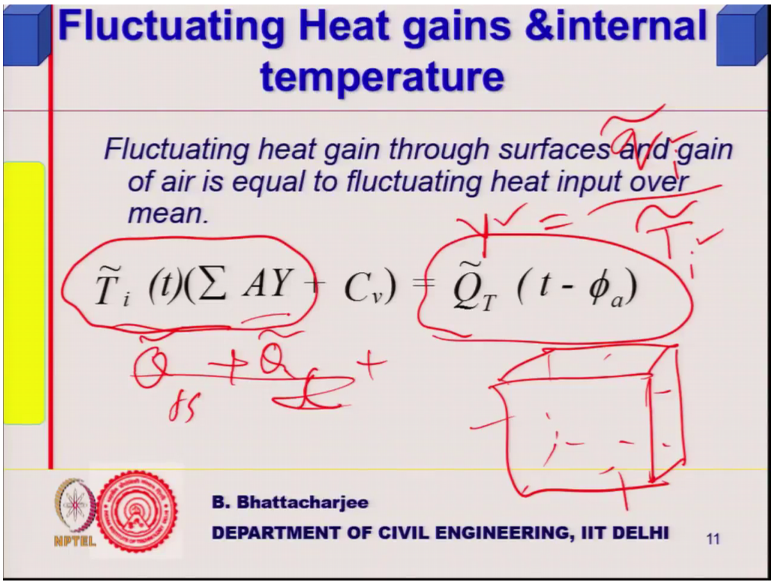

Let us see how we take care of this in the overall scenario. So, fluctuating heat gain through surfaces and gain of air is equals to fluctuating heat input over mean. That we have defined already, but let me just take this. So, what we are saying is total fluctuating heat that will come in for through all the surfaces you know we said Q fluctuating fs plus Q fluctuating as you know c etcetera there all of those fluctuating heat component if you take into account, this fluctuating heat component ,we assume to enter into the through the room surfaces.

We assume that they enter through the room surfaces and this must go in increasing the flies fluctuating component of temperature whatever comes in through the wall, all fluctuated gain all of them are not through conduction. Some of them are through conductions, some due to ventilation, some due to direct radiation, and some due to casual gain.

So, all the heat transfer that is occurring we assume that that takes place through the envelope surfaces internal surfaces such that T swing of inside temperature I can find out provided I know q in because this was nothing, but admittance. What was admittance? How did you define admittance? Admittance is the amount of heat that should come in for unit temperature swing in the inside temperature. So, if the inside temperature swing is T i and assuming room temperature is constant all over the place. So, swing is T i this multiplied by Y must be equals to heat that is coming in here one more assumption we are doing we are assuming that it is not only the conduction, all the heat it comes in from different through various mechanisms through different surfaces all that contribute to the fluctuating temperature gain.

So, if that is the case then T i t AY must be equals to the fluctuating component of the heat gain, all that I sum up.

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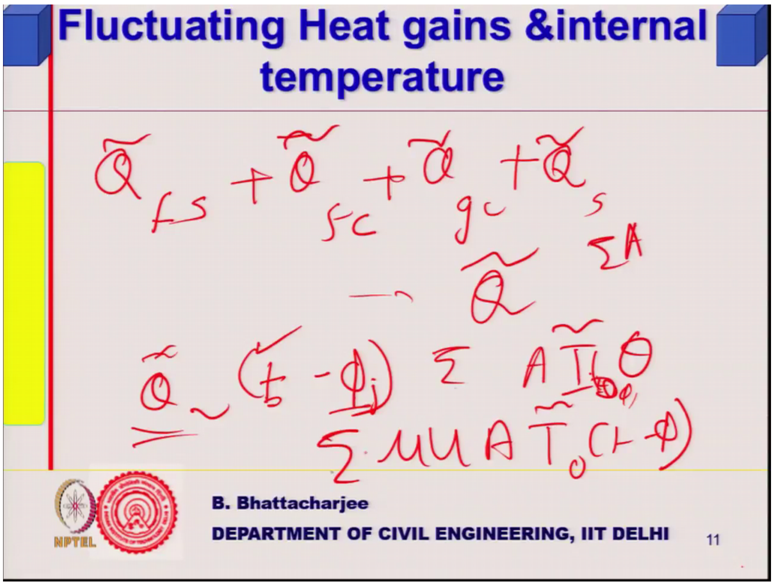

If you remember we had several component Q bar fs I have wrote, that was directly solar gain falling into the opaque surface plus Q c that is through the conduction, you know different components that we wrote yesterday. Q swing gc through the glass through conduction plus Q I think we wrote something like s you know different components we wrote the other day some of them. So, all these I call as Q total at any point of time whatever is the total input.

Now, this we assume this Q, that is, total that is coming in and that will be t minus phi hours earlier, because some of them will have time lag appropriate time lag I will have to consider. For wall we know the time lag how did you calculate out this Q? We found out based on decrement factor and you know decrement factor and it is corresponding time lag, for conduction we found out decrement factor and it is corresponding time lag then ventilation of course, we are we just you know we said that steady part we have taken care of we are taking care of now the fluctuating component of it.

What about the radiation part of it? Radiation we said that it was A I swing into theta A I swing into theta and this I might be you know I might be t minus some phi, depending upon, but this will have no phi here because radiation solar radiation directly comes in instantaneously. Similarly, we had mu uA if you recollect mu uA T o swing t minus phi, that is the conduction heat gain, sum of all these will give me the conduction fluctuating conduction heat gain. All these heat gain that is occurring I sum them up and that I call as because corresponding t I have to corresponding phi j would be there this would be for different surfaces. So, for all surfaces and for all modes of heat transfer I sum of the heat that is coming in at any time minus the corresponding time lag.

Some will come instantaneously, for example, direct radiation will enter instantaneously, but others conducted you know the heat transfer I mean that is occurring by conduction through the wall will come with your time lag it will come later. So, I must take that all that into account and this is my current time this is the amount of heat.

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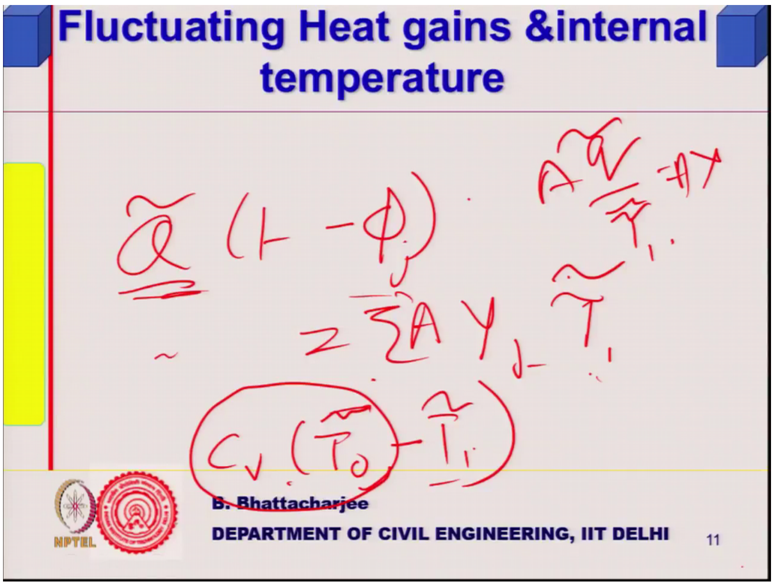

So, that will be sum of sigma of all those components and that must be equals to sigma A Y, you know that must be equals to that must be equals to. So, this Q t phi just let me write it first all this sum Q bar t minus phi j corresponding you know phi j as I said must be equal to A into Y sigma of this into j surfaces sigma AY into T i swing because by definition q divided by T i you know by definition q by T i swing q swing T i swing I am calling it as Y. So, if I multiply all by A sum it up for all the surfaces. So, that is that is what the equation is.

So, total heat that is coming in we are assuming that that we will go in increasing the fluctuating component of heat you know temperature fluctuating component of temperature inside, room temperature is constant and that is what I am trying to do, but one problem remains. As for as ventilation is concerned ventilation part of it I have taken care of. The part I did not take care of is C v T o swing minus T i swing. This part I did not take care of, while calculating the mean. So, this component will also go into it is this I mean this component you know this has to be taken into account and that is not what is happening when I in this equation actually.

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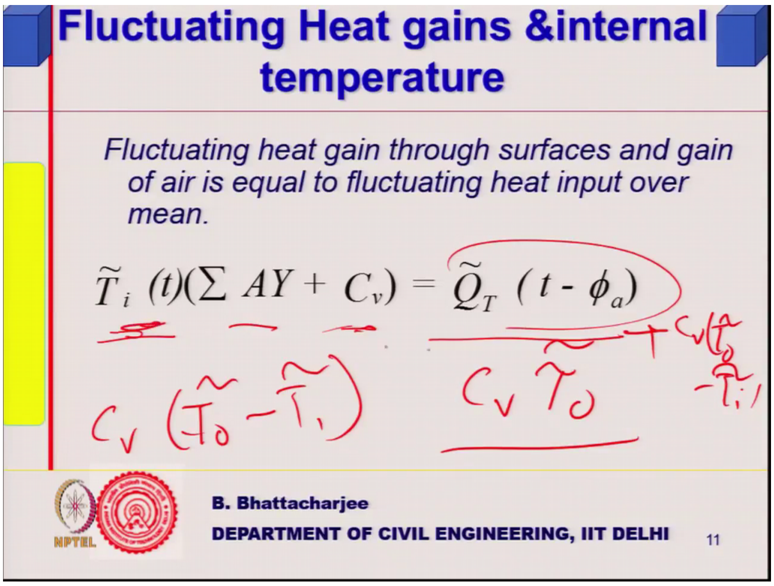

So, all fluctuating throughout the surfaces of air is equal to fluctuating heat input over mean. So, T i AY plus C v, T i that component remains C v into T i, I did not take into account. So, C v into T i and in this one C v into to swing that I will take care of that is taken care of here this part still remains because if you remember we did not take care of T o swing minus T i is swing. So, if I add this whole thing here, C v T o swing minus T i swing, T i is a unknown here and is equals to you know, it would be something like this it is all out.

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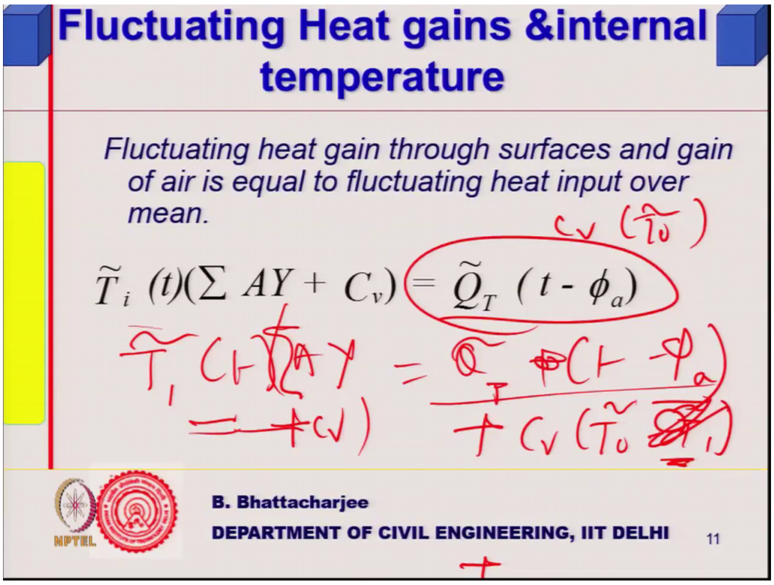

It will be T i t AY sigma for all surfaces equals to Q total that you know leaving ventilation part t minus phi appropriate as I said and also for the admittance I have to take into account plus C v T o i minus T i swing because C v I did not take care of this part. So, this part is the rest of the things except the C v let us say then this T i will come on this side because T i swing is unknown. So, this will be T i plus C v, if I write it like this part can cancel out.

So, this total includes C v T o swing this total must include C v swing then say you know T o swing then I can write expression on this in this manner. All here that I am trying to say you sum up everything all the heat input fluctuating component of over above the mean for the ventilation part you sum that up together with that heat flow C v into T o swing outside temperature swing the amount of heat that will come because just because the swing of the outside temperature and left hand side you will have AY plus C v sigma AY plus C v because C v T i swing has to be subtracted out and that is the equation would be.

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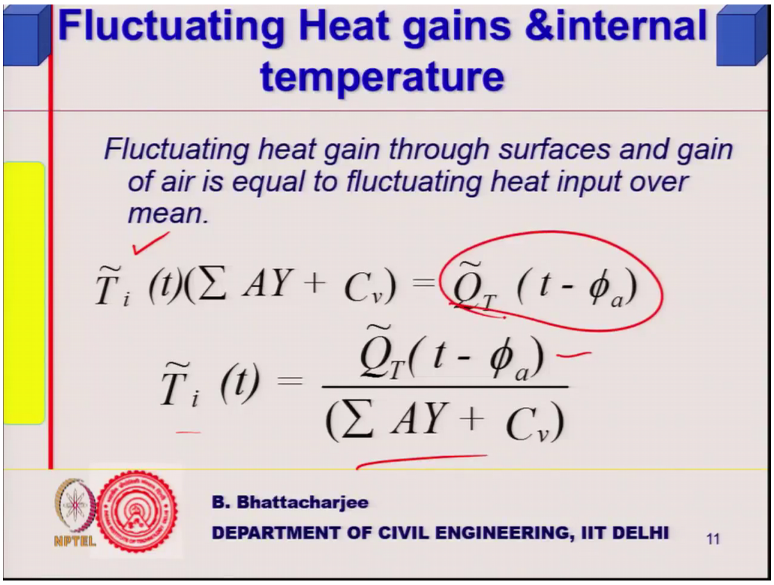

And, you can now, find out T i swing from such an expression you can find out. So, T i swing will be given as everything is included in all this. All that we are assuming that whatever heat comes in that comes through the

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Surfaces. Although they are not really conduction admittance was related to conduction, but what we are assuming is whatever it comes in because what we are saying is for any heat input into the room that will go in increasing the fluctuating component of the heat gain.

So, this is an assumption actually casual heat gain is taking place at different points in the room, but we are assuming as if it comes through the wall only as if it is coming through the inside wall only. We know then and air temperature inside the room is constant. So, that is again an approximation. So, this is how we can calculate out the inside temperature of a room and let us solve an example problem maybe mean temperature we have looked into last time.

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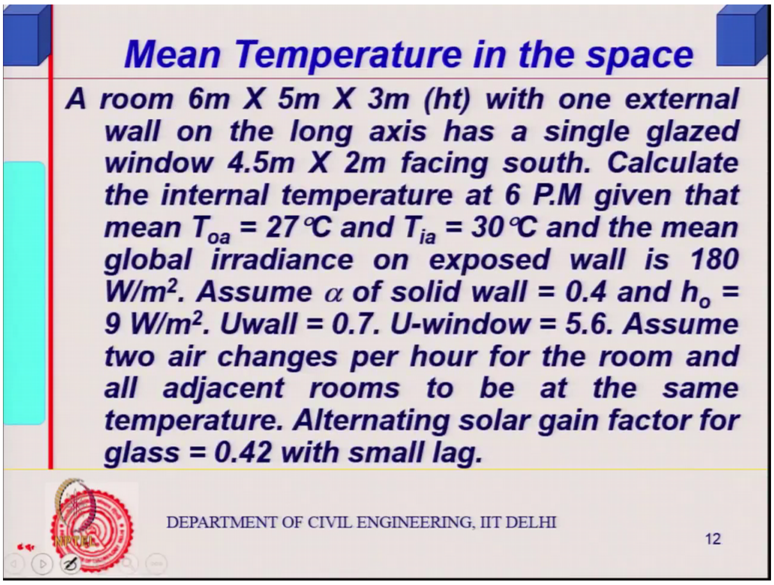

We looked into now, let us look into the problem same room same room we continue to see with one external wall etcetera all remain same T oa. Now, what we are saying is calculate the internal temperature at 6 P.M at a given time; given that mean T oa is 27 that is out earlier also it was there and T ia is 30. This is I have just said that you know T ia is 30 and the mean global irradiance exposed wall is 180.

Assume alpha of the solid wall is etcetera these are all same to air changes per hour and to be same an alternating heat gain factor for glass is 0.42 with small lag. So, all things remaining same, now I want to calculate our temperature at 6 P.M.

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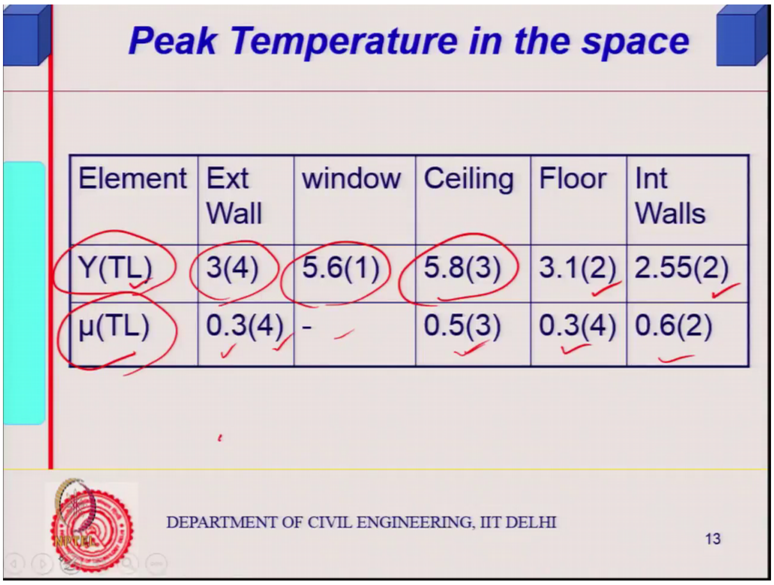

Peak Temperature in the space

Element	Ext Wall	window	Ceiling	Floor	Int Walls
Y(TL)	3(4)	5.6(1)	5.8(3)	3.1(2)	2.55(2)
μ(TL)	0.3(4)	-	0.5(3)	0.3(4)	0.6(2)

So, some additional data I need the outside temperature outside given this are the also the data must be available to me this data must be also. So, admittance values for all the walls are given and within bracket are given the corresponding time lengths right. So, TL is given here. The decrement values are given here and corresponding time lags are there given here for window there is no decrement, for window there will be no decrement factor, ceiling is given, floor is given, internal walls are given.

So, now I want to calculate outer inside temperature at peak temperature at peak time I want to calculate out the peak temperature I want to calculate out. This is the data given with this data given I want to calculate out the peak temperature.

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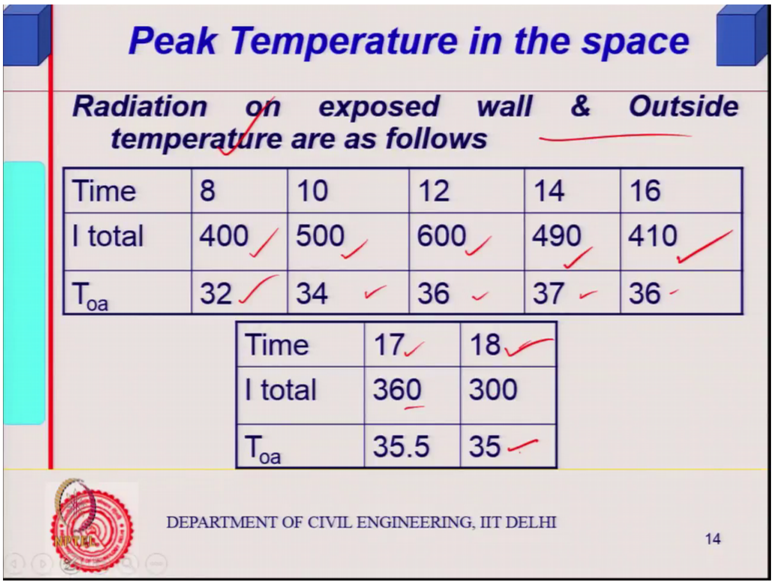

Temperature data is given here time 8 radiation 10 am 12 am 2 pm 16 etcetera and outside temperature values are given here right. So, I am interested in calculating at 6 pm that is 18 hours so that everything is given up to 18 beyond that it is not given right. So, whatever temperature was there at 18 hours, now I am interested in 18 hours, there may be something more 6 pm I want to calculate out radiation exposed wall outside temperature outside temperature I might need after that there may not be any radiation actually. So, after 6 pm there may not be any radiation, but temperature may still be there.

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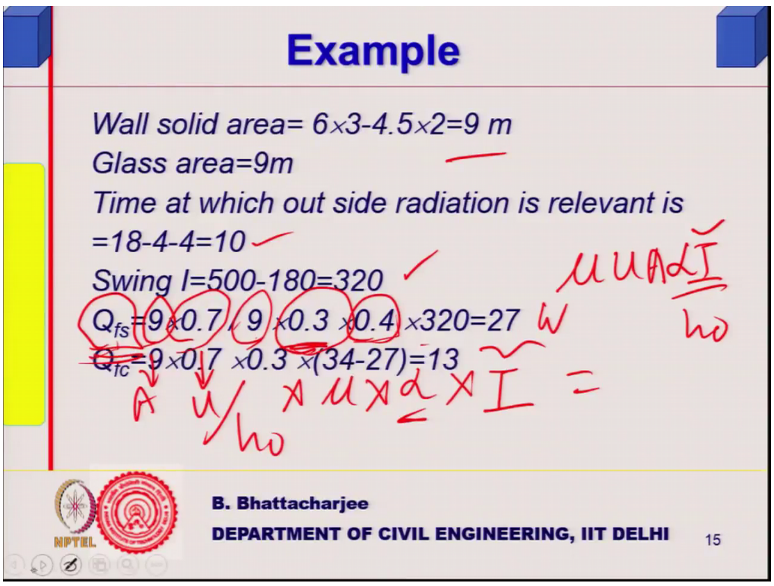

So, this was anyway their glass area we calculated it earlier as well, then time at which outside radiation is relevant is how much is a see if I am interested in finding out the temperature at 6 pm, 18 hours, the radiation 4 hours earlier because time lag for admittance is given as if you look at this table this is the radiation at 6 pm, but this will if I look at through the wall which was exposed external wall it had 4 hour time lag 4 our time lag; that means, the radiation which came 4 hours earlier would now effect, but temperature rise inside the room takes place because there is a temp time lag associated with the admittance also.

So, when you know at some time the heat comes in and 4 hours later the inside temperature rise takes place because admittance has got a time lag of 4 hours. So, the temperature at 18 minus 4 means it 14 minus another 4 because the temperature at 10 am or radiation at 10 am will actually be entering into the room at 2 pm 10 plus 4 2 pm, but that will cause a temperature rise at 6 pm. So, 8 hours you know I must take into account.

Similarly, for all others for window there is you know window glass the admittance time lag is only 1 hour and admittance value is you know admittance value is 5.6 it does not have any mu, decrement because heat will come straightaway for ceiling 3 hours and so on. So, this time lags has to be taken into account and I am calculating accordingly as you can see I am calculating it accordingly right. So, glass area 9, 18 hours minus a 10 am then I should take the radiation, because 4 hours because the room temperature at 6 pm will correspond to heat entry at 2 pm and the heat that is entering at 2 pm actually is due to radiation coming still 4 hours earlier which means at 10 am.

So, all the time lag we have to take into account and then calculate out. So, swing therefore, 180 was the mean and at 10 m the radiation is 500. So, the swing of radiation is 320 swing in radiation a fluctuating component of the radiation is 320 and therefore, Q fs. Q fs is due to what it is due to radiation falling onto opaque body and that would be area multiplied by u divided by h naught, remember h naught was 9, last class we talked about. Then there is a decrement factor right and this was the area there is you know decrement factor and there is there is decrement factor, U value decrement factor h naught and alpha into i.

So, let me write this is area, this is u, this is divided by you know this divided by h naught multiplied by mu multiplied by alpha into I swing that is equal to 27. You know area was 9 meter square that is what we have seen. Solid area is 9 meter square time is 10 m corresponding to this we have calculated that a fluctuating component of radiation that is say 20 that is at 320 and this is alpha value, last class last time when we solved for the mean we use a same value this is decrement factor mu.

So, mu u A, that is the heat coming in mu u A alpha I by h naught I swing that will be the heat coming in due to radiation falling into the opaque surface. So, that comes out to be 27 watt per meters, this is 27 watt.

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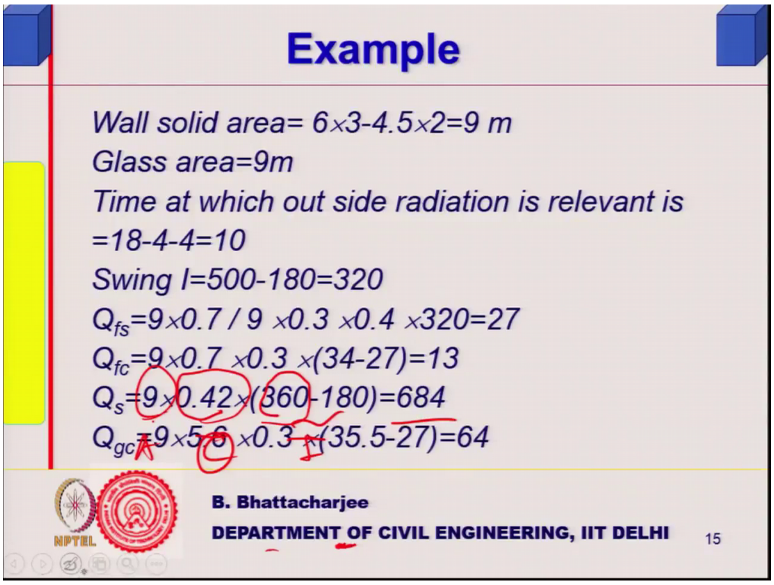

So, that is how we calculate out and Q fc due to conduction. Now, I will take same 10 am time temperature and that is 34, mean outside is 27. So, fluctuating component of the outside temperature is 34 minus 27 at 10 am it is 34 and this is mu, this is u and this is the area. So, here mu u A into delta t, that is, 13. So, this is the conduction gain through the opaque body, sum total of this two, then follow it up with Q direct solar radiation. Direct solar radiation there is no time lag.

So, at 6 pm this is you know sorry 6 minus 4, I mean 2 pm this is 360 because admittance 4 hours I will have to take into account, but I do not have to take into account of that glass direct radiation because it will have negligible time lag. So, 360 minus 180, 0.42 is the solar gain factor 9 and this is what it is. So, AI this is theta and I fluctuating is equal to 684.

So, this is through the Q s stands for direct solar gain through glasses.

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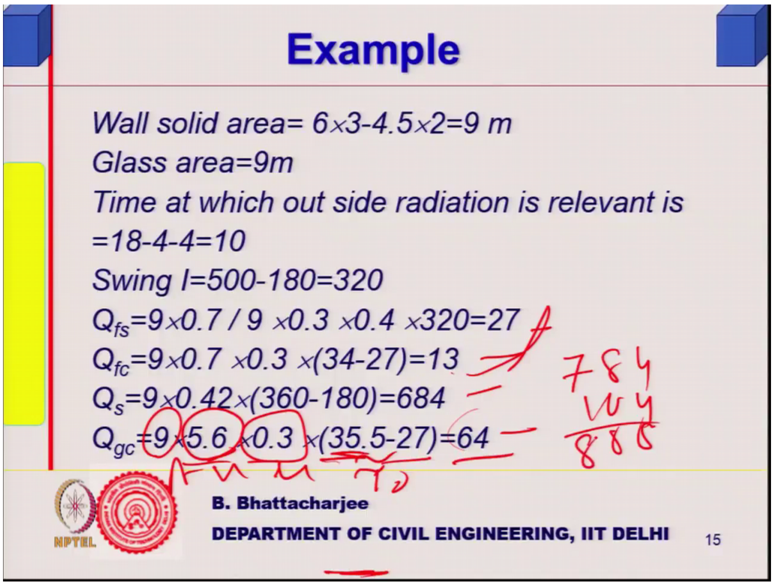

This conduction through glass and when I have conduction through glass it had 1 hour of time lag. So, 5 hours earlier you know I calculated out because this was 2 hourly temperatures were given. So, I take the average 5 hours earlier is 35.5 minus 27, that is the fluctuating temperature and this is the mu, this is the u and this is A So, A u mu and tau showing 64, that is what I will find out and then we are assuming there is no casual heat gain.

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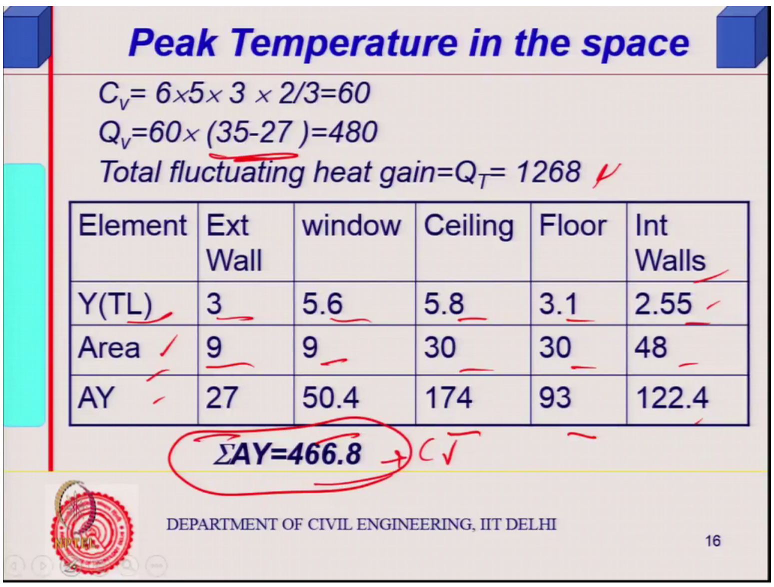

We are assuming there is no casual heat gain C v is 60 that we calculated outside. Q v is equals to 60 minus 35 minus 27. Now, this is what 27 is outside mean, 35 is the temperature at that point of time at 6 pm sorry 6 minus 4, that is, at 2 pm because 4 hours time lag will always be there because of admittance.

So, 35 minus 12, 480 this is to be added. So, you sum all of them and you get 1268. 480, 60 plus 684 plus 27 plus 13 you know if you sum all of them up sequentially as we have done just look at them all that we had we summed up. We summed up all of them 64, 684, 13, 27. So, this makes it 40 this is 104 plus 684, 700 and 84 plus 104 will make it 888 and then and followed by this is 888 followed by 60 plus 480.

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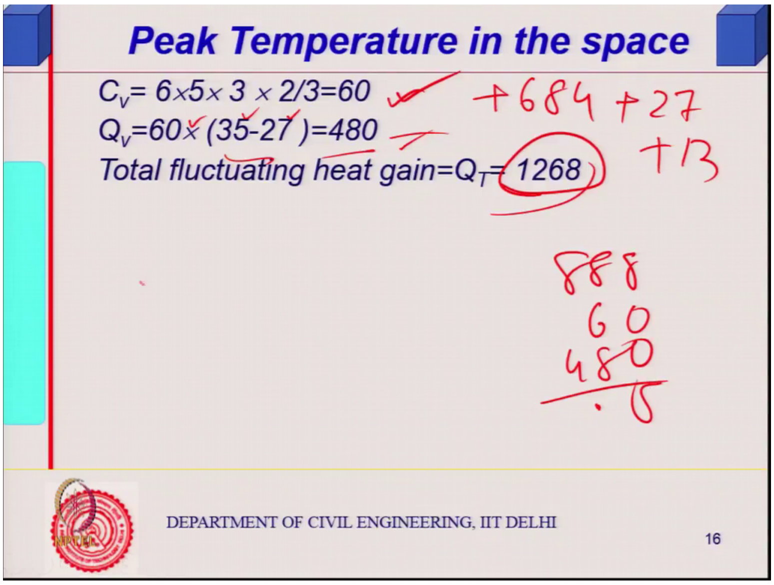

So, 888, 60 480 would be 8, whatever it is you know maybe I might if I have made a mistake there is a possibility, but it comes out to be 1268 in that manner. So, that is total fluctuating heat gain. Now, this must be equals to sigma AY plus C v into T i swing because half of the C v part we have taken, you know this is the outside part. Inside part remains. So, therefore, I calculate out now I calculate out Y for each one of the walls are given, area corresponding ones are given, I find out AY and then sum it up for all in, but here remember even internal wall you have got to consider you know all walls you got to consider.

Unlike, the well heat coming in comes to through one wall, but we are assuming that you know in a kind of a gross manner all the heat casual heat gain or ventilation heat gain this is all as if the wall receives them you know that comes in, but get distributed through the internal walls, that is an assumption we are making and that enters into the room 4 hours later because 4 hours is the time lag and causes a fluctuation in temperature. So, AY for all walls I must consider. You know internal walls includes is inclusive because we assume this is the assumption we are making that it will get distributed through all the walls.

In fact, what will happen is supposing there is a ventilation heat gain, the air exchange is occurring this would result in heating up all the walls internal walls right it is it not selectively may come through one of the windows, but finally, the room temperature and air temperature there is no surface temperature internal surface temperature they would be there is a you know like it cannot be that one wall is very warm compared to other walls they will get distributed in some manner because we are assuming room temperature air temperature inside the room is constant.

So, what we do is, we calculate for all the walls here AY, so, while calculating the heat gain you take specific ones while calculating the sum of the admittances multiplied by area it is for all the walls. So, that is what we do and then this sum is 466.8. So, what is my T i swing, this divided by this plus C v. So, this plus C v let us see what is it this plus C v 1268. So, this is a you know already I have taken care of this 1268 divided by this, so, 2.7.

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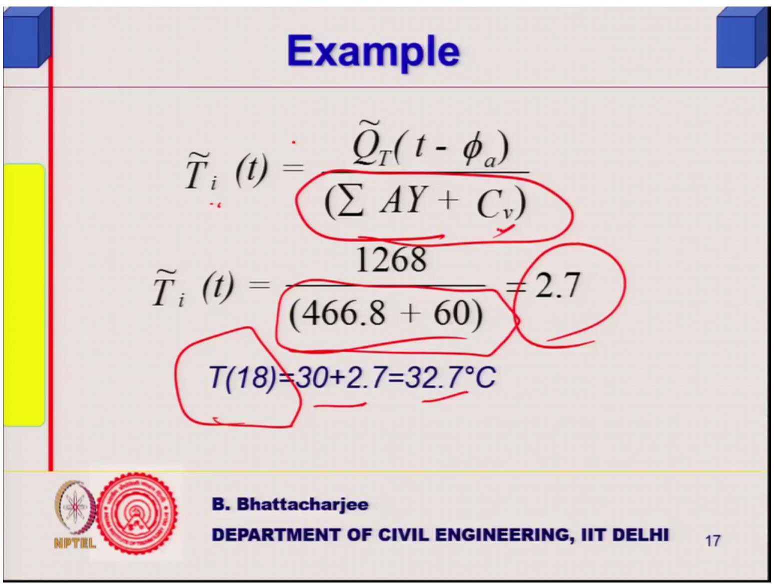

Now, at 6 pm what is the temperature then mean plus 2.7. So, T at 18 will be 30 plus 32.7 degree centigrade. So, at every time therefore, you can find out in this manner you can find out to all 24 hours. W hat is the temperature inside. So, all that you have to do is summing up calculate the heat gain taking the appropriate time lag and you calculate all casual heat gain, direct solar gain, all ventilation heat gain all and we make an assumption that as if it is all entering through the all internal walls and causing a change in temperature of the inside.

Therefore, you take admittance of all the walls C v part of the C v or ventilation it gain mean him in ventilation gain we took care of, but part of it we did not take care of. So, C v into T o swing that is added into the heat input and while calculating T i swing C v comes into picture here and that is how we calculate out. And this you could repeat for all the time of the day. I think we will you know answer some of your questions then go to the next one.