Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 13
Admittance Method (contd.)

Having defined decrement factor, let us define something else we call it admittance factor now decrement factor relates outside temperature swing to inside flux for unit temperature swing how much will be the flux inside that is what we find we define another factor called admittance factor.

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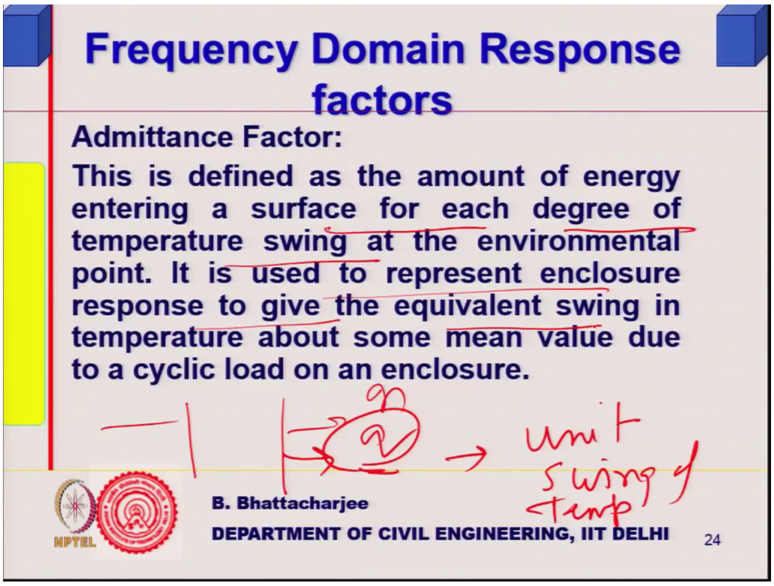

This is the amount of energy that is entering into the inside surface for each degree temperature rise temperature swing you know whatever is for example, is in the same surface. So, in this surface itself this is outside this is inside, let us say how much is the heat flux for unit swing of how much is the heat flux for unit swing of temperature how much is a how much is a q required to cause unit swing of temperature unit temperature serve temperature right that is the idea.

This is defined as the amount of energy entering the surface for each degree temperature swing at the environmental point here right it is used to represent enclosure response to give the equivalent swing in temperature about some mean value due to a cyclid cyclic load on the enclosure. In the enclosure, there is a cyclic heat load due to that how much will be the cyclic temperature right that is what we are trying to find out in other words we are trying to find out qi divided by t I you know how much qi I required for unit temperature right, qi by ti q earlier I was finding out qi by q now I am finding out qi by ti now qi I will find out from the decrement factor use that to find out the ti ti that is the idea that is the idea that is the idea actually alright that is the idea.

So, let us see, I mean I can admittance is nothing, but one over impedance conductance transmittance were similar in similar terms remember resistance we talked about impedance is the resistance in a periodic or cyclic or alternating situation and one over an impedance is admittance. So, admittance is basically you know ti over qi you know ti or qi I mean admittance impedance would be ti over qi admittance will be qi over di qi over ti that is idea.

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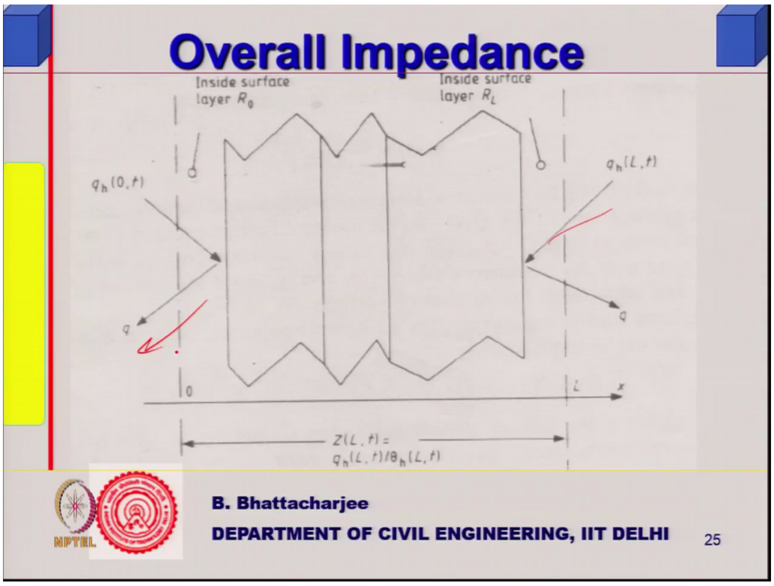

You know like for example, if something is coming here this is causing. There is layer layered construction inside q inside q, how much is the temperature rise here that is what? Is a mathematically defined as qlt tlt and we denote it by y which is nothing, but qi by ti heat flux swing of inside temperature when I am keeping outside temperature constant when I am keeping the outside, there is no fluctuation outside there is no fluctuation you know it is like first; I allow inside to remain constant allow it to come in for a outside swing.

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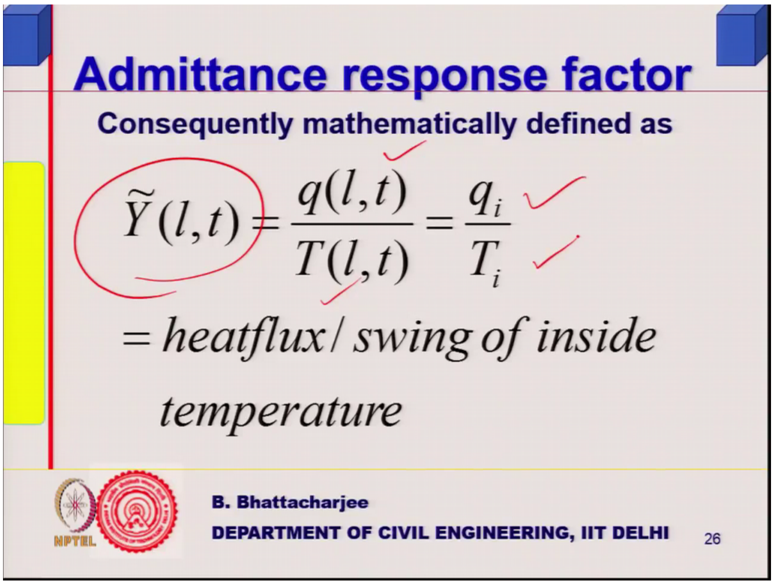

Now I say the outside is constant and this is similar thing we do you know if a moment distribution if you have studied you first allow some rotation find out the you know fix T fix it fixed end moment allow the rotation at the moment.

In the linear system similar analogy is there, you do something similar, heat flux per unit swing of inside temperature Y bar can be determined from transmission matrix assuming constant outside temperature now our equation was something like this ty ti qi was ABCD to qo last time we took an inverse now possibly I did not need not take an inverse because I am trying to relate to 2 I mean ti to ki ti to qi and to is 0.

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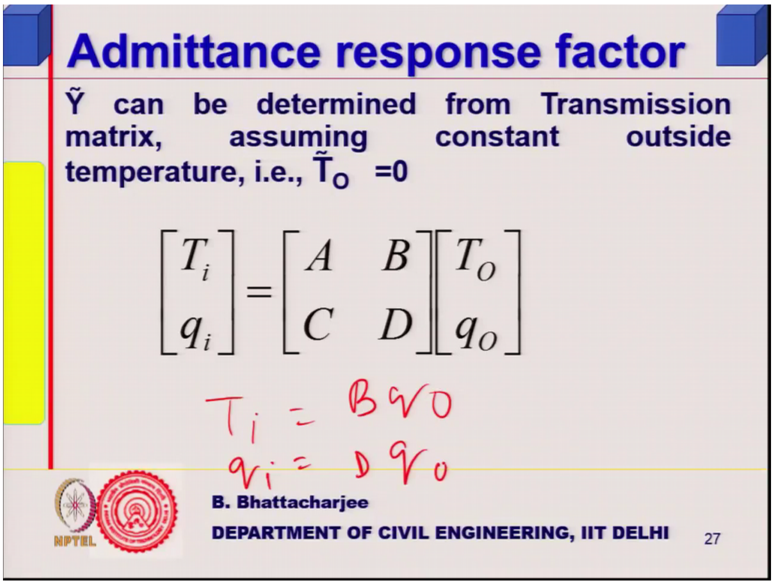

2 things will go you know it will be T_i will be simply equals to Ato plus Bqo since to is 0 this will not be here Q_i will be Cto plus Dqo, ratio I can find out this will cancel out, that is what is done.

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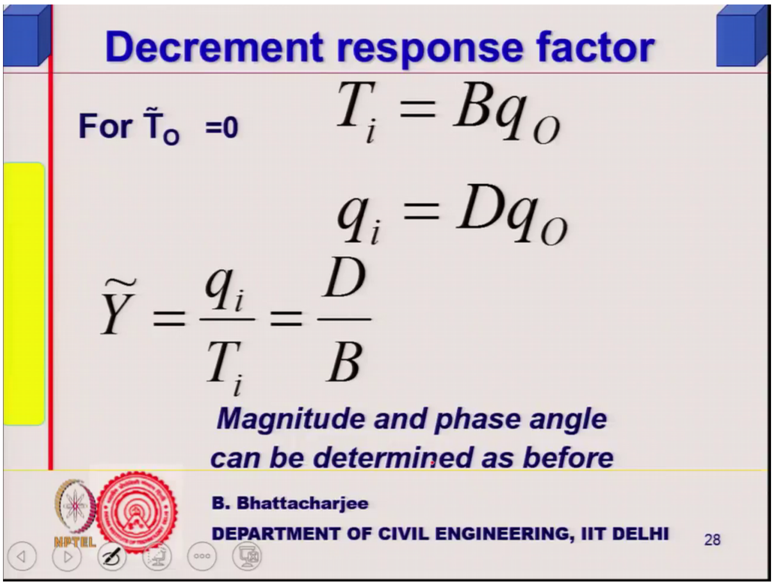

For 2 is equals to 0 this is what it is and admittance is given by Q_i by T_i d by B .Again it will be a complex number again it will be a complex number such that there is a small time difference between temperature increase and heat coming in heat comes in and after sometime there will be a temperature increase you know. There is there is, that is that is what it is here of course, we are dividing it this is a there is the difference between these 2. I mean q_i by T_i. D by B I can find it out magnitude and phase angle can be determined as before in the same manner you determine the magnitude because it will be X plus I_y and the root x square plus y square will give you the you know magnitude and 10 inverse of Y by X it will give you the phase angle.

There are other response factors such as surface response factor this is the ratio of heat flux readmitted to the surface right usually internal for example; you know how much of it is going inside again to the total flux absorbed. What is the flux absorbed how much it is reentering that is what we find out.

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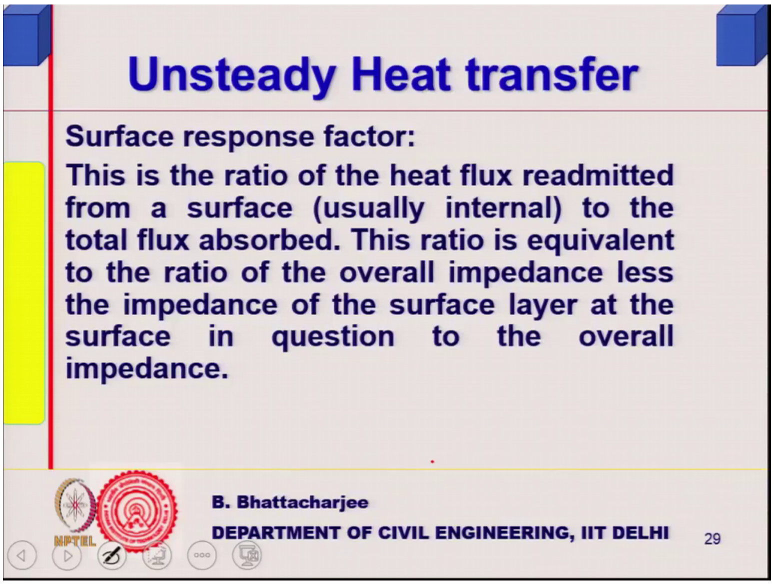

And this ratio is equivalent to the ratio of overall impedance less the impedance of the surface layer because that would cause it to reenter into a system we do not use this surface response factor.

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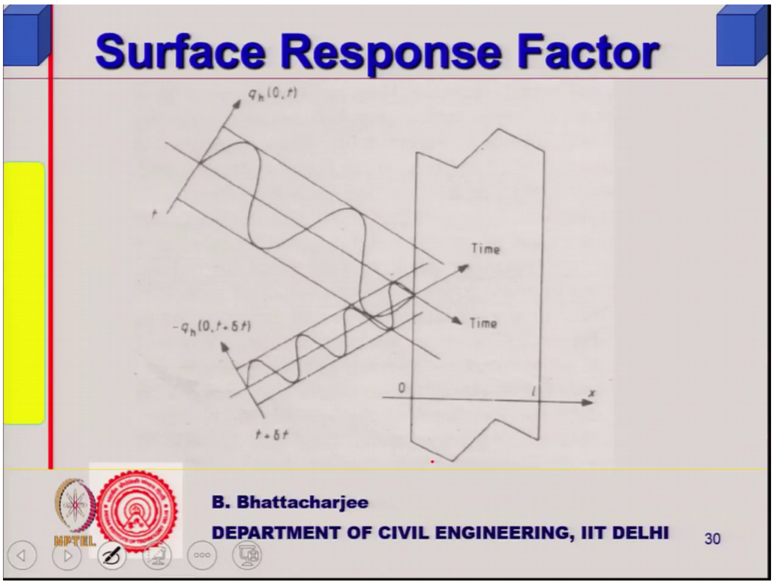

Too much you know it is coming in part of it is readmitted, that is what it is we do not use it so.

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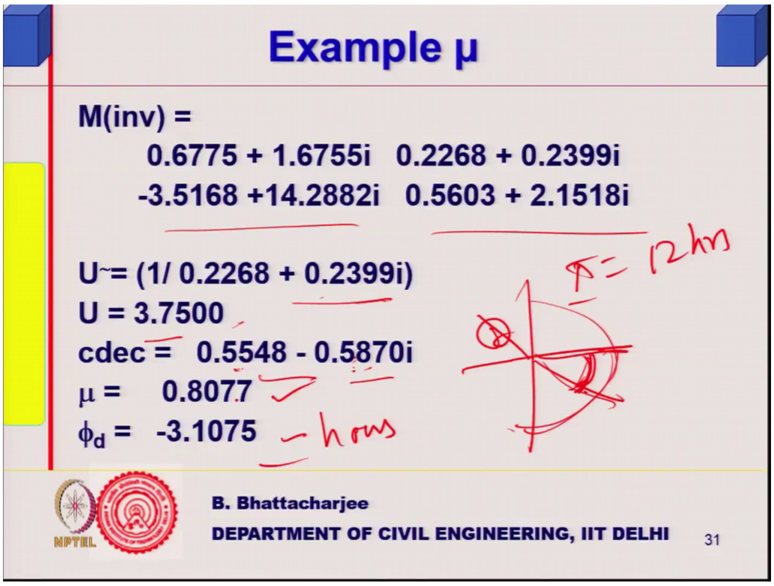

Mu calculation we can now we can look into some of those example calculations. We will see how use this at a response factors or response factors to find out the internal temperature of unconditioned room or find out the heat flow in a conditioned room where inside temperature is by and large constant actually there is a what we call design differential you know differential existing in air conditioned system because it is never constant, but for our purpose in this class we assume it to be constant if you are actually doing a control system then how much fluctuation you allow that would you know this operational differential we call it that that one has to look into and take account of that in a design of control system, but we are not interested in that here we are we will assume the inside is constant in case of in conditioned room and in unconditioned room inside temperature is unknown we will try to find that out.

In conditioned room inside core temperature is called you know constant how much is the heat flow energy load that we can calculate out right not the machine load how much is the through the envelop what is the energy gain that we can calculate out using this 1 right cooling load into the system if it is withdrawn at certain rate it you can see. First we are let us have an example calculation of Mu. Mu calculation of the same 1 M inverse of that matrix that we talked about if you calculate out will be something like this you know M inverse of this matrix will be something like this overall matrix that we had it is inverse would be something like this u is equals to 1 by 2 to 6 set to 3 at 9 and you can find out U 1 over U inverse is this U is this.

Complex decrement factor is given by this you take it is. In fact, it would lie in this quadrant right no Y in this quadrant it lies in this quadrant this is negative real is positive. Somewhere here and this is in hours, magnitude of this 1 is this square plus this square under root gives you this and this will give you some angle in radians right now phi radians corresponds to 12 hours. This 3 hours would be possibly it comes to some 5 divided by 4 close to some you know 4 or something, from that you can find out 10 inverse of this by this right 45 degree it would be close to 45 degree 45 degree means somewhere there..

This is 12 hours no this is not 12 hours this is this is 6 hours half of this will be you know 3 hours. That is what is you can find out from this right, that is how we can you can check this calculation yourself example of Mu.

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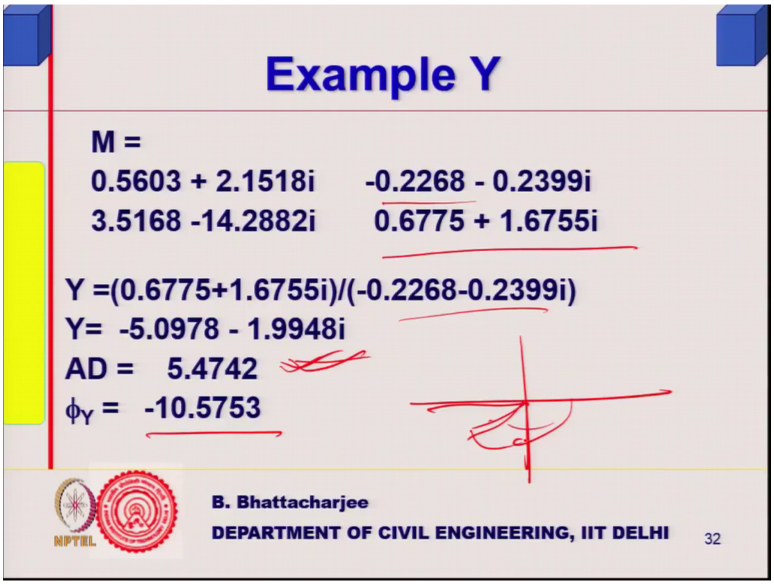

Example of Y for the same 1 it was D by B, D by B could be something like this rationalize the denominator multiplied by this minus this plus this and divide by this you get twice goes to this. This is what you get admittance value you get something like this and it is corresponding angle you get something like this right.

Both are in the negative both are somewhere this and this somewhere there somewhere there it shows this is actually 6 hours 10 hours comes out to be something else, that is how you calculate out Y and you know you calculate out that is how you actually calculate out you know mu and let us see now calculate out the inside temperature make use of all this to calculate out the inside temperature of a room now in order to do that I must look into.

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So far we looked into conduction heat transfer and shown how you can shown how we can calculate out the steady as well as some response factor because of a temperature suing which can be utilized to calculate out you know if you know the inside swing how much if the heat flow inside you can calculate out and also that would cause how much doing that you can calculate out

We will make use of these factors, but other heat transfer you should look into ventilation heat exchange is fairly simple because ventilation heat exchange means outside the air is coming and inside air is same you know inside air is going out right because volume of the room is constant. Outside air enters at a particular temperature therefore, specific density it will have a specific density. In fact, it will have a specific density and specific heat value also would be corresponding to the temperature right and inside the air goes out now supposing outside air is cool it will come and get it will absorb the heat from the room inside the air is warm. It will absorb heat from the room and the air that has gone out it will go out the room temperature the all the air that goes out will be at the room temperature.

Basically it absorbs heat means it is you know outside here it is temperature increases sensible temperature sensible heat it exchange is occurring right. Mass into specific heat into delta t mass into specific heat into delta T now mass here is a basically rho density keeps on changing rho into volume of air that is coming in volume of air that is coming in minus rho same volume where will go out rho into same volume of air you know and rho is a function of temperature. 1 can actually one can write it you know V meter cube letter say is the airflow.

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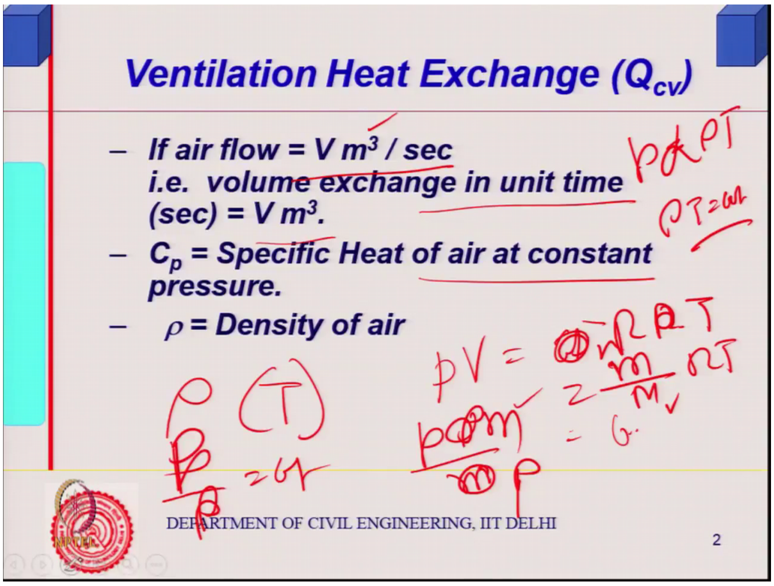

Let us say A B meter B meter cube is A B meter cube is a first second is a flow of air that is coming in from outside.

It can come we are not talking of force based ventilation by design in an unconditioned building I leave openings fenestration is the terminology used for openings used for by design not by default and infiltration for example, there is a leakages through the window or the door below the you know this is not fitting in perfectly this would be infiltration right something will you know air will come on come in and go let us say V meter cube per second is a flow V meter cube per second is the flow V meter cube per second is the flow then volume exchange in unit time is V meter cube that is what we are saying.

Now, specific heat of air let us set at constant pressure because pressure is constant you know there will be slight variation if it is air conditioned have an exhaust and things like that, but here I am not doing anything. Pressure is constant, you specific heat of air at constant pressure C_P rho is the density of air and. Therefore, simple way, but as little bit complicated I could make it because rho is a function of temperature right rho is a function of temperature and how it varies you know P_V is constant pressure into this is constant ideal gas right.

We per unit mass if I even operate mass, but density is nothing, but mass per unit volume mass per unit volume. This I write as P into volume is mass M by rho is that correct or I have written it wrongly m by rho it should be M by rho it should be P_M by rho and that should be constant right now rho basically in other words P by 4 same P by rho is constant for a same mass right an R_T etcetera I think I am not going to that. P sorry P is constant all mess P_V NRT etcetera N is nothing, but I can write mass divided by mass divided by mass molecular weight of air R_T.

Rho is m by v rho is M by V. P is equals to rho T P is proportional to rho you know or P is constants or rho t is constant in our case rho t is constant rho t is constant using ideal gas law I have made it a life a little bit.

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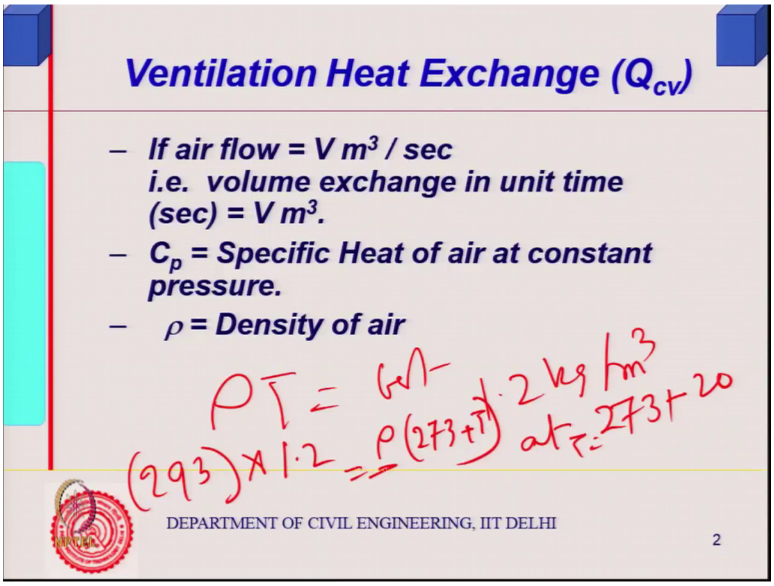

Complicated this value is simple rho t is constant now if rho t is constant we know 1 point 2 kg per meter cube at 273 plus t is equals to 273 plus 20 density of air at 20 degree centigrade is 1.2. At any other temperature you can calculate out because this would be 2 7293 into 1 you know into 293 into 1.2 is equals to rho into 2973 plus T.

At any other temperature rho you can calculate all right, but we do not go into this complicacy in this particular course again we are simplifying we are assuming a constant overall constant rho and t values over the I mean rho over the range of temperature that we are operating on right approximately take a constant value for rho and C constant value for.

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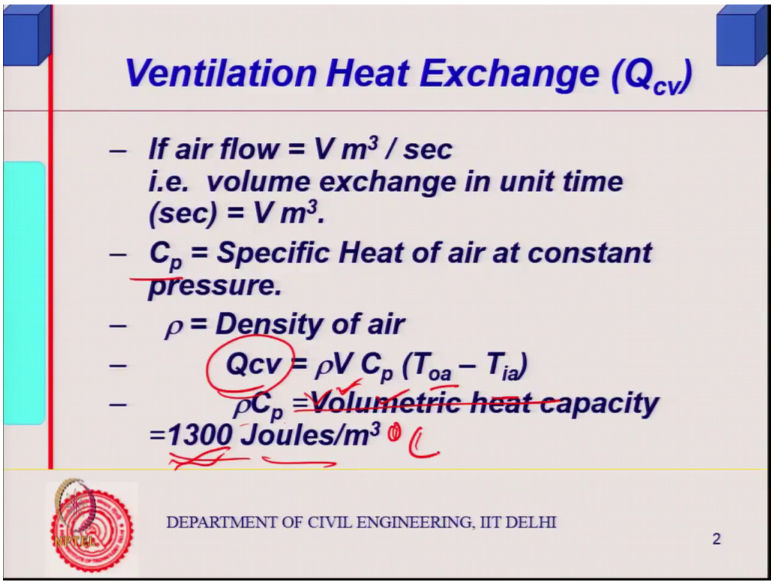

Rho and C_p because C_P is also a function of temperature a little bit, rho is density of air, we what we are saying ventilation heat transfer is equals to rho C_P V Toa minus Tia because whatever air comes in it will attain the room temperature yeah and whatever is going out is same you know outside.

The temperature difference, V comes in and v goes out simultaneously V goes out at TY inside temperature. Depending upon whether is gaining, let us say outside temperature is high inside is less direction could be anything. This can be written like this q ventilation heat transfer now V, we write in terms of the room volume room volume V we write in terms of room value slightly change this. Volumetric heat capacity and we take this value constant for this class as 1300 joules per meter cube if you are doing and trying to design an air conditioning system then you have to go into more details, but for our purpose this class purpose we are taking approximately rho CV C_P is goes to 1300 joules per meter cube right because C_P is what joules per kg per degree centigrade and rho is kg per meter cube.

Rho C_P is in terms of joules per meter cube right is it correct yeah, but it should be part degree centigrade also should be part degree centigrade also. This is should be part degree centigrade also or you know the or Kelvin whatever it is.1300 joules per meter cube degree Kelvin that is what to use and V_R is the volume of the room we define a term called number of air changes per hour number of air changes per hour; that means, if N into V_R is the flow per hour what we are trying to say is that in 1 hour time total amount of air exchange that is occurring is N times the room volume is N times the room volume what we are saying is that air comes from the outside comes from outside and somewhere goes out.

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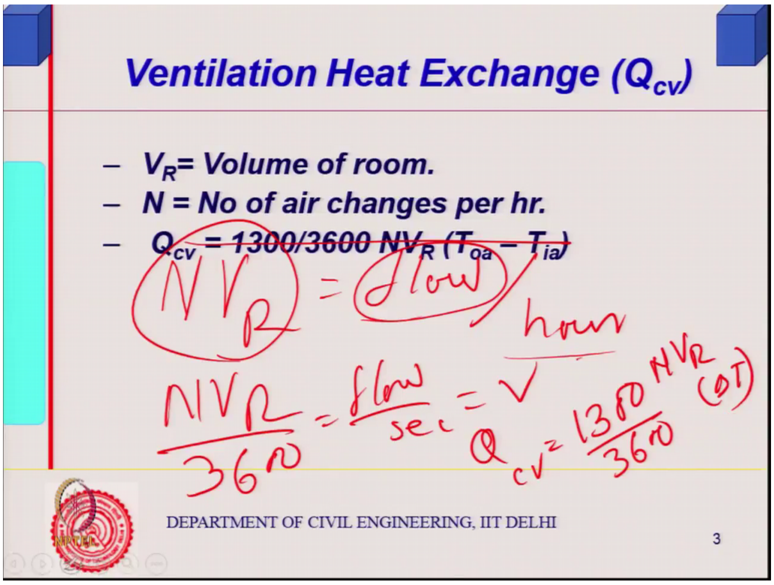

There is an air exchange right and number of time the complete room volume get exchanged in an hour that we call as number of air changes per hour we call it simply number of air changes.

N is the number of air changes per hour. NBR is a flow per hour and flow is therefore, I write it QCB is 1300 by 3 6 0 because this was you know if it is in flow is in meter cube per second. This will be divided by NVR is the flow per hour. NVR divided by 3 6 0 is the flow per second which is nothing, but V which is nothing, but V, you know. Our QCB was 1300 because we said rho C_P is 1300 into NVR divided by 3 6 0 into delta T temperature difference and that is what I am writing TIO minus Tia that is what I am writing that is what I am writing and some books simply takes this as one third NVR you know Toa for this purpose only for the purpose of design of envelope for thermal designing of envelope, right.

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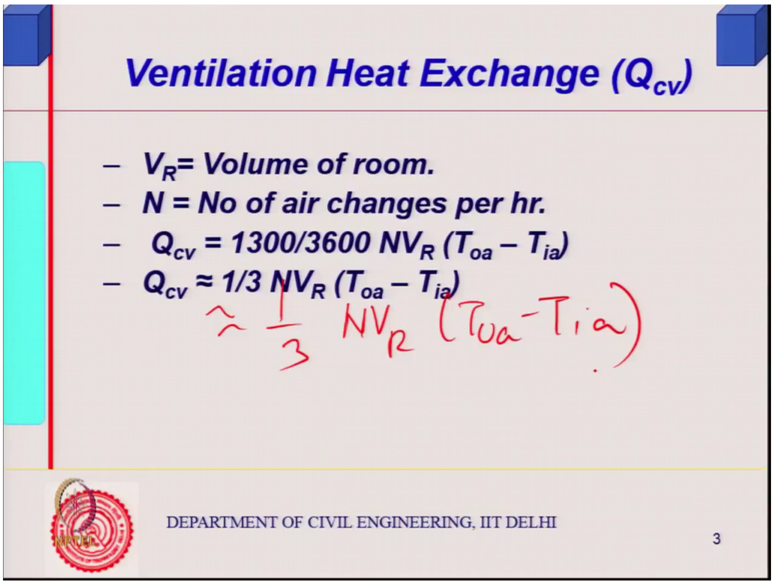

You can you can take more accurate values as and when required we might take a great value, this is taken as 1 third NVR 1 third NVR 1 third NVR QIA minus TIA.

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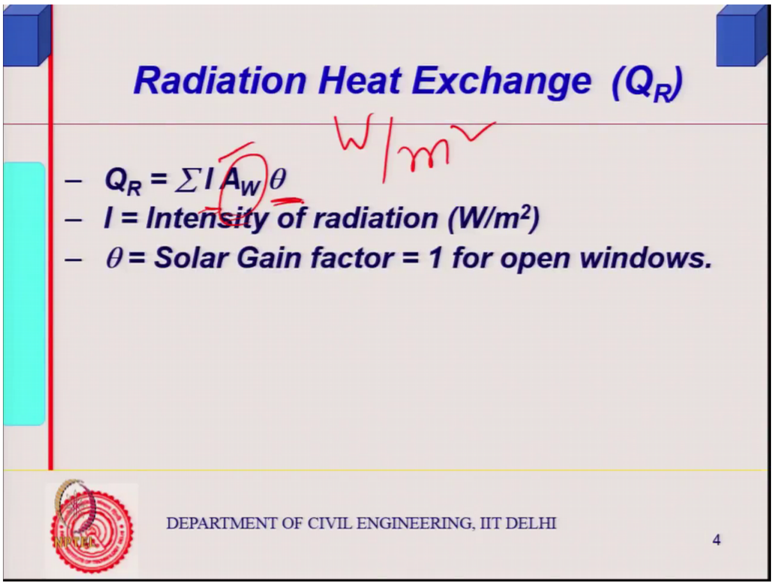

Ventilation heat transfer heat exchange is something like this and if we assume constant N you know N is given in code, when we talk of ventilation design, we look into do natural ventilation design minimum N required for hygienic purpose in a conditioned room or even in any room natural ventilation even that is given in the code because you have got to have at least 3 to 6 air changes in a habitable room to remove carbon dioxide to remove carbon dioxide etcetera you know. That is hygienic ventilation required for thermal you might need even more we will to come to that sometime appropriate appropriately when we are dealing with it when we are dealing with it right, so that is it and there is nothing to erase right.

This is how we calculate out ventilation air exchange radiation heat exchange I have not used fluctuation or anything at the moment radiation heat exchange simple through the glass I is the intensity of radiation area in this given in watt per meter square. If I know the radiation in you know intensity of radiation on the surface which is actually IB cos I etcetera remember IB cos I that we calculated out. That is the watt per meter square coming onto the wall or glass multiplied by area of the wall into something we call solar gain factor solar gain factor.

I intensity of radiation theta is solar gain factor theta is solar gain factor if it is one for open window because everything will come in for a window open it will come in, but if it is glass it will allow part of it to come in part will be reflected back part will be absorbed by heat also because glass itself will get heated up right depending upon type of glasses depending upon type of glasses for example, you might have heat reflecting glasses right which will reflect the heat, but one thing related to glass very important is that you should allow visual light to come in. It should allow visual like to come in, but theta is related to NV the all the other energy that is coming in AW is the area of window.

Radiation heat exchange you treat like this ventilation heat exchange we treat just the way I just mentioned and conduction through the opaque body or radiation falling onto opaque body you can treat it the way we did for you know unsteady state heat conduction equation casual heat gain.

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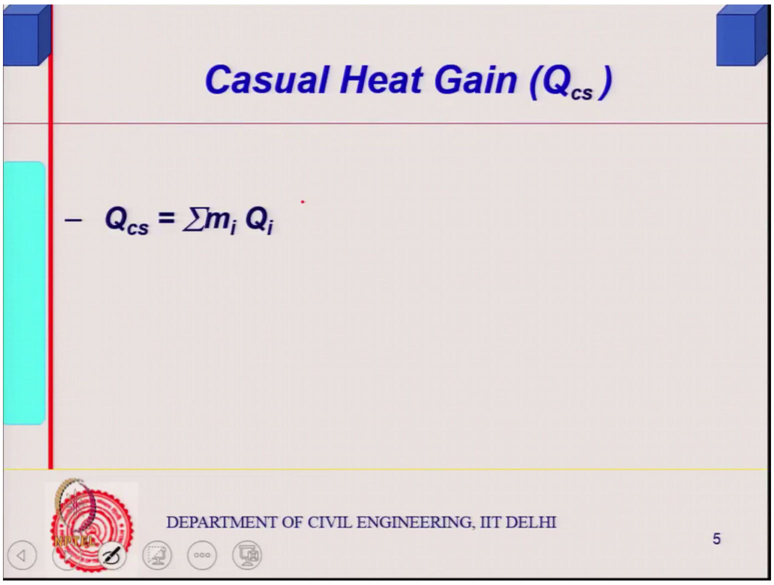

Casual heat gain is a heat gain due to appliances and human this casual heat gain you know that would for example, all the all the all the all the heaters fan if you have a refrigerator and things like that that would actually generate heat and that heat individuals generate metabolic heat as I said because if you are working you know if it is in a factory sort of a situation a lot of people are because these days not such factories are not too many, but supposing you have a factory sort of situation where people are working physical labor that you know making something to move.

Let us say a precast hollow core slab factory people have to walk you know and. So, on and even carry something drag a EOT electrical overhead crane EOT crane right. That that is you generate heat. All these are included in casual heat gain for all the day and take a average if you are taking the mean heat gain. That is what it is, now, you can calculate with those now we can go on calculating out the temperature in a space now we know the major modes of heat transfer we looked into and what we found we looked into if you remember to collect; we had conduction through opaque bodies because outside temperature is there and opaque body is receiving direct radiation that will also come through conduction and we also looked into how we express and you know these 2 for the purpose of this heat transfer; we take an equivalent temperature, we call it sole air temperature and then we have looked into if it is unsteady scenario how we treat it to find out how much heat will come in also we looked into ventilation heat transfer ventilation due to opening radiation heat transfer etcetera.

Now, we can actually use this all these equations that I have given for each mode of heat transfer we can sum them up to find out how much is heat coming in and correspondingly what is that temperature right now 2 aspects we bifurcated 2 things one the steady part and the fluctuating part we just study we handled in a separate manner fluctuating part we handle through those response factors that we discussed for a single harmonic that is an approximation, but that is as long as you are choosing the right envelope for the purpose of you know for the thermal design purpose right.

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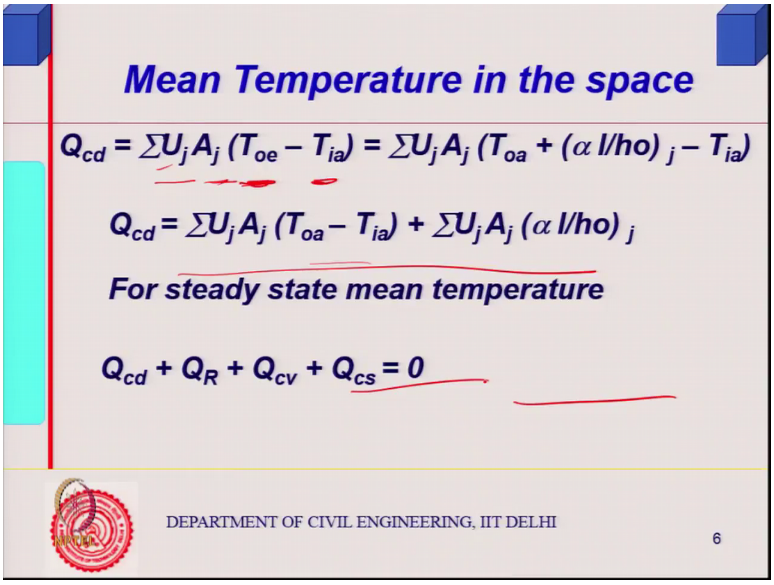

QCD therefore, let us write this equation conduction temperature QCD just recollecting those same you for all the surfaces j stands for J 1 to whatever M N number of surfaces AJ is the area and if it is receiving solar radiation then you will use toe which is the solar temperature minus Tia right and where it is not receiving radiation it will be simply Toa minus Tia inside temperature that is the equation of heat transfer right. This is this is this is for this for this is for you know opaque body is receiving radiation not receiving radiation only this term would be there.

For steady mean steady state mean temperature what we do is we assume that whatever heat is coming in that must be equals to 0 because my temperatures are all constant I had outside mean constant and inside mean also was constant. Therefore, total heat gain mean heat gain must be equals to 0 because there is no change there is no change right for the mean only mean inside mean is constant outside mean is constant now what is physically happening you see inside mean I have said is higher usually outside mean is somewhat lowers I am talking of mean not the total temperature.

Now, what it means is the some heat will come in from outside by conduction right conduction and also by some heat will come in outside by conduction, but the ventilation conduction heat transfer might take place because that is the opaque body outside temperature you know outside I mean basically that if you if you see because I am talking of only of the mean these are all are mean basically QCD mean QCD mean and this will be going out this will be coming in. This is be entering this will be going out and for mean I am talking only of the mean not overall there will be gain and loss sometime during the day and daytime they will be gain there will be loss because of fluctuating 1, but when I am this hypothetical mean I am separating out.

Mean QCT will be going out because temperature difference exists that the delta T delta T bar or you can call it delta t radiation it will come in right because suns radiation we are talking of we are not talking of the terrestrial radiation going out which you think is very small. It will come in CV will also go out because outside temperature is higher and this is also a gain casual is always a heat gain. Heat gained by because of human activities and functional purpose in the space appliances and human being heat gain casually came due to that or heat gain due to radiation in flux has to be dissipated mean all average is has to be dissipated out through mean conduction heat loss and mean ventilation heat loss right.

This sum total is equals to 0 that sum total that is right because the inside mean is remaining constant outside mean is remaining constant. Hypothetically if I have no fluctuation then heat generated must be going out otherwise temperature mean would have increased day by day inside mean would have increased outside mean I am assuming in it as constant. Since this is not happening this is what I can assume. This gives me a way to find out inside mean this gives me a way to find out inside mean because that is the unknown. I can set an equation all heat gain or heat loss equals to 0 mean heat gain and heat loss equals to 0 and find out that inside mean inside mean right for an unconditioned building for conditioned building anyway temperature inside is constant and that is equals to the mean temperature no fluctuation practically even if there are a small fluctuation that we can take care of.

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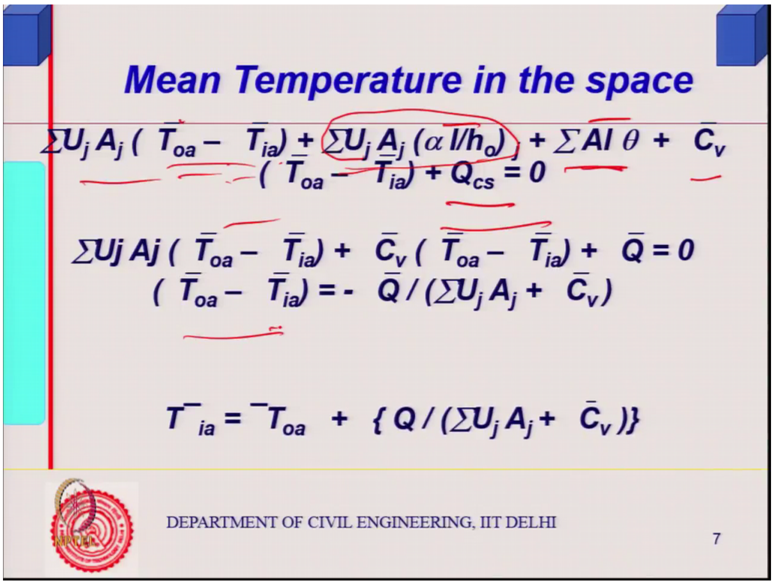

I put this equation like this Uaj Toa Tia Uaj Toa Tia Uaj etcetera AI theta CV you can see that this part does not have Toa minus T_{ia}. Even the radiation falling onto the effect body that would cause gain only no loss that would caught gain again this is called cause gain this will cause gain this is what cause of loss and this mean outside these are all bar you can see that Toa bar Tia bar all are actually I bar I bar you know all these are Tia bars. These are we write as mean we denote by A bar. If you put all of them equals to 0 you can separate out this and find out the Tia find out the Tia.

Find out the Tia bar is equals to Toa bar plus q by and here I am using CV bar because CB average CB, I am taking because day time, there will be change in here changes might change. So, I take the average everything average calculate out mean of I would vary from for the whole day I take the mean I add them up divide and find out the mean similarly t temperature mean we have found out earlier CBN would change number of air changes will change from how to or you find out mean and that is how I find out Tia. So, we will a problem on this.