Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 01
Introduction & Environmental Factors

So, good morning everybody this is lecture one.

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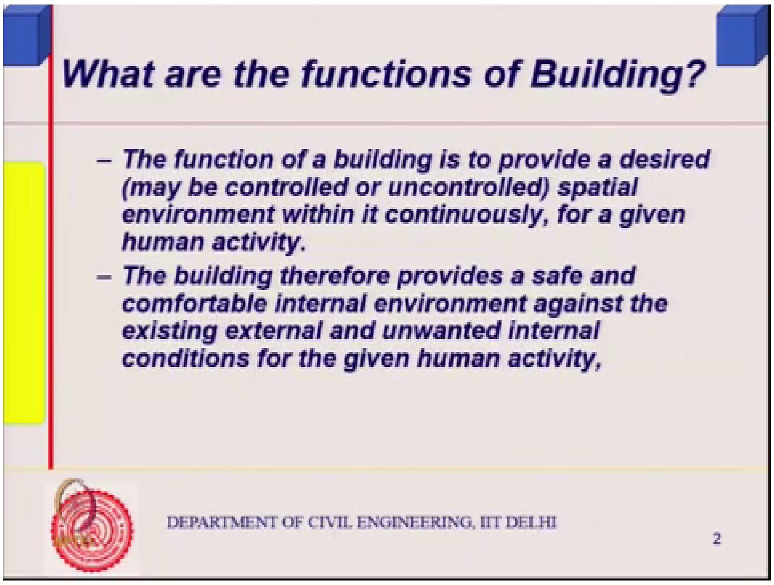

First it is related to functions of the building. So, what are the functions of buildings as you can see this, first thing is it must provide a safe shelter structurally safe all right and desired spatial environment within the space right, for any human activity for example, this is a classroom. So, this is what is called teaching of readings, you know teaching of readings. So, it must have good acoustics. So, that you can hear, must have good visual environments. So, that you can write right and of course, comfortable from thermal point of view, it is one of the most important thing right, thermal point of view.

So, for that human activity here is teaching, teaching of reading right which means teaching learning interaction. So, that is what it is. So, building must therefore, provide safe and comfortable environment internal environment against existing external and unwanted internal conditions for a given human activity.

Now, what is external condition for example, high temperature outside lot of humidity relative humidity high. So, I must have, I must have a comfortable environment against such kind of external perturbation. Similarly noise outside or noise generated within. So, it should be comfortable against such a thing, but; obviously, safety is most important and building must accomplish all this economically.

We would normally one would be talking about lifecycle cost in this context, but anyway cost is not enough, you know issue in our approval rate right. So, first to talk about safety which you have learned through an undergraduate programs.

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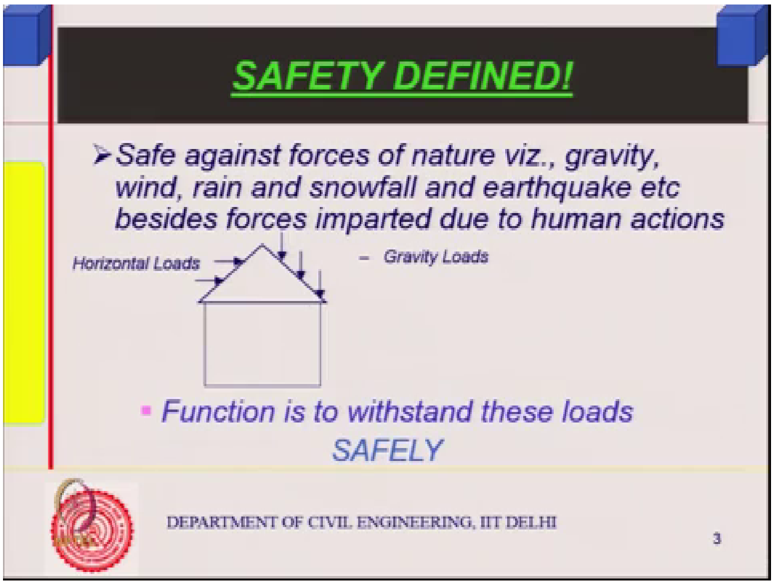

It is safe against all kind of natural forces right, safe against natural forces such as gravity load first of all gravity, you know like if you have to stand somewhere they your own weight would be there. So, gravity load small load. So, many of them are vertical load wind rain etcetera wind and earthquake they also contribute to horizontal loading into the building impacts and so on right.

Because of human actions load can also be there. So, if I show it schematically there are many of them are gravity loads, most of them are gravity load and there could be horizontal load as well because of earthquake and wind and it must be safe against all these forces. So, that is what we are saying. So, that is the safety and we are not discussing this in this course.

Safety is not already you have so much of elaborate understanding of the same. So, we will not discussed this.

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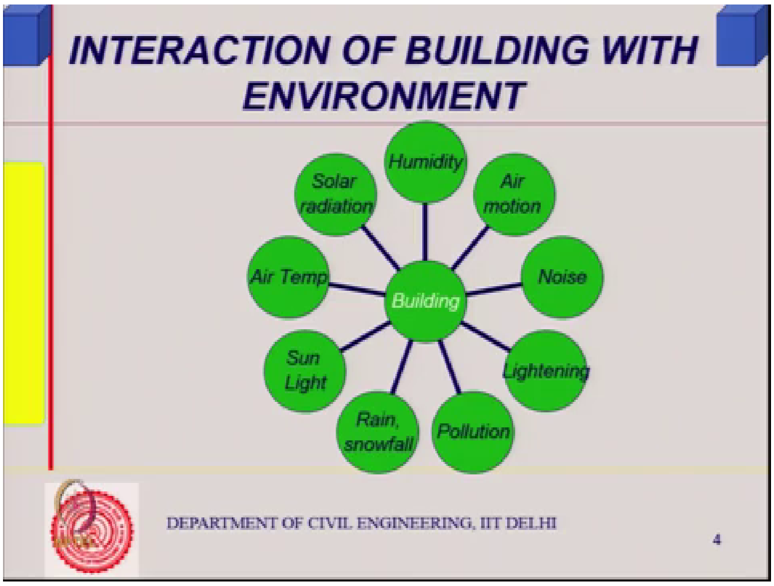

So, building interacts with surrounding environment earth, that is what we are looking here and you have humidity air motion as you can see noise lightning pollution rain and snowfall precipitation as we call it, sunlight, air temperature, solar radiation and all that. So, as you can see these are the arms as you see building is at the center it interacts with all those environmental factor outside.

So, to start with we will discuss this environmental factors how we account for them how do we quantify them, how do we quantify them any measurable item how do we measure them, because in technologies science and engineering you know, basically technology science based engineering right not empiricity would like to reduce.

So, I would like to model effect of air motion on to the building we are looking at the comfort not the loading part of it right, similarly effect of you know temperature outside heat transfer into the building and so on. So, therefore, in order to do that we must quantify them, we generally mathematically generalized physical system models when we talk about mathematical modeling we generalize it basically it is a mathematical generalization. So, that is what we like to do and therefore, we must look into each of this one how they we measure them and how do you quantify them right, in physical or terms of maths and physics let us see.

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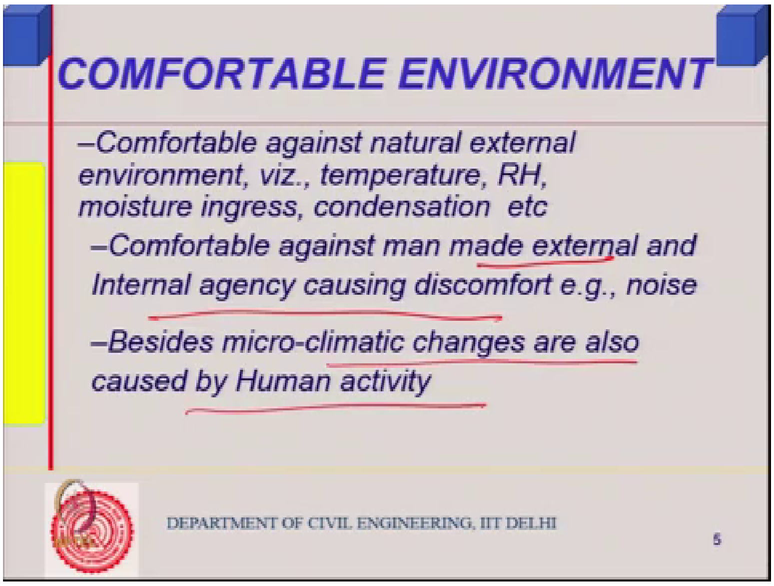

So, comfortable a moment convert it must be comfortable against external temperature, relative humidity moisture and gas condensation etcetera right and must be comfortable against man made external and internal, you know external as well as internal red colored. So, it must be comfortable against man made external and internal agency causing discomfort.

For example noise, besides micro climatic changes are I will tell you what is micro climatic changes for example, you change the you know your activity human activity lot of building they will change the thermal conditions surrounding the building. So, we will talk about that later on.

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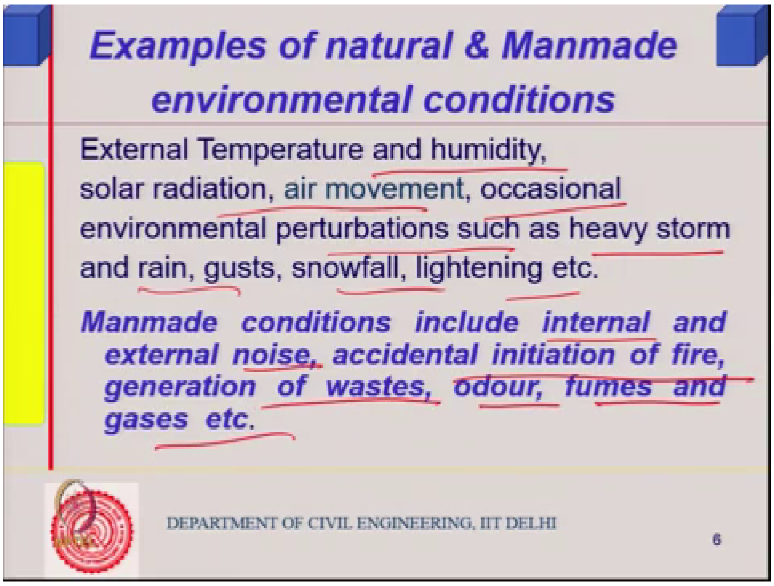

So, examples if I say external temperature, humidity, solar radiation, occasional perturbations such as heavy storm, rain, gust these are external, manmade, internal external noise accidental initiation of fire which I am not discussing again in this course, generation of wastes, odour fumes and gases etcetera. So, these are manmade thing they can cause discomfort right ok.

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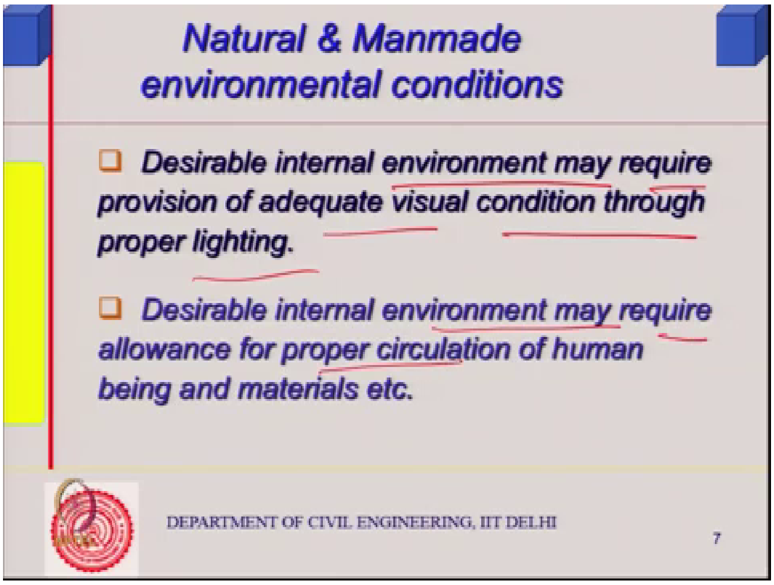

Then desirable internal environment may require provision of adequate visual condition through proper lighting. So, these are desirable condition and desirable internal also may require reliable proper circulation of human movement and materials, you know space this is an architectural issue again we are not discussing here. Circulation space, comfortable ergonomics even you know space between 2 rows minimum distance between 2 rows.

So, we are not talking of this in this class except for in case of auditorium design we will talk a little bit related to this.

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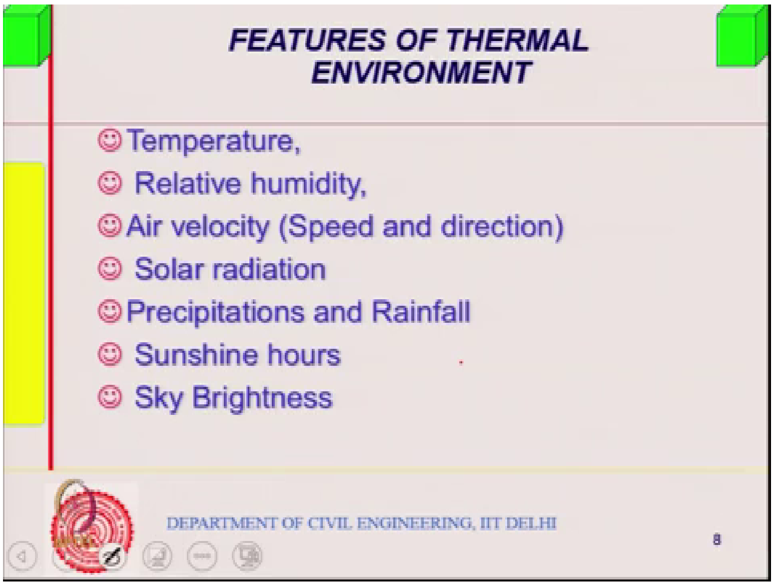

So, that is kind of you know interaction what we will have. Now, as I was telling you that we look into the environmental features which we like to quantify and in terms of some measurable items. So, temperature is one of them, first is the temperature. So, we are looking at the thermal aspects. So, thermal environment temperature is one of them, now temperature how do you measure we will come to that. Next one would be relative humidity, air motion, air velocity, speed and directions is an important solar radiation these are all related to thermal comfort. Then precipitation or rainfall because that is that is what causes relative humidity change significantly and sunshine, hours how many hours sunshine is there.

Then sky brightness is related to day lighting sky, sky brightness is related to day lighting. So, these are the features of environment and based on this kind of features we actually classify climate. So, climate is you know climate classifying or group the whole globe into several climatic zones and then zones in a given region, also we will talk about that a little bit later. So, these are the features based on we define them let us see how do you measure temperature.

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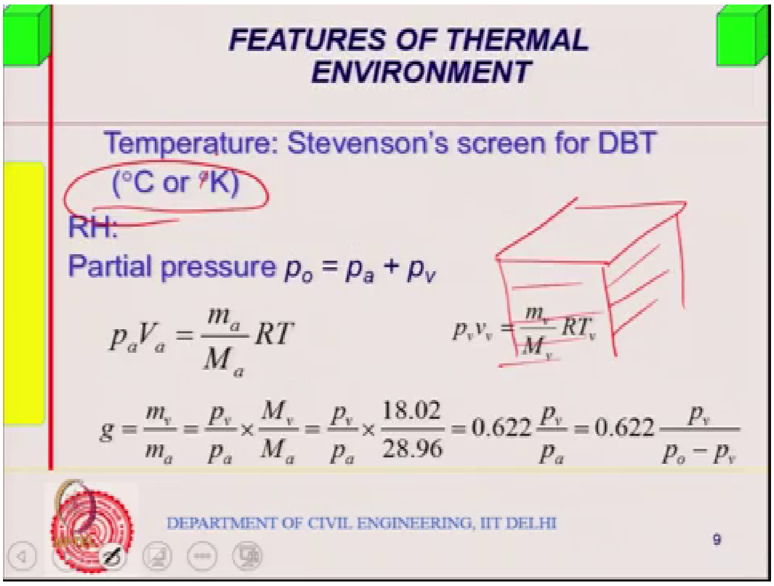

If you want to measure air temperature is measured in what is called Stevenson screen. Now, do I have a diagram of this, if I do not have I will just draw it for you no problem it is like a box, it is simply like a box you might have seen and it will have louvers right. So, it is a closed box. So, that direct sunlight does not come in, wind does not affect their air motion, there is no air velocity significant air velocity inside it remains dry, there is no rain coming into it protected from the rain and you measure what you call dry bulb temperature inside. So, what you measure is a dry bulb for example, if it is a thermometer well there are better varieties of measuring devices.

Liquid thermometers are well known, mercury thermometers where expansion of market mercury you know because it has got a linear expansion or expansion does not vary with the temperature itself rate of expansion. So, temperature change volume change per unit temperature will remain constant over a very large range that is why mercury's use, some cases alcohols are used then there are other things like what we call, platinum resistance thermometer because resistance has changes with temperature.

I am not discussing them you have a you, if you I I believe some of you might take a course on lab. So, in laboratory class they might discuss this thermocouple is very popular, what is the thermocouple you have a hot junction and a cold junction and if you put this you know 2 dissimilar metal when you connect them together there is a potential difference that would exist or alloys you can understand that you know for example, different metal will have different tendency to lose electron.

So, if alloys will have similar sort of things. So, if you connect two dissimilar of them momentarily there will be as current flow because there will be a potential difference existing between the two, but if one of the end is at high temperature and another is at lower temperature so there is a potential difference generated between these two. Now, this potential difference is a function of the difference in temperature between hot and cold junction.

So, since thermocouple works in this principle, but then again voltage EMF generated part degree centigrade must be constant. So, every type of thermocouple will have its own range of measurements for example, copper constantan, chromel alumel, platinum and platinum rhodium thermocouples. So, these are these are used basically for measuring temperature, thermistors there are several other measurement devices we are not going in details into this. So, the unit is of course, degree centigrade is not degree Kelvin, it is Kelvin, simply Kelvin written you know absolute scale of temperature.

So, this is one thing, this is all measure of temperature now relative humidity, what is relative humidity? Let us first define relative humidity I think I will come to the algebra part of it later on, but I think I have not defined yeah, you see the air is nothing, but a mixture of let me go back to this and write it here straight away.

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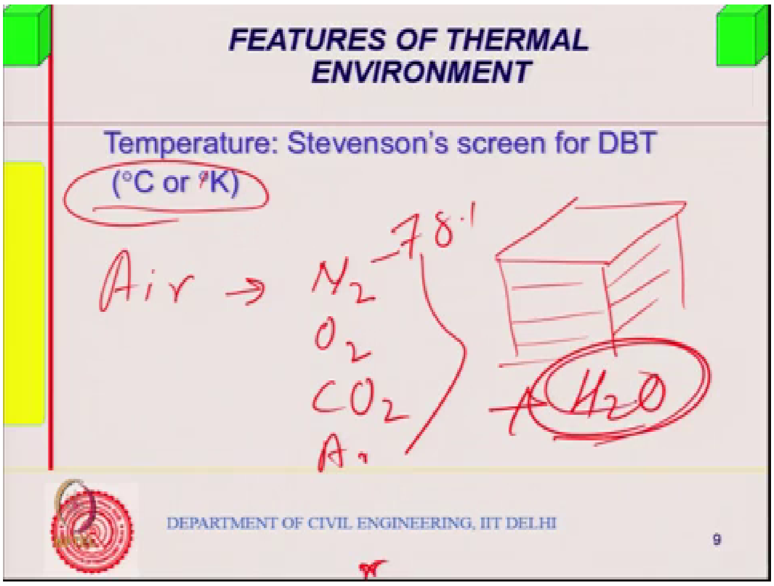

Here essentially is a mixture of nitrogen, oxygen, carbon dioxide, little bit of argon right I think it is a a r argon not ag ag silver. So, a little bit of argon and obviously, moisture vapour right. Now, this is around 78 percent as you know 21 percent or whatever it is I am not really interested in this, but I am interested in this part. Now, it forms a kind of gaseous phase solution. So, this is the vapour, moisture vapour and this moisture vapour has got an importance related to thermal comfort, as usual see later on the body would like to maintain a fixed temperature right, you know deep body temperature has to be constant.

So, if outside surrounding atmosphere is warm, warm under the deep body temperature it would actually you know heat flow to occur from outside to inside, but then what you would like to reject it. We will discuss this mechanism sometime later on, but one of the mechanism is losing by evaporative cooling. So, for example, in the skin moisture the skin if it evaporates, latent heat of evaporation will be taken from the skin itself and it will cool down the body itself it will cool down.

So, therefore, relative humidity or moisture content in the surrounding environment is important because if it is dry it can absorb a lot of moisture, if it is already saturated because it is a kind of a solution as I said. So, there is a air has got a capacity to you know absorb moisture vapour and this is a function of temperature itself, higher the temperature it can absorb more moisture vapour.

So, relative humidity is related to that, relative humidity is a kind of measure it is the capacity for the surrounding environment to absorb moisture. So, we talk in terms of you know we talk in terms of relative humidity.

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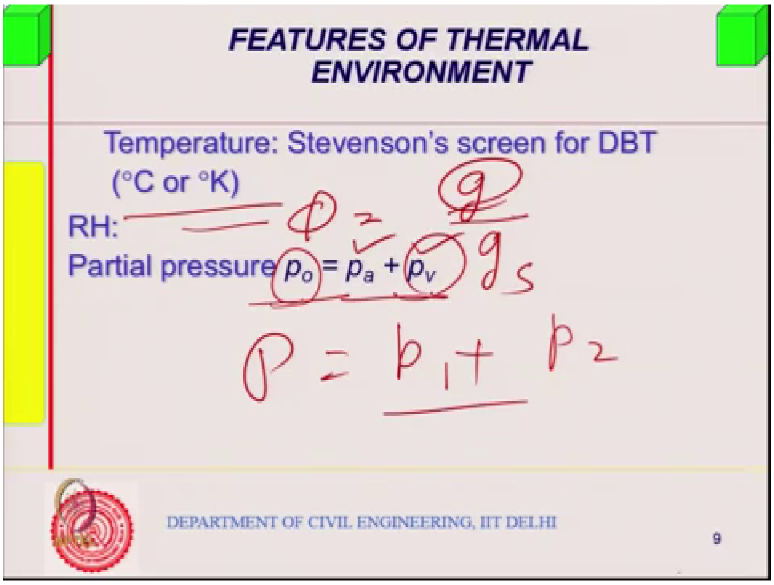

We talk in terms of moisture content, that is if I denote it by phi it will be moisture content g sometime we denote it by g moisture content we denote by g as we shall be doing in this class divided by g s, saturated moisture content at that particular temperature that is how we define so relative humidity we define this. Now, how do you define partial vapour pressure or partial pressure of 2 gases supposing I have 2 gas and I you know individually it occupies a volume v gas 1 the pressure is p 1 and second gas which occupies the same volume its pressure is p 2 right.

Now, when I mix them together same mass of the 2 and mix them together and put in the same volume the total pressure will be sum total of this one, you can understand from basically connect theory of gases because pressure is nothing, but molecule hitting the boundary of the vessel, when I pack them together 2 gases; obviously, they will exert more pressure. So, partial pressure is the pressure of the gas in a mixture which is the pressure when it occupies the same volume as the mixture itself. So, p is p 1 plus p 2 partial pressure. So, in case of air partial pressure of air for partial pressure of vapour is a total pressure right.

Now, if I, if relative you know if the g is more moisture content is higher, this will be also higher. So, I can relate this to partial pressure vapour pressure as we call it to the relative humidity all right let us see how do you do it, let us see how do it.

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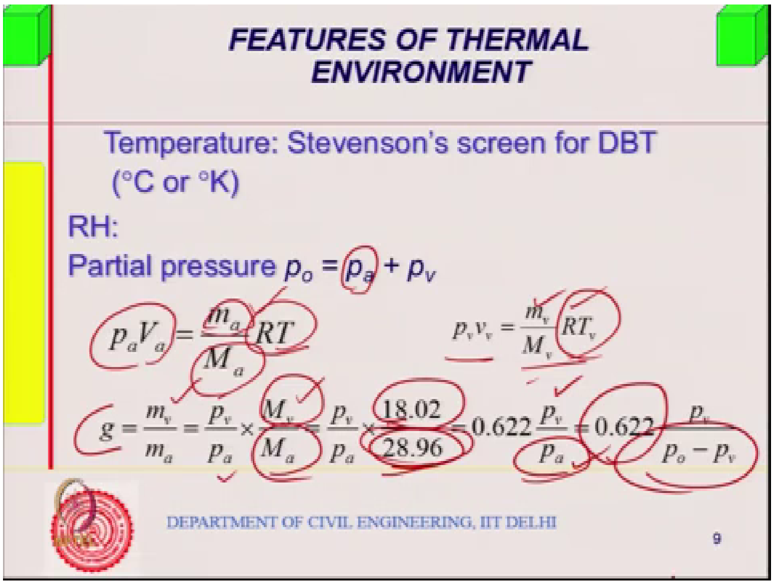

So, partial pressure will be written like this and we treat them as ideal gases. So, P a let us say it is only the dry air, V a is equals to the mass of the air there divided by molecular mass of air RT, similarly for vaporize I can write in the same manner and both of them are occupying same volume by definition. So, g is mass of the vapour divided by mass of the dry air that is how we define the moisture content, this will be simply from this one it follows right. So, g is mass. So, this divided by this and therefore, it would be this divided P V, m V divided by p a m a right, v will cancel out from both the sides this will also cancel out because temperatures are same right and this universal gas constant because already we have taken end into account.

So, this value molecular mass of water is 18.02 and molecular mass of air is 28.96, now what does it come because nitrogen we know is 28.78 multiplied by nitrogen molecular weight of nitrogen because it occupies 78 percent is a, 78 percent is a nitrogen, oxygen we know 21 percent or whatever it is. So, when we sum them up I get 28.96. So, this therefore, p v by p a comes in and pa is nothing, but atmospheric pressure minus vapour pressure.

So, you can see that moisture content is a function of vapour pressure and 0.622. So, it is it is actually can be related to the vapour pressure of air right ok.

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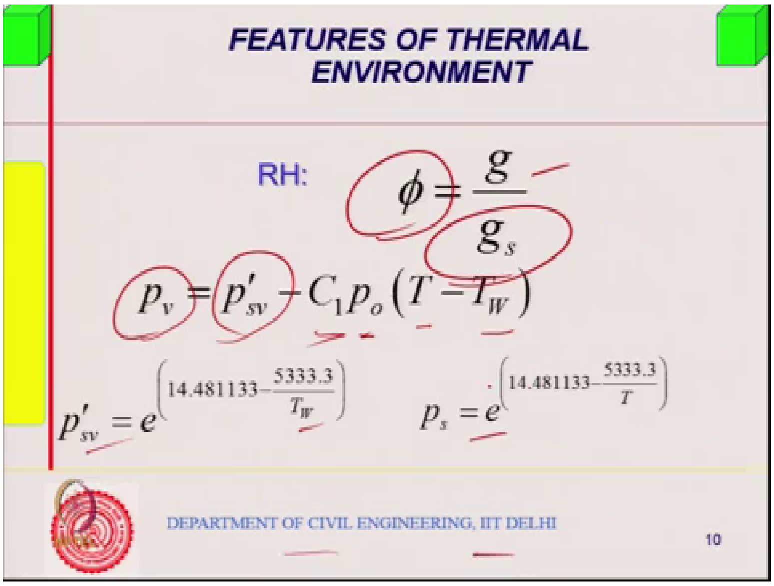

Now, there are some empirical. So, relative humidity is g by g s saturated moisture content at saturation for the same temperature. So, there are some empirical formulae maybe I will solve a problem sometime, but there are other ways of finding this out also phi g etcetera, it is through psychometric chart I will come back to this sometime later on.

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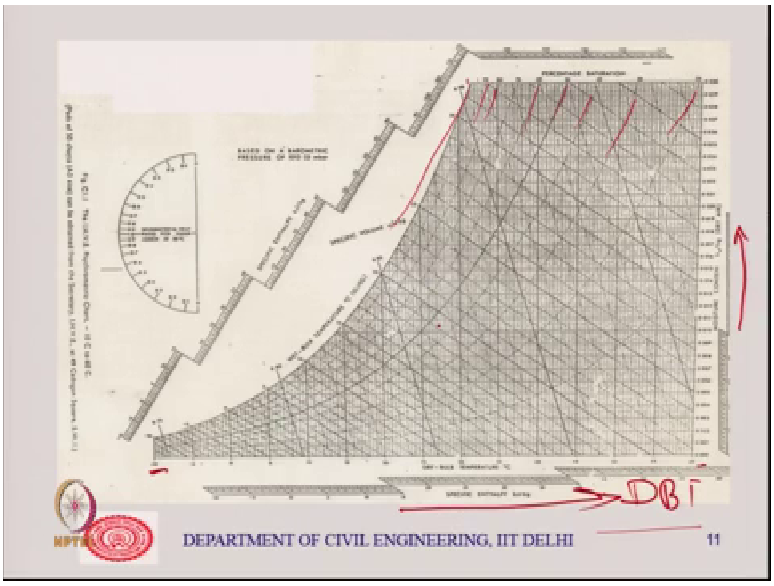

This is called a psychometric chart, a psychometric chart is one where in this direction here you have got dry bulb temperature dvt, you know you may not be able to see this very clearly there could be difficulties, but my intention is not to show here or read it here, but you might be familiar with it, because you can refer to this in sp 41 or any book of the reference that I have given Marcus and Morris, Kenneth Berger and so on so forth I hv guideline x ray hand book and so on many places you will find it.

Now, now this axis is DBT and this from minus 10 to I think it is plus 60. So, what this range this particular graph is, I mean it is there for various ranges some will have up to thirty or whatever it is. So, this DBT is along this direction this direction is a moisture content in kg per kg, you know absolute moisture content kg per kg. Now, this is the saturation line, this is a saturation line this is the saturation line this is the saturation line. So, if you know DBT if you know moisture content relative humidity lines are you know relative humidity lines of this saturation line there is 90, 80 etcetera etcetera. So, these are relative humidity line.

So, you can actually if you know the moisture content relative humidity value we can find it out from there, also there is something called wet bulb temperature, how do you measure relative humidity then it will come. Now, this curves can be fitted into an empirical equation as I said and you have vapour pressure is given a saturated vapour pressure minus some constant into atmospheric pressure T minus T w is called wet bulb temperature I will just define what is called wet bulb temperature and some again as I said empirical formula is given psb and ps at any any temperature. What is the saturation pressure those are those are values are empirically obtained maybe I will solve a problem some time that will be clear I will come back to this later on.

But let me now define what is wet bulb temperature, let us see if it is there before the mathematics comes in wet bulb.

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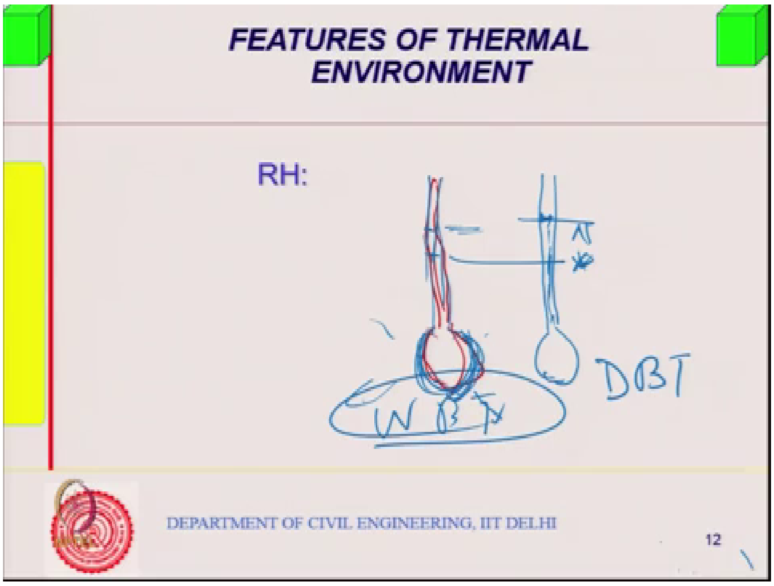

Temperature is supposing I have got a thermometer I have got a thermometer right something like this, supposing I put a wet cotton here it is a thermometer that thermometric bulb, you know it is a thermometric bulb, thermoelectric bulb and I put cotton here wet cotton here another case I have just the bulb and no cotton or anything of that kind right. So, I will have the unit could be mercury simply. So, this is dry bulb temperature now where will the supposing I have got relative immunity 100 percent right where will be this height or reading of this thermometer.

Student: (Refer time: 21:56).

It will be same, because this is wet and nothing can evaporate right, but supposing the relative humidity is low then what will happen moisture from here from the bulb, which is covered with a wet cotton or jute will evaporate and this will result in depression of this mercury here, which we call wet bulb depression right. So, this would be somewhat lower, do you get it if I have some jute or wet cotton around wet it has to be wet. So, they used to have something called wheeling hygrometer, where they will have you know a wrapped around a jute wet jute draped around textile means very important you know many other places temperatures relative memory is very important.

So, they will go on or in a room where you want to control humidity they will go on moving around this and then measure the depression of the wet bulb temperature or reading of the wet bulb temperature, the difference between these 2 is a function of relative humidity, it will be maximum when, when it will be maximum? When it is 0, 0 you know it is totally dry environment, it will be maximum and there will be no depression when the environment is saturated, environment is saturated.

Student: Saturated.

So, DBT and WBT wet bulb temperature. So, relative humidity, you know relative humidity can be measured through wet bulb temperature, there are other techniques like hygrometer you might have seen, a hygrometer willing hygrometer I was saying hygrometer measures relative mobility. Earlier days they would use horses tail, you know horses hair basically fibers are very sensitive to relative humidity their dimension changes occur swell or shrink. So, they would use horses tail long one which will expand or contract depending upon the relative humidity and this movement can be converted into you know some kind of analog movement analog scale and all that. So, we used to have one in the lab of the similar kind anyway. So, wet bulb temperatures can be measured through hygrometer and one way is to measure the wet bulb temperature and dry bulb temperature both right.

So, that is what it is. So, that is how we measure relative humidity, if I have to go to this a little bit lets go to a little bit of physical chemistry or you know you might have heard of osmosis.

Student: Permeable.

If I have a semi permeable membrane and I have a concentrated solution on one side and you have simply the solvent on the other side after some time.

Student: Concentration.

Concentration becomes same on both the sides, now this can happen in air also right why does it happen because the molecules the solute will have Brownian movement and if they collide with the concentration is same on both the sides they collide with each other and come back to their original. So, concentrations are does not change, now do not have much of a relevance here, but still I will just quickly tell you, but supposing I have 2 columns one has got the solvent other has got the solution and I have a semi permeable membrane in between I am not drawing the diagram, but just trying to explain you quickly and if I put a pressure on the pure solvent side I find that concentration does not change you know. So, that is osmotic pressure.

So, concentration gradient can cause movement same thing with vapour concentration gradient. So, vapour concentration you know if there is concentration of the water molecule where moisture vapour molecule is less at one place inside so there will be a movement. So, this is given by fixed diffusion equation diffusion law. So, this dc is the concentration.

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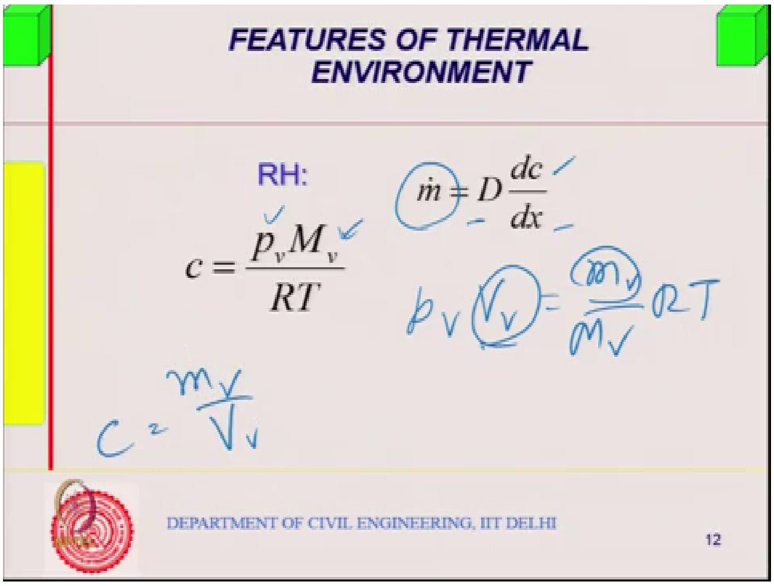

Dc dx rate of mass flow can be written as some diffusion coefficient into dc dx and c is nothing, but concentration is mass per unit volume.

Student: Volume.

Student: Volume.

So, you know if I have rho v c concentration can be written in this manner, you know if you have if you remember we had p v V v was equals to m v divided by m v into RT. So, concentration will be given by V v divided by you know mv divided by vv concentration is nothing, but m v by c is equals to m v by V v mass per unit volume and therefore, it follows from here pv mv divided by RT right pv mv divided by RT right so that is what it is. So, m dot now I can replace this pv I mean, I can write it like this you know diffusion coefficient m dot you know combine this equation dc dt.

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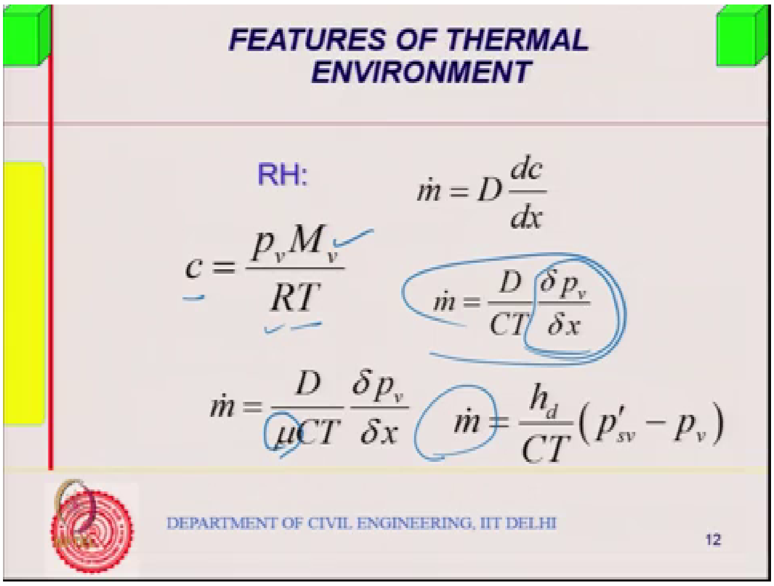

So, you differentiate this with with respect to x this is constant this is constant right and let us say temperature is constant then this will be function of simply vapour pressure gradient.

So, mass flow is the function of vapour pressure gradient right, mass flow as a function of vapour pressure gradient. So, the amount of moisture that can evaporate from your body is a function of that vapour pressure gradient as well. So, you know and this I can add to a frictional coefficient this is if there is no kind of a resistance, but there is a frictional resistance then I will just put this mu as a frictional resistance term and that is how I can write this mu dot and you know its convective. So, convective heat or movement as usual see we will see that the rate can be proportional to this. So, I think we will stop here.