Material and Energy Balance Computations
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Lecture –58
Humidity and Psychrometric Chart - II

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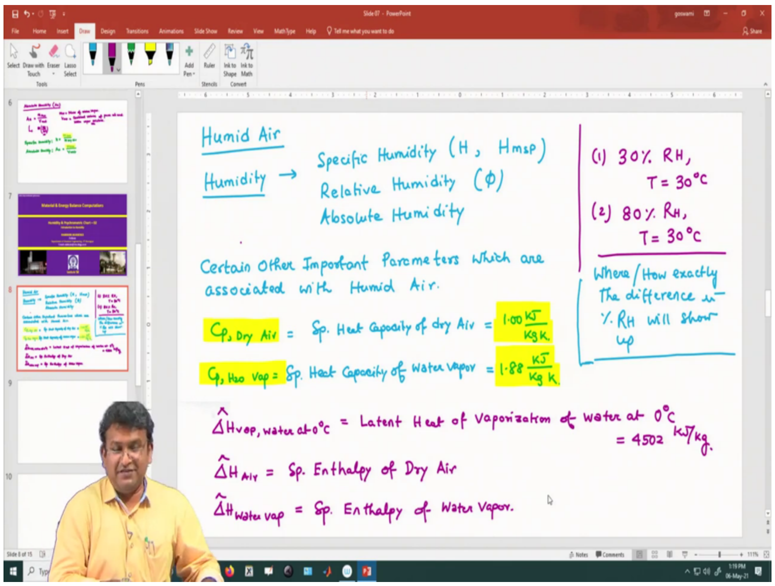

Welcome back. So, we started our discussion on humidity and we now understand after previous days previous class what is humid here and how is humidity expressed. Now I can assure you that you are going to learn one of the finest concepts today part of it you know actually from your high school education. For example, all of you know the physics of dew formation. So, we will talk about dew point etcetera.

But one critical thing I will actually teach you which probably is going to be new for you. So, before even before I come to it formally let me just show it to you through the question open to you can think typically when I am teaching in IIT, Kharagpur this is what I do I actually write some question and then the students start thinking and then after sometime we converge upon it in an online medium.

Of course, that is not fully possible but still nonetheless it may not be a bad idea to start thinking about where exactly a difference is going to be manifested. So, for example we have two qualities of air at two different places or two different days for example one of them is let us say 30 degree 30% relative humidity and let us say temperature is 30 degree centigrade this is air quality 1 and on the other instance for example you have 80% relative humidity and the air temperature is again 30 degree centigrade.

So, where exactly my question is very, very clear where or how exactly the difference in the percent relative humidity will show up. Of course, the relative humidity is different. So, that you can straight away say that what sort of strange question is this of course the relative humidity is different that itself is going to show up, but the temperatures are same. So, my question is more specific does it have an effect on temperature and if so how?

So, we will talk about it of course from a practical standpoint you can say that if it is 38 relative humidity and 30 degree centigrade temperature you will somehow bear the heat but if it is 80% R H there is every possibility that you will be sweating a lot that is what you know. And please do not laugh or anything because all these practical considerations are very important what you are learning in your textbook and in this course are all very practical things.

They are not anything out of the world that you read on one hand some stuff some abstract entities and you see observe something is happening and you are unable to sort of connect those two that is not what the intention is. Even when I was I taught you how to estimate the physical properties this is exactly what I told that you get hold of something new and you say oh I do not know because nobody is telling me there is no data sheet and therefore I cannot do any calculation that is not the approach of an engineer approach of an engineer is something is better than nothing.

So, I we will revisit this particular question later but apart from humidity there are certain other parameters certain other important parameters which are associated with humid air. So, they are specific heat capacity of dry air. So, this is the specific heat capacity of dry air which is 1.00 kilo joule per kilogram Kelvin. Specific heat capacity of water vapour this is specific heat capacity of water vapour which is 1.88 kilo joule per kilogram Kelvin may not be in the context of this online co course or the questions that you are likely to encounter in the examination.

But maybe these two are numbers worth remembering it is actually worth to remember these two numbers. So, this is dry air, and this is water vapour only. So, there should be a relation one can analytically obtain which you will all see is that you can probably find out a relation for the specific heat capacity of humid air which depends on the humidity of the air itself because humidity is going to control how much amount of water vapour is present in your system.

And the best probably the best option for this humidity is going to be use the specific humidity because that essentially talks about the ratio of the amount of water vapour present in per kg or per unit mass of bone-dry air. So, the we will come to that and the other important parameters are delta H latent heat of vaporization for water at zero degree centigrade is the specific heat it is not specific heat, it is the latent heat of vaporization.

And this is equal to all of you know the value is 4502 kilo joule per kg and delta H air is the specific enthalpy of dry air and delta H water vapour is the specific enthalpy of water vapour. So, these are the other important parameters we will learn some analytical expressions and then what I what is the topic of this module is this psychrometric chart once we start learning about psychometric chart you will find that you do not have to calculate anything everything comes from the chart that is the strength of the psychrometric chart and that is something which is going to be totally new for all of you.

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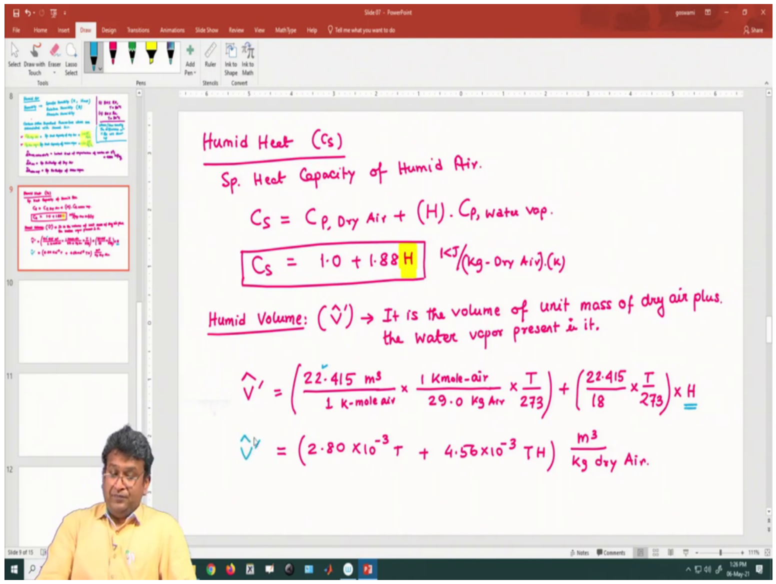

So, humid heat as they call the symbol is C_s which is nothing but the specific heat capacity of humidity and since we know the definitions of these two C_p dry air and C_p water vapor the relation is very simple. So, it is going to be C_p of dry air plus as I mentioned the specific humidity multiplied by C_p of water vapor. And therefore, you get a relation since we already know the numbers the numerical value you get a relation 1.0 + 1.88 H. So, this is the value of humid heat which is nothing but and this is in terms of kilogram kilo joule per kg dry air per Kelvin.

So, C_s is nothing but C_p of humid air and as you can see through the specific humidity it depends on the humidity itself. So, if you have dry air absolutely dry air then your H is going to be zero and then the value of C_s becomes equal to 1.0 which is the C_p of dry air similarly we can also define something called humid volume humid volume sometimes V cap dash is used it is the volume of unit mass of dry air plus the water vapour present in it.

So, this is what it is and this you can actually calculate as. So, it is the volume of unit mass of dry air. So, what is the unit mass of dry air how can you find out you know that you know always know the molar volume. So, for one mole the volume is let us say its 22.4 m^3 and so therefore for one kilo mole you know the volume which is 22.415 m^3.

So, therefore per unit kg of dry air the volume is going to be 22.415; I will write it. So, this is meter cube per one kilo mole air and one kilo mole air I always prefer to write it like this. So, that you can clearly understand the; conversion its 29.0 kg air and this now depends as a function of temperature. So, it is going to be. So, this is at 273 K or 0°C under normal NTP. So, divided into T divided by 273 is the volume of dry air at any temperature this is the volume of this is the volume of the dry air.

So, see it is the volume of unit mass of dry air. So, this is actually the volume of unit mass of dry air and what about the moisture presents in it. So, similarly it will be 22.415 divided by 1 kilo mole of moisture multiplied by 1 kilo mole of moisture into what is the weight its 18 kg into T by 273 multiplied by the amount of moisture that is present and which is given by H. I hope all of you can just try to look into it.

So, this relation you can find out and it turns out its 2.80 into ten to the power minus 3T plus 4.56 into 10 to the power -3T H meter cube per kg dry air. So, I will repeat it once because the expression looks big nothing else. So, what exactly is humid volume? Humid volume is it is the volume of unit mass of dry air plus the water vapour present in it. So, what is the unit mass of dry air at any temperature?

We know that for molar volume is known. So, for one mole one mole of dry air at 273 Kelvin the volume is known that is 22.415 m^3. So, for unit mass you can just divided it by the molecular weight which is 29.0. In this case you can take 28.84 absolutely no problem and then if you are not at 273 K. So, if you are at any different temperature it is simply T by 273. Similarly, the mass the volume corresponding to the unit mass of water vapour is 22.415 divided by 18 multiplied by T by 273 for the temperature correction.

And the amount of moisture that is present or the water vapour that is present you it can it is obtained from the specific humidity because it is per unit mass of dry air. So, you get such an expression for humid volume.

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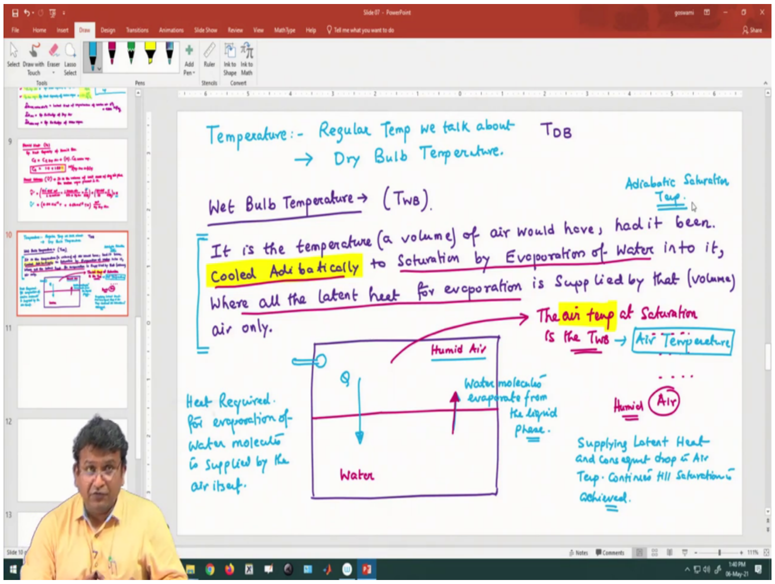

Then comes the definition another very critical concept and that is the temperatures. So, we all know that we measure the temperature with a thermometer and whatever is the temperature 32°C or whatever even the temperature we talked about here this is actually the normal temperature or the regular temperature we talk about and this is actually called the dry bulb temperature. So, if the temperature of air measured by a thermometer freely exposed air but shielded from radiation and moisture.

So, this is the dry bulb temperature. So, you actually have a thermometer which is placed in air and you simply measure the temperature all you do is that you do not expose it to direct sunlight. So, that it additionally there is some heating effect because of radiation. So, whatever is the temperature we have reported. So, far it is the dry bulb temperature. So, this is very common now in the context of humid air there is another very important concept very important concept and this is one of those beautiful concept builders you can say.

And we will try to finish it in today's lecture if not possible we will continue in the next lecture absolutely no problem and this is probably a new terminology for all of you and which is known as known as the wet bulb temperature. So, this dry bulb temperature is typically represented by T DB and this is represented as T WB. So, let us first try to understand. So, as far as wet bulb temperature is concerned, we will do two things we will first understand what exactly wet bulb temperature is? and then we will talk a little bit about how to measure the wet bulb temperature.

So, it is very interesting it is I will write down the definition you do not have to memorize it but please read it is the temperature a volume or a given volume of air would have I will explain do not worry had it been cooled adiabatically to saturation this is very interesting and this is where it differs from dew point or dew formation it is cooled adiabatically to saturation by evaporation of water into it.

Where all the latent heat for evaporation is supplied by that volume that follower that air only. Now this is very interesting I will read it but probably it will not make much sense it is the temperature a volume of air would have it means that it is a fixed volume of air we are considering nothing else this volume is not that important temperature of air would have had it been cooled adiabatically to saturation by evaporation of water into it where all the latent heat of evaporation is supplied from air only this is what is the wet bulb temperature.

So, what it is. So, let us try to understand and I can assure you that we will understand. So, it fully it is not that easy a concept I mean you can talk to many people and they will fumble what is the concept of wet bulb temperature. So, suppose we have a container closed container not I guess all of available know the physics of dew formation because in winter mornings all of us know that dew forms. So, what happens you have some you have this air of course it is humid air.

And at night the temperature cools down and what actually happens as the temperature cools down you can now go to the expression and show this particular term this particular term actually reduces. What is this? This is the saturation vapour pressure or the vapour pressure. So, vapour pressure or the partial pres. So, the vapour pressure actually reduces with temperature this is obvious because as the temperature increases the tendency of evaporation increases as the temperature is lower the tendency of evaporation is lower or in other words the moisture holding capacity the moisture holding capacity of air of saturated air progressively reduces.

So, what is dew formation? You have some moist air and now its temperature progressively reduces to such an extent that it attains saturation because of reduction of temperature and the excess amount of water falls or condenses as due. We will talk better about dew formation when we talk about psychometric chart. But here we are not talking about the process of dew formation because of one simple reason because the cooling that is done cooling is done adiabatically.

So, in case of dew formation there is reduction of temperature of air. So, therefore it is not an adiabatic process. So, what exactly can happen here. So, here you what happens is here you have humid air how you can saturate you can saturate or the how can this air get saturated? This air can get saturated if more and more or if the water molecules evaporate from the liquid phase.

Now in order to evaporate this it needs some amount of heat to be supplied otherwise why will these molecules evaporate because if the liquid and the vapour phase are in thermal equilibrium why should it evaporate? So, as it says as the definition says the heat that is required for the evaporation of these liquid molecules is actually supplied by the air. So, the heat that is required for evaporation heat that is exactly where is what is written in your definition heat required for evaporation of water molecules is supplied by the air itself.

So, as a consequence what happens as the air is supplying heat the temperature of air drops and up to what point it will drop? It will drop or up to what point it can supply heat? It will drop up to the point where the vapour phase gets saturated. Once the vapour phase gets saturated even if the air offers more amount of heat it is not going to help in any additional vaporization will also be compensated by additional condensation.

So, this supply of heat continues supplying latent heat and consequent drop in air temperature continues till saturation is achieved. And that temperature that air temperature the air temperature at saturation is the wet bulb temperature. So, please do understand here whatever heat is being supplied we will write in terms of an equation. So, the same amount of heat is transferred back in the form of the kinetic energy of these molecules that are evaporating from the liquid phase to the vapour phase.

So, net heat transfer to the surrounding is actually zero therefore this is an adiabatic process. So, it is cooled adiabatically the by the saturation, saturation by evaporation of water. So, there is evaporation of water and into it where all the latent heat for evaporation is supplied by the air. So, air is supplying the latent heat with that latent heat more and more water molecules are evaporating how it happens we will come to it.

First you understand the concept this is also known as or analogous to adiabatic saturation temperature. This is how you actually achieve adiabatic saturation how you do I will talk about it I will teach you. So, first you understand the concept. So, you have humid air which is not saturated. So, percentage is not 100% now that air supplies heat that air supplies heat to the water phase. So, the water and as it supplies heat that heat evaporates more and more amount of water molecules.

So, consequently what happens two things happen number one is the extent of humidity or the relative humidity goes up progressively goes up and as the air has supplied some heat its temperature gradually comes down. So, how long will the heat supplying of heat continue? It will continue till the air that the vapour phase has attained saturation and that is the minimum up to which the temperature can drop.

So, when the air phase attains saturation that temperature of air that air temperature this is very very important wet bulb temperature always refers to the air temperature. So, if you attain saturation of the vapour phase by this whatever is the final temperature you get; and I repeat the thermometer has to be here please do not make a confusion that since its wet bulb temperature its bulb is immersed in water.

Wet bulb temperature is not the water temperature wet bulb temperature is the air temperature. So, this is if you if you specifically attain saturation like this, this is what is called the wet bulb temperature. It is also similar to the adiabatic saturation temperature I hope the concept is clear I will not be able to finish the mathematical part associated with this which I will take up in the next class and I will revise it there.

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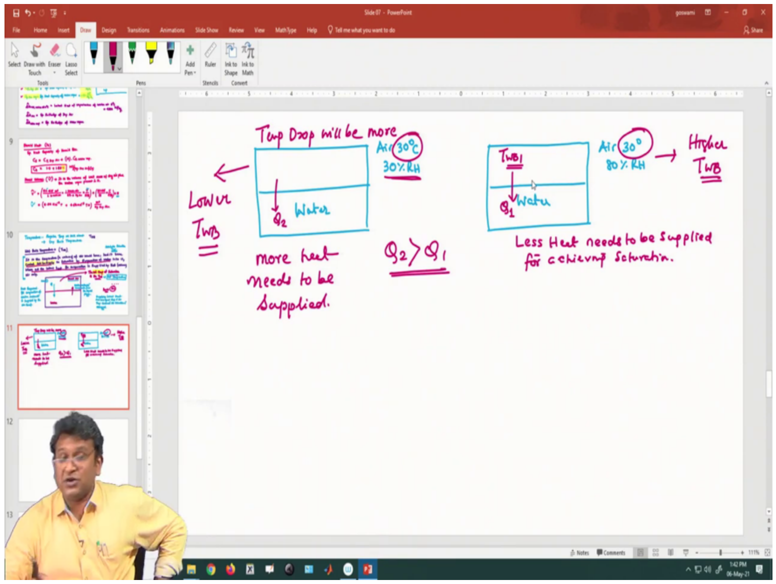

So, now coming back to my question, so, if you have air at 30 degree centigrade and 30% R H and air at 30°C 80% R H what is going to be different of course here as it supplies heat here it needs to supply less amount of heat for achieving saturation. So, some wet bulb temperature you will get where the drop is lower as compared to here you need to supply more amount of heat to achieve saturation why because here the relative humidity is only 30 percent. So, you are actually far away from saturation.

So, you need to supply more amount of it and as you are going to supply more amount of heat your temperature drop will be more. So, here you will have lower wet bulb temperature here you will have higher weight bulb temperature I hope now it becomes clear that if you have the same dry bulb temperature and interestingly this 30°C is nothing but the dry bulb temperature and now depending on the humidity its manifestation will be on the wet bulb temperature.

So, for two years having the same dry bulb temperature which one whichever is closer to saturation will actually have a higher weight bulb temperature. I hope all of you understand because here the heat that is required is lower and consequently the temperature drop is going to be lower. So, that is a very important concept we talked about thank you very much for patiently hearing and we will continue this discussion and introduce you to the concept in the last two lectures as a psychrometric chart the concept of psychrometric chart, thank you very much.