Introduction to Atmospheric Science

Prof. C. Balaji
Department of Mechanical Engineering
Indian Institute of Technology-Madras

Lecture - 19
Problems using Skew-T ln-P Chart

Good Morning. So, today we will look at saturation mixing ratios and then we will define relative humidity, saturation mixing ratio, and then dew point, frost point and all this and first go through let us go through the formal definitions and then we will see how to place all this put all this on the what is that Skew-T ln P chart and then go to some little bit advanced concepts like lifting condensation level which will help you determine the height of the base of the clouds and so on okay which will be which will correspond to what will be the relative humidity at that condition, 100 it is fully saturated.

So you will have to look for some, you have to look for the air parcel getting 100% saturated. So we will see how to get that using the charts. You can get all these using formula but it will be very tedious. Chart will be very helpful. So little bit approximation will be there but it is okay chart is pretty fast. Now, you already looked at the saturation vapour pressure yesterday.

And the saturation vapour pressure increases with temperature we saw that okay and after that we looked at the solution to the quiz problem okay we solved the 5 problems which involved the concepts which we studied in the first 6 or 7 weeks. Now we will move on.

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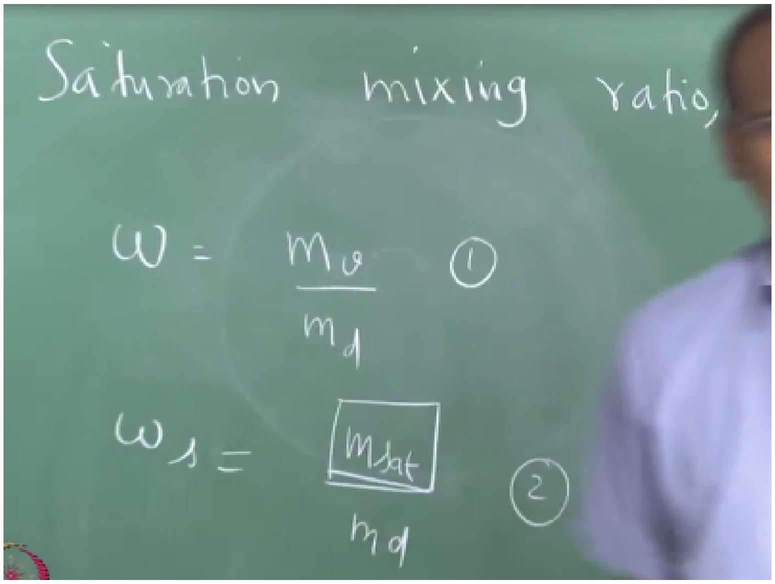

Saturation mixing ratio, is given by omega s. Omega is mixing ratio. Omega subscript s means omega subscript saturation. Omega is given by m v/m d no mixing ratio; m v plus m v + m d is specific humidity. Both may be equal that is a different nearly equal that is a different story. What is this? m sat. So please take down the definition.

The saturation mixing ratio omega s is given by the ratio of the mass of the water vapour, the saturation mixing ratio omega s is given is defined or what did I say is given by the ratio of the mass of the water vapour that is saturated mass of the water vapour that is saturated in a given volume of air the mass of the water vapour that is saturated in a given volume of air to the mass of dry air.

It is given defined by the ratio of the mass of water vapour that is saturated in a given volume of air to that of to the mass of the dry air. Mathematically it is given by equation 2 omega s equals m sat by just take 2 minutes. Both m sat and m d follow the ideal gas equation because m v is also vapour water vapour is very much an ideal gas. So apply the ideal gas equation you will get the dry the gas constant for dry air R d.

You will get the gas constant for water vapour random variable. You also know the ratio of R d and R v which will be epsilon. So manipulate that and simplify the expression for omega s okay. So that is problem number special effects, problem number 28 okay.

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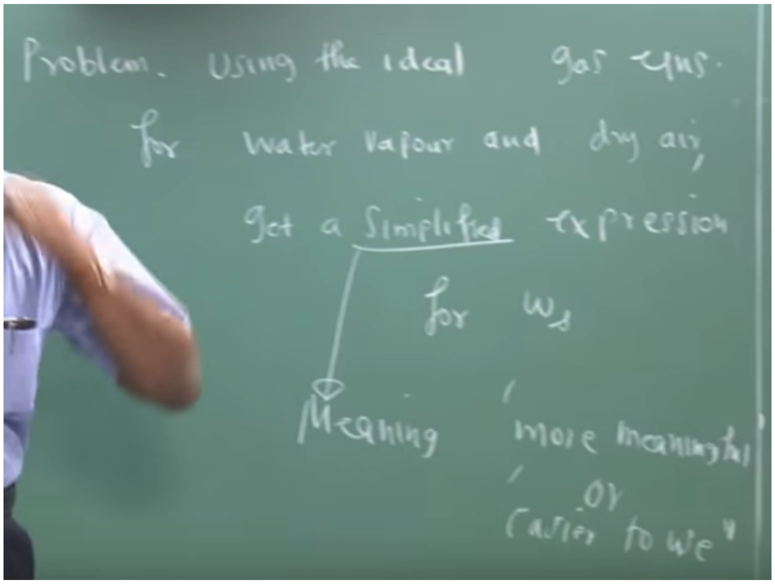

When I mean simplified I have to qualify this I am looking for something which is more meaningful or easier to calculate because if it is I wanted in terms of the pressure because pressure if you know height you know pressure. So with height we can get many things. So pressure and height are the two most pressure, height, and temperature are the important quantities. So we want to be able to reduce this to that.

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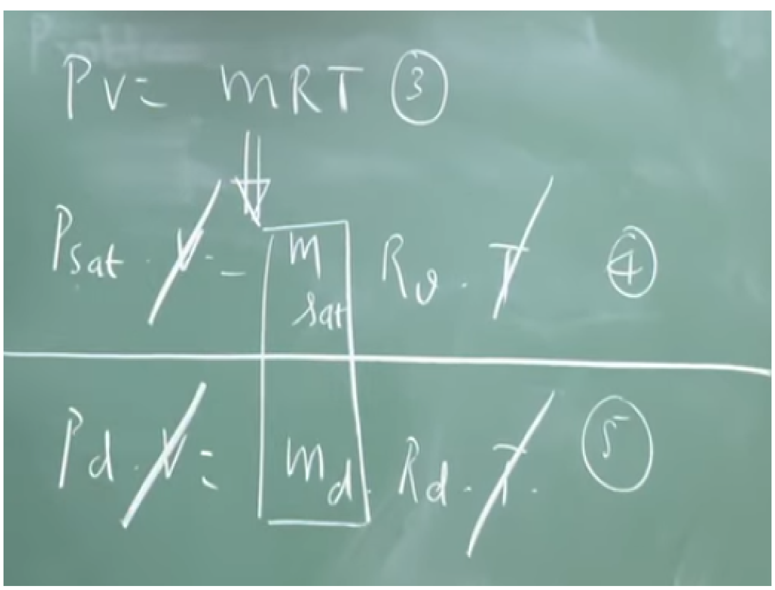

Correct? Both are occupying the same volume V. Do not say V 1, V 2 and all that and mess it up. Something should be constant, the volume is. For this I will use m sat. Temperature is the same, very good okay. I am applying both for the water vapour as well as for the dry air okay.

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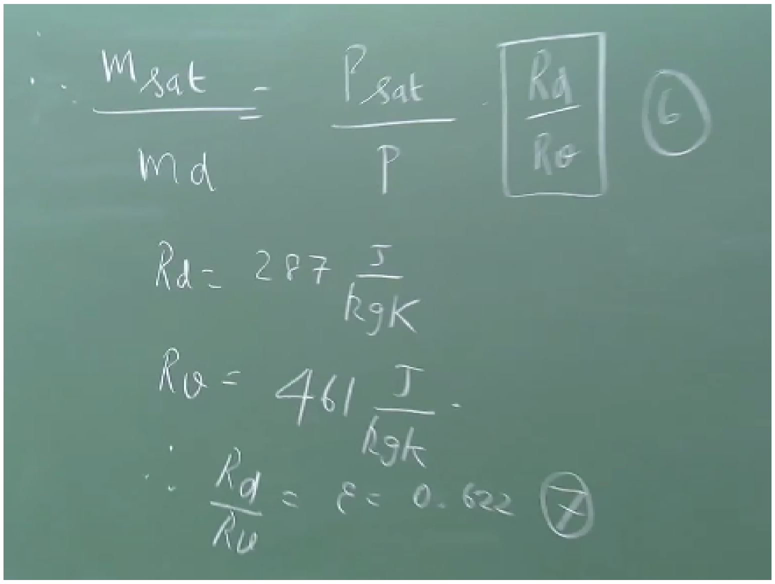

Equal P sat we will just write it r Random variable alright. 461 I am writing this again and again so that at least a revision. So it gets strengthened. You will never forget this.

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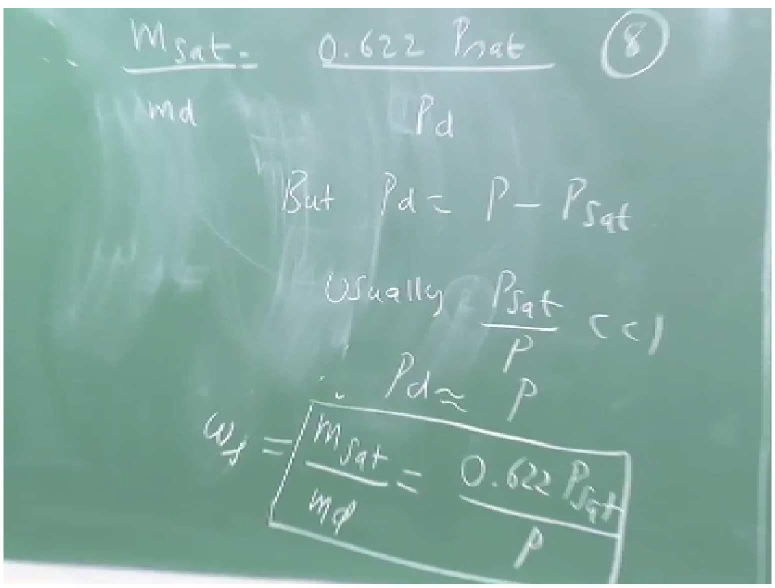

So therefore can we make can we simplify this further? What is P d? P minus very good. So why. Why P is approximately equal to P sat. It is applicable for the range of temperatures in the earth's atmosphere. We are not talking from 0 K to 5000 K; 220, 40, 60, 80 of that order P is much greater than P sat okay. At the given temperature so what is this now? Let us not lose track of this. This fellow is equal to omega s very good. Saturation mixing ratio is equal to saturation mixing ratio.

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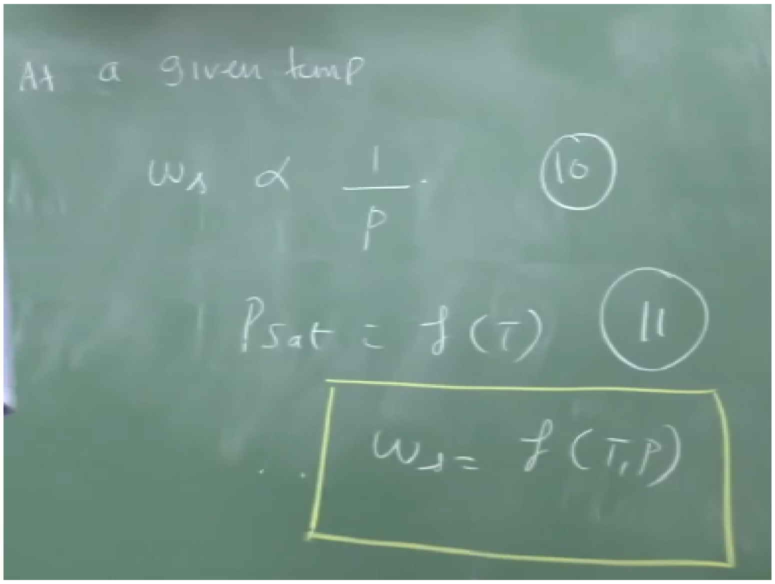

At a given temperature what is the relationship between omega s and total pressure P? Inversely proportional, very good. Omega s goes as 1 over P correct. What about the relationship between P sat and temperature what happens as temperature increases, P sat increases. How do we know, yesterday we have seen. So P sat is the function of T. Omega s goes inversely with pressure P sat is a function of T. Omega s is a function of both P sat and P.

Therefore omega s is a function of T and P. So two variable problem okay. Therefore, very important. So if you want to work out formula it will be messy. It is easier to use charts okay.

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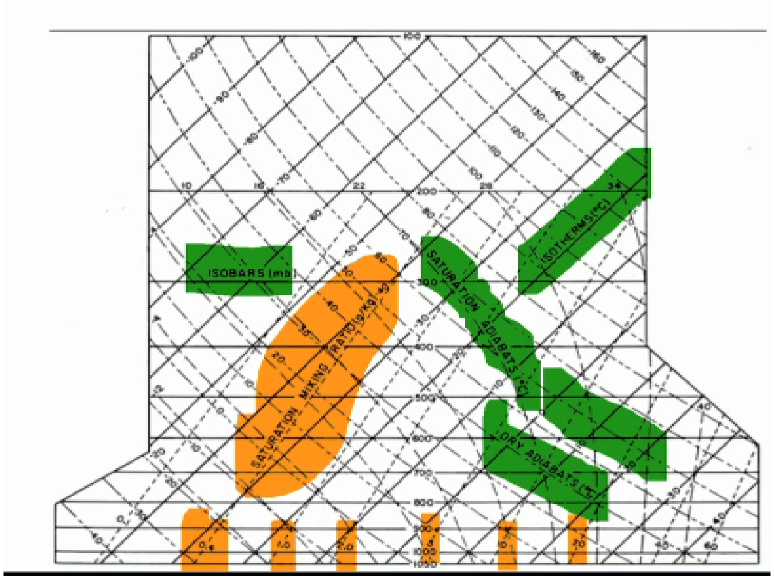

Where are the saturation mixing ratio lines? Oh I have taken some highlighter. It is okay nice. Ho saturation mixing ratio correct 40 it is 40 or what is it 0.4. No I do not think it is 0.4. It is 0.4? 0.4 Oh that 40, 50 is the other line. So it is here 0.4 and k 1, 2, 5, 10. So the saturation mixing ratios are going up like this. What about the dry adiabats? Dry adiabat. All these fellows are dry adiabats okay. Already you know the isotherms, isobars, isotherms.

What I have not explained to you so far, saturation adiabat. That is we have to see that now okay. So please note the saturation mixing ratio is going there straight line going from what is that sloping and left upwards whatever. Is it okay. We will revisit this. I do not know how to clean this up. We can go to the next sheet afterwards okay. We have some more we have some more terminologies. Next is a important concept. Relative humidity.

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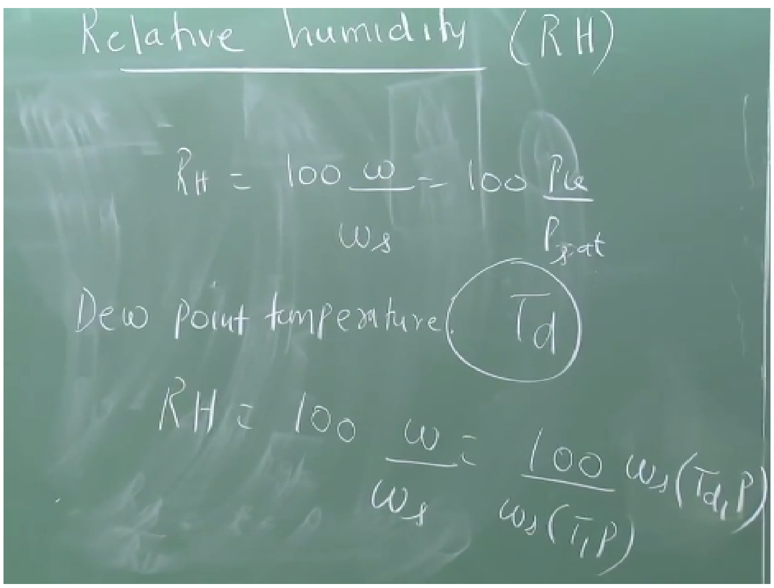

Symbol is, usually short form is RH. What do you think relative humidity is? If the mixing ratio for a corresponding pressure and temperature is omega and for that temperature and pressure the saturation mixing ratio is omega s then omega/omega s into 100 will give you relative humidity in percentage. That means if it is fully saturated omega equal to omega s so omega s/omega s into 100 relative humidity will be 100%.

So relative humidity for completely dry air is 0. Relative humidity for fully saturated air is 100. It is varying from 0 to 100 but we already saw that omega itself or omega s can be only in gm/kg; 5 gms, 10 gms, 20 gms. It cannot be 500 gms per, water vapour cannot hold that, the water cannot hold so much. That is why the best unit is for omega is gm/kg alright okay. Can we also write it like this?

It is possible because the total pressure is the same T for both the cases okay. So if I give you the vapour pressure and the saturation pressure you can get the RH. If I give you the omega and omega s also you can get the RH. Dew point temperature. Please take down the definition of dew point temperature, ready? The dew point temperature T d, T d dew point temperature. The dew point temperature T d is the temperature to which air must be cooled.

The dew point temperature T d is the temperature to which air must be cooled at constant pressure for it to become saturated; temperature to which air must be cooled at constant pressure for it to become saturated with respect to a plain surface of pure water. I come again dew point temperature is the temperature to which air must be cooled okay at constant pressure, you have to follow an isobar, for it to become saturated with respect to a plain surface of pure water.

So RH is actually, can we write it in terms of dew point. What is that? Please hit the bulls eye. It is omega s at T d and P. It will be fully saturated at that temperature. If it is cooled that is how much should be the air cooled such that it becomes fully saturated at that pressure. Are you getting the point? If you decrease the temperature relative humidity goes up okay. If it keep on decreasing till the relative humidity become 100%.

That point that temperature is called dew point understand. If we keep on heating air what happens, the relative humidity decreases. So suppose the temperature let us talk about Chennai now, September today is September 17th. Assuming that the temperature changes by a few degree centigrade during the day relative humidity will be more in the morning or in the afternoon?

Morning ha, so you will feel more sticky at 9 o'clock 10 o'clock rather than evening 2 o'clock or 3 o'clock. You may feel uncomfortable at 2 o'clock for some other reason. The humidity, the stickiness will be very if it is warm and it is very humid you will feel very uncomfortable when you go for the a slot, b slot, or c slot okay. So relative humidity in a tropical or some countries like us can be so the 10 o'clock sun is much more uncomfortable than the 3 o'clock sun okay.

So let us write this. I am not going to write 10 o'clock sun and all that. So this I am going to write, so I am going to write ha please help me 100 omega s, not T d P man that is something else okay. Do not get reminded about home which got split recently okay. Omega is a T d P divided by omega at T P okay.

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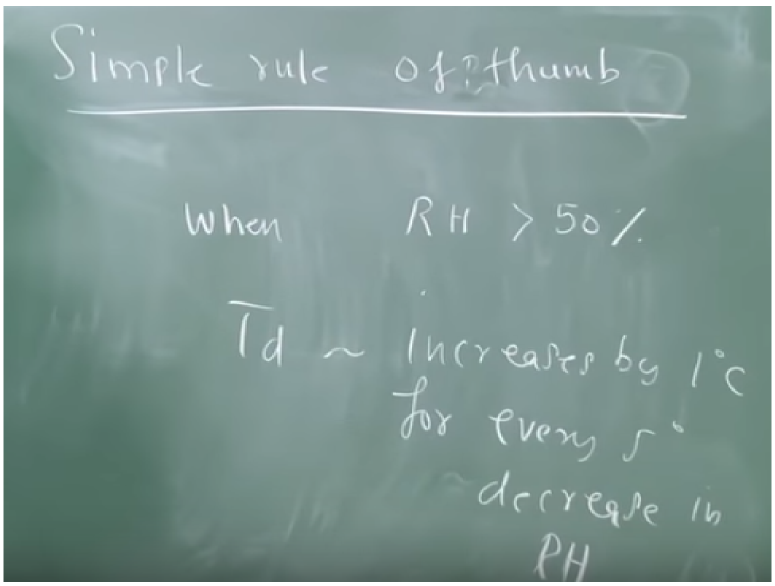

I will give you some simple rule of thumb which you should not use in the exam okay. So what I am giving now is practical meteorology, quick this thing okay not for vigorous study. When the relative humidity is greater than 50% okay the dew point increases the simple rule of thumb is the dew point increases by 1 degree C for every 5 not 5 degree 5% correct 5% decrease in RH.

Now, I am going to ask you a simple question. If you answer that I know for sure that you understand. If you do not know the answer to that question you have not understood this today's lecture.

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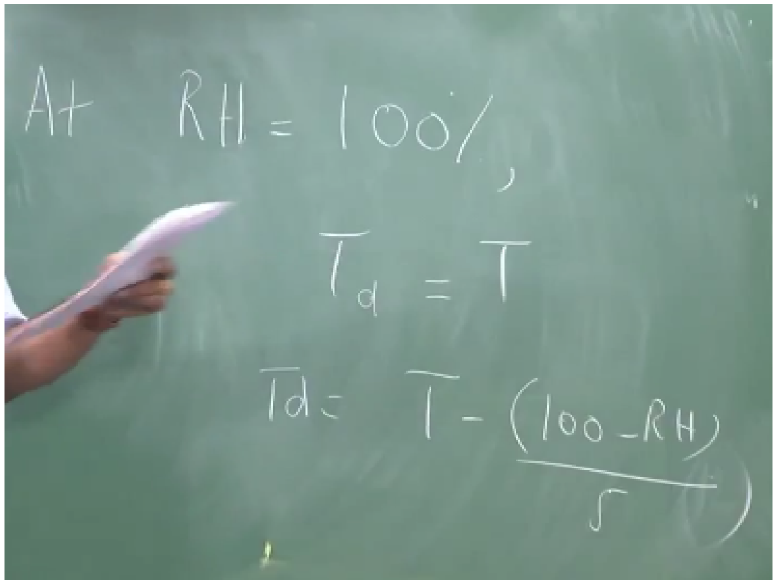

At, is it okay. At 100% RH T d and T are one and the same okay. So T d, using this rule of thumb. Problem number 29. Using the simple rule of thumb, problem 29, using the simple rule of thumb, determine the difference between the actual temperature and the dew point temperature; using the simple rule of thumb, determine the difference between the actual temperature and the dew point temperature for an air parcel.

Determine the difference between the actual temperature and dew point temperature for an air parcel whose RH is 80% eight zero for an air parcel whose RH is 80%. Very good, okay. I want all of you to get that 4 degrees. Who will be higher? Who will be lower? T d will be lower. So immediately in air-conditioning people will ask what is the dew of that. What is the dew point in this situation okay. So the dew point itself is a measure of human comfort in warm and humid climates okay. So 29.

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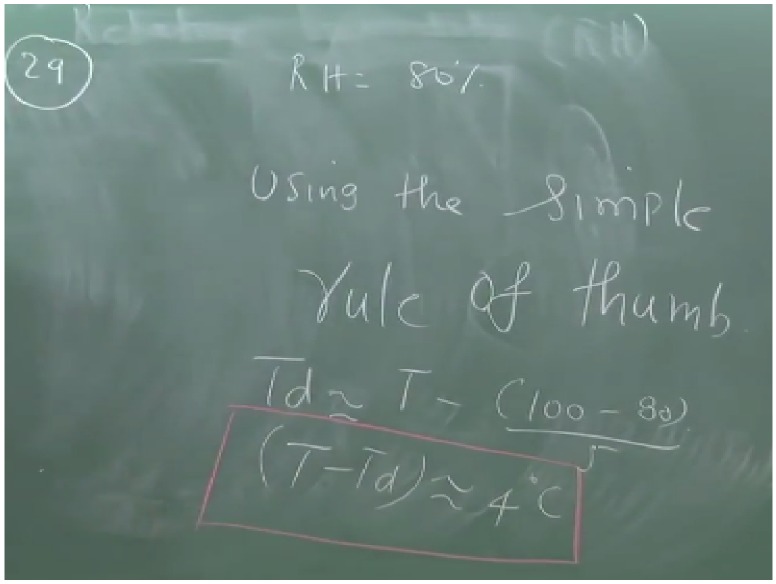

Alright, next. Beyond dew point if the water becomes ice so that is something frost point. So you have to though it is impossible to discuss about frost point in a city like Chennai okay for German's frost point has meaning. Chennai is hot, hotter, hottest but there is a definition. So you have to understand what frost point is okay. Next one is frost point. Please take down. Frost point is the temperature to which or frost point colon, temperature to which dry air must be cooled.

Temperature to which dry air must be cooled at constant pressure temperature to which sorry temperature to which air must be cooled oh I am very sorry. Dry air then it is surrender. Temperature to which air must be cooled, I stand corrected, temperature to which air must be cooled at constant pressure to saturate it with respect to a plain surface of pure ice. I come again frost point, temperature to which air must be cooled at constant pressure to saturate it with respect to a plain surface of pure ice.

Now, let us solve a problem. You have to pull out your Skew-T ln P chart. Okay, this will be the first exercise involving some fundas what you have learnt in today's class. So we will build on this in tomorrow's class and subsequent classes. Problem 30. So, by the way, once frost point is defined you can define the relative humidity, saturation mixing ratio all this with respect to ice instead of water.

But unless otherwise stated in this course in atmospheric thermodynamics course generally relative humidity and saturation mixing ratio are always with respect to water. Very cold countries when you are discussing such kind of thermodynamics then you can discuss it with respect to ice. So ice is not at all a consideration for us okay. Now, 30.

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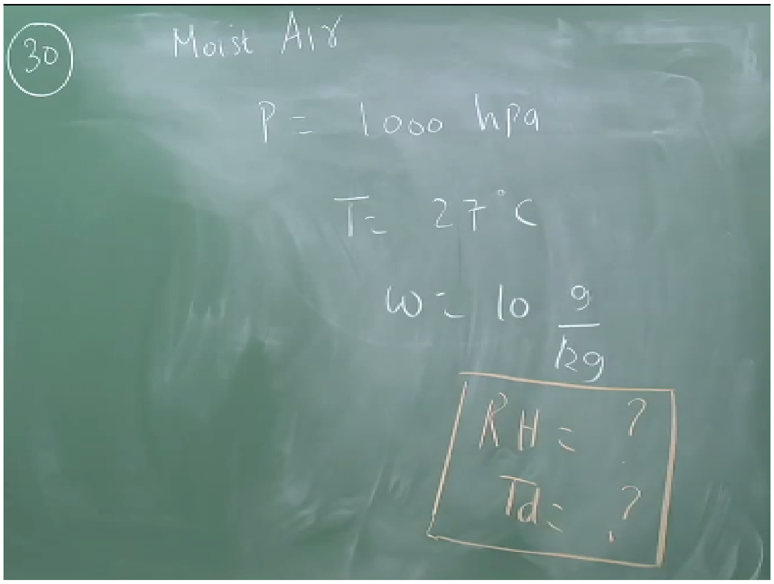

Air at 1000 hPa, air at 1000 hectopascal, air at 1000 hPa and 27 degree Celsius. Air at 1000 hPa and 27 degree C has a mixing ratio of 10 gm/kg. Determine the RH that is determine the relative humidity and the dew point of air. Determine the RH and the dew point of air. 1000 hPa, 27 degree C, mixing ratio 10 gm/kg. Determine RH.

"Professor - student conversation starts" 4.35. What is 4.3? RH. Don't use the rule of thumb. Just wait **"Professor - student conversation ends".** So, please work. I will give you a couple of minutes. So I will get this sorted out and I am going to show the result on the this thing and then we will stop. We will complete this problem and stop for today.

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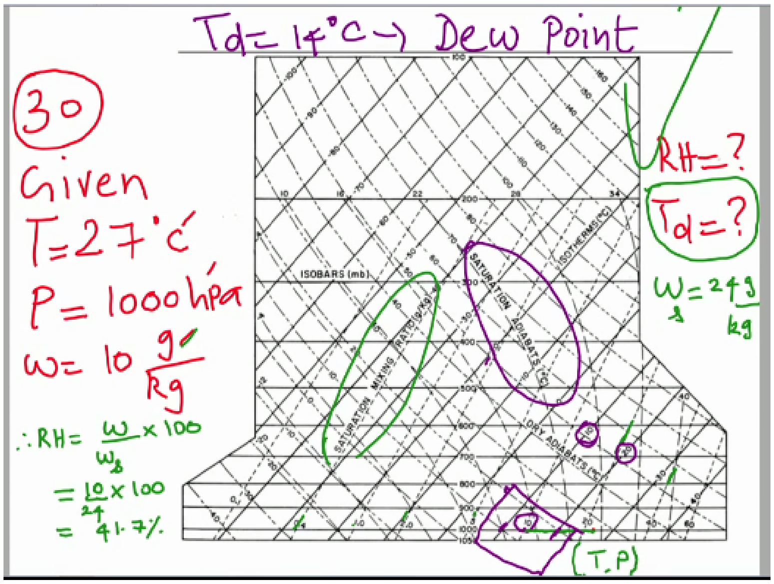

First locate the point and call it as point 1 and put it as T and T and P. So problem 30. Okay, so the question is clear. Given T is 27 okay. So shall we solve now okay. First locate the 1000 one thousand is here 1000 at 27 degrees. Where are that isotherms? These are the isotherms okay. - 20, - 10, 0, 10, 20, 30. So 20 to 30 I am somewhere here, correct? Very good that is our point. Any doubt Marius you got it? You cannot see it.

No, no okay that is what I am saying. 1000, that 1000 line okay that 1000 line. So take the 1000 hPa, Marius, I am explaining to you. Take the 1000 line okay and then take the isotherm. Isotherms are here right - 20 that is - 20 - 10, 0, 10, 20, 27 okay it is here right. We cannot make it bigger no? **"Professor - student conversation starts"** Not the dotted line. No sorry this line. Ya I told the solid line only. Now it is okay? No, that is okay.

It is small that is what okay. Now, what is omega s for this situation? 25, No, no 22. 25 are you getting. Which is omega s? saturation mixing ratio. Dotted lines. So those are the dotted line. 0.4, 1, 2, 5, 10, 20, this 40? How much is this? 25 okay 24 let us take compromise and take so okay 24 gm/kg okay **"Professor - student conversation ends".** Therefore RH. About 41.7% very nice. That is good. Now the important part is coming.

I want to find out the dew point okay. Please go to the definition of dew point. Dew point temperature T d is the temperature to which air must be cooled at constant pressure for it to become saturated with respect to a plain surface of pure water. I come again the dew point temperature T d is the temperature to which air must be cooled at constant pressure for it to become saturated with respect to a plain surface of pure water. Air is having 10 grams per kg.

The funda now is what will be the temperature at which 10 gm/kg will actually be the omega s for the pressure 1000 bar. I will come again. So the funda is what will be the temperature at which this omega of 10 gm/kg will become omega s itself but what is the other coordinate, pressure is 1000 h Pa. So along the same pressure horizontally you have to move towards the left correct. So you move towards the left like this. I got 13 or 14.

Okay so you go like this. You are reaching 10? 10 is the saturation. Saturation mixing ratio is that dotted line okay. What is the temperature for this? No, temperature you have to be careful. Temperature is the solid line. So it requires lot of skill to let us do that. How much is this, - 20, - 10, 0, 10, 20 okay. So this is 10, this is 20. We are here. So take your pick. 14 okay agreed. So T d okay.

All that I can ask we can actually you can give temperature, pressure and one of the temperature and pressure and one of the saturation one of the moist air parameters to completely fix. For example I can give temperature is 27 degree C, pressure is 1000 hPa, dew point is 10 degree C for dew point is 13 degree C find out what will be the relative humidity and find out what will be the omega okay.

So there are various ways of so from dew point also we can proceed alright. So all are not independent. Dew point, omega, omega s all the 3 are not independent. There is some coupling. Are you getting the point? T and P are basically different. They are not moisture parameters. Beyond that you require one moisture parameter okay. Is it fine? So we are able to use everything. There is one thing which we have not used. I will again mark it.

That is the saturation adiabat. It is not a great this thing. Next class. During an adiabatic process the dry air follows a dry adiabat. The moist air will follow a that is it. Thank you.