Introduction to Atmospheric Science
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Lecture - 25
Problems on Chinook Wind and Static Stability

Okay, so we were looking at this long problem where there is a wind right. There is this wind which is coming on one side. It is carrying lot of moisture. It is having some particular temperature and pressure. Then that air parcel is rising. It rises up to the LCL. Then it rises beyond. Then it becomes supersaturated. So it sheds some of its moisture as rain on the windward side of the mountain.

It further climbs and then comes on to the other side of the mountain. Why is it moving, because of the wind. It is moving to the other side of the mountain. Then when it is coming it is following what is called a dry adiabat. When it is falling in dry adiabat we see that the temperature is increased alright. So we will now plot it on this Skew-T ln P chart and show it and then if the internet works, if the internet works after this okay if the internet works we will also look at what the internet is saying about this phenomenon.

That is some wind is coming on the windward side, shedding its moisture and going to the right side. They have some phenomenon like this in Germany also, some particular type of wind alright. So this was problem number 38. So we will. The first 5 minutes I will just quickly run, jot down only the highlights, the important variables so that it helps me when I sit down and plot it on the Skew-T ln P chart.

That will be a revision for you and also for those people who missed the class and it will be very useful for the people who are taking the course or want to watch the course on nptel alright. So for the benefit of the people who did not come to the last class, the problem runs like this. An air parcel at 1000 hPa has a temperature of 30 degree C and a mixing ratio 14 g/kg correct. Is this correct?

An air parcel at 1000 hPa has a temperature of 30 degree C and a mixing ratio 14 g/kg. What is its wet bulb temperature, first question. Then the air parcel is lifted to the 700 hPa level by passing over a mountain and then 80% of the water vapour that is condensed out by the ascent is removed by precipitation.

Determine the temperature, potential temperature, mixing ratio, wet bulb potential temperature of air parcel after it has descended to the 1000 hPa level, same 1000 hPa level but now it is on the other side of the mountain okay. So we are looking at the story of the air parcel as it moves from left to right or right to left whatever and mountain is in between.

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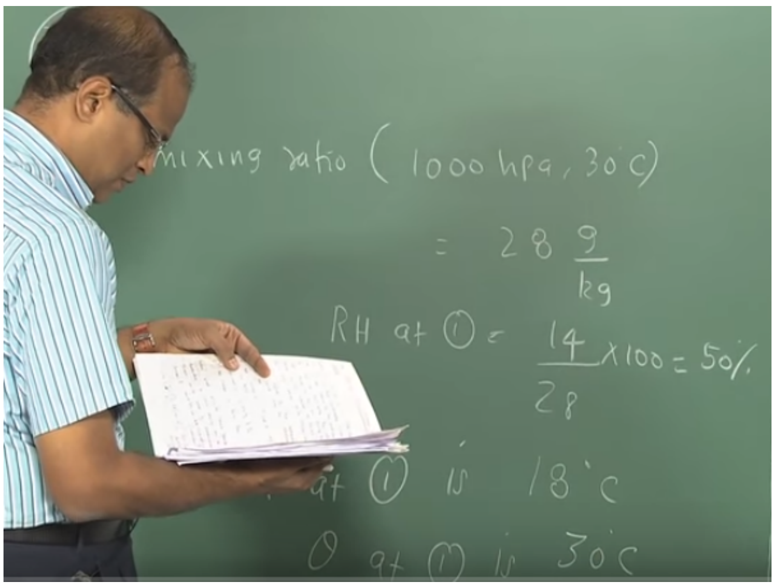

So the first thing was saturation mixing ratio 28 right. How much did you say 30 is it, 28 okay. T d is, 18. What is the theta? How do you get theta? 30 I thought, 30, dry adiabat okay.

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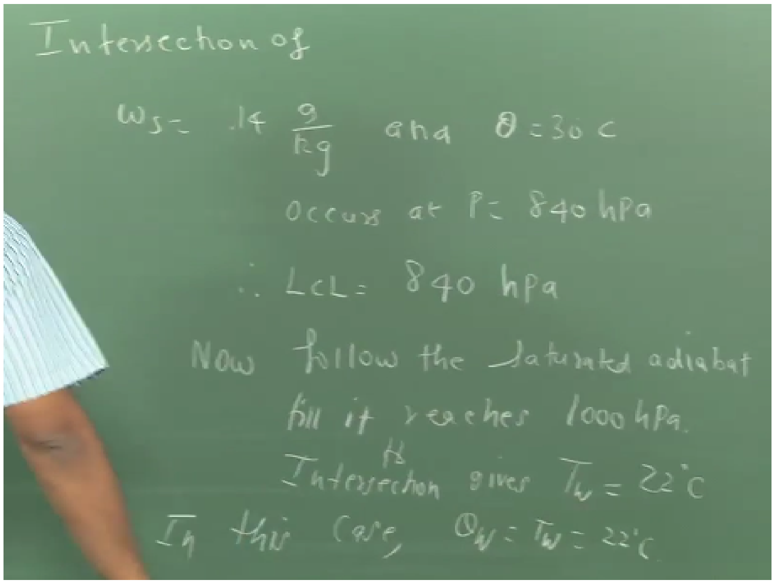

840 okay. Then. Now follow the saturated adiabat till it reaches, intersection gives, very good wet bulb. Now we will stop and then do it on the chart okay so that it is helpful.

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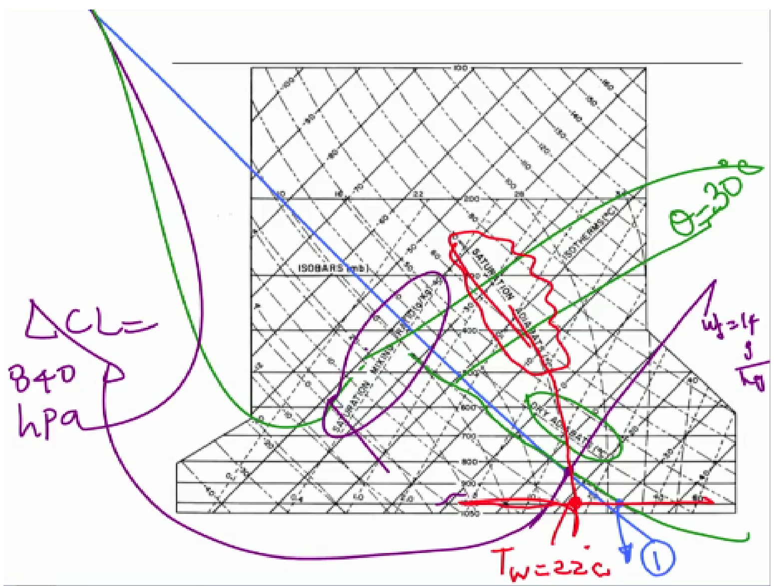

Okay, what are the initial condition, 30 degrees okay. See today, today it is giving trouble okay. Then the dry adiabat is, where is the saturation mixing, saturation mixing ratio. Where is the saturation mixing ratio, 14 here is it no. Saturation mixing ratio is the dashed line? Where are the values for that? Just above, oh this 0.4, 1, 2, 5, 10 ah I got it. Omega s is 14? They are intersecting. Now I follow the saturation adiabat. So it cuts the 1000 somewhere. Now Karthik I want to clean this up. I want fresh sheet. Okay very good.

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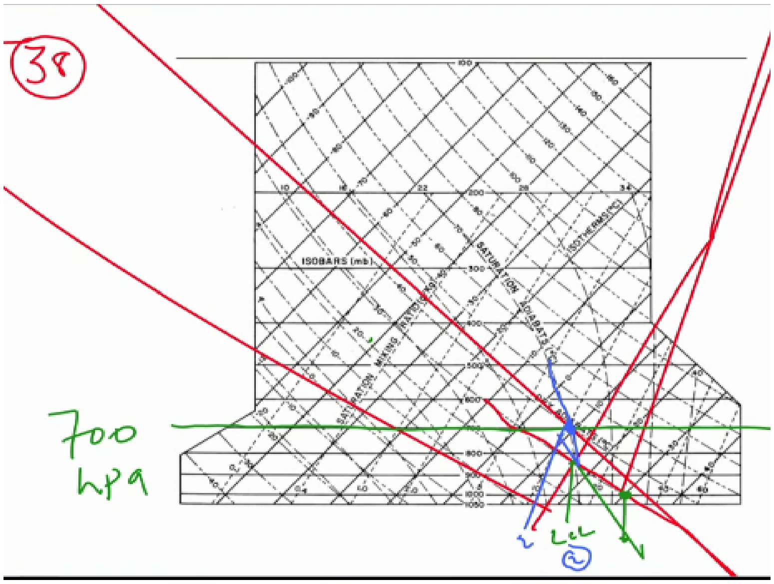

So we got. Let me write whether, I want to check whether the line is following 30. Problem number 10? Okay, it is alright. We will proceed. What is the wet bulb potential temperature? In this case, the wet bulb potential temperature is same as T w because the original pressure of the air parcel was only, you write that. We had a rule right. The wet bulb temperature is the arithmetic mean of the actual temperature and the dry bulb temperature.

Actual temperature is 30, sorry actual temperature dew point temperature. Actual temperature is 30. Dew point temperature is 18. Average is 24 but wet bulb was 22. But not bad, it is close. It is alright okay. We will proceed now.

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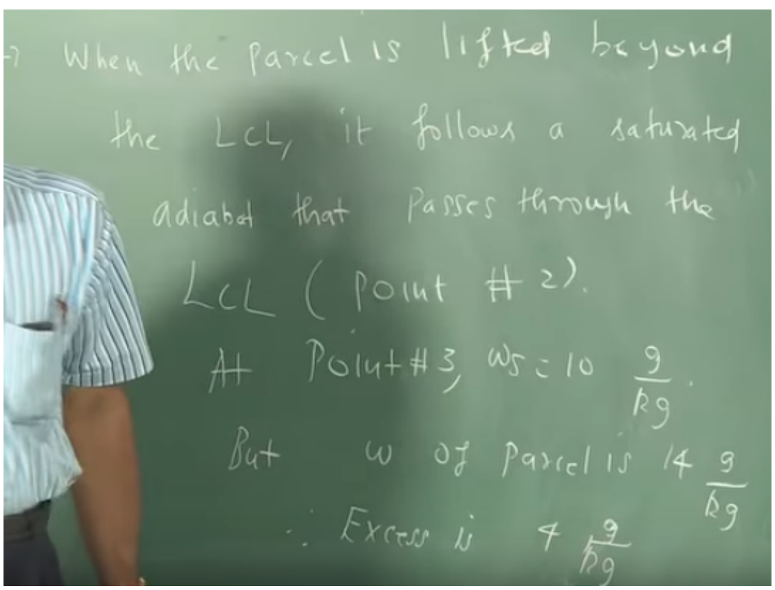

So when it is lifted, when it is lifted up to 700 hPa which line the red line, it follows some red line or whatever that theta is a constant line theta equal to 30 degree line is what it follows up to the LCL then correct? Then it follows the saturated adiabat up to so it went here okay. LCL you can call. Did it go here? Now what is omega s at 3. But omega of parcel is 14. It cannot load so much okay. So the excess is 4 g/kg. 80% of that becomes rain okay that is what is in the problem.

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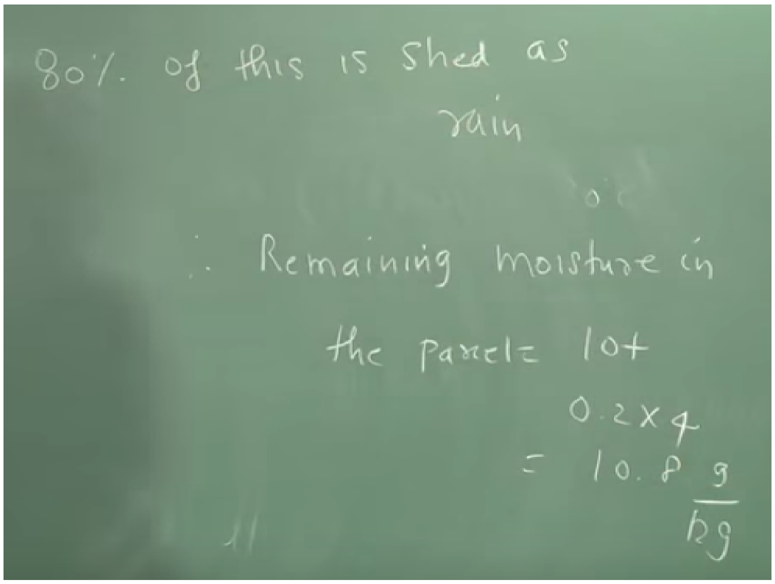

Here I am saying remaining moisture the correct English will be moisture remaining in the parcel whatever remaining moisture in the parcel. So 20% of that 4 g/kg plus 10 which is the saturation corresponding to that so it is or you can take it as 14 - 3.2. It is having 14, 3.2 became rain. So 10.8 is left. Either way it is correct. It is the same. Now what you have to do is, again I will erase. You please note the, you noted point 3 no? Very good.

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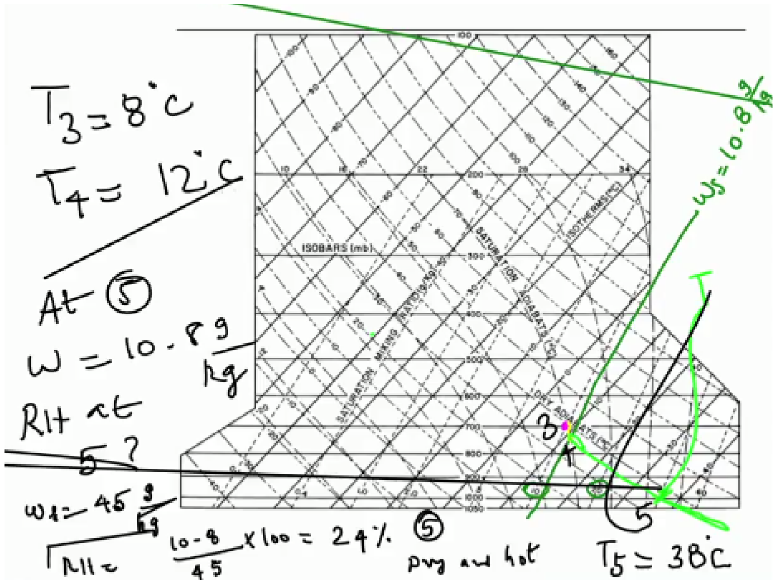

So it was 700 and 710. That is correct, oh very good. Let me fix the point. Now, attention please. Please follow the saturated adiabat until the omega s becomes 10.8 okay. So that is a very fine this thing. So the are you getting my point? The saturation mixing ratio is 10 and saturation mixing ratio is 20. So I look at saturation mixing ratio which is like 10.8 or something. Okay so just wait. That point is correct right okay. Come again 710?

Hey you said isotherm 10 what did you, dashed line 10 okay very good 10 okay. Wait. This one? Here fine right. Then, I will change the colour. Marius what happened? You are thinking about the holidays. That is dead and gone in time. We live in the present. Okay now what do we do. Saturation mixing ratio. Now is this okay? 10 and 20? I want 10.8 so I will take it as 11 okay. Alright, I got that. So it will come down up to that alright. Then now it is fully saturated.

After that it is going to the other side of the mountain. It is coming down. Not shedding any moisture. As it comes down it becomes drier and drier. So it will follow the dry adiabat okay. Where is the dry adiabat, okay. So I will like to call it as so T 5 equal to 38. What did I ask? Okay when it cuts what is the T 4, what is T 3, 8 very good. T 4, I got 12; 10 okay so what is the omega s at what is omega at what will be omega of the air parcel now okay.

So we started with 14 and we are running with 10.8. What happened to the 3.2? It went out as rain. But we started with 30 degree C and we came out to 38 degree C. Please evaluate the relative humidity at 0.5. What is the RH at 0.5? How to do that? You know the omega. You have to get the omega s right? Which one? What is that 41, 42? Omega s. Where did you go all the way? Which one okay. Let us say 45. How much is it? Did you see that?

Air at 30 degree C and 50% relative humidity which was very comfortable became air at 38 degree C and 24% RH. It becomes dry and hot. It became dry and hot. Reasonably a moist and comfortable air became so this is let us work it out let us write all this on the board okay. So remaining moisture okay. So T 3 is please tell me. T 3 is 8, T 3 is 80% okay.

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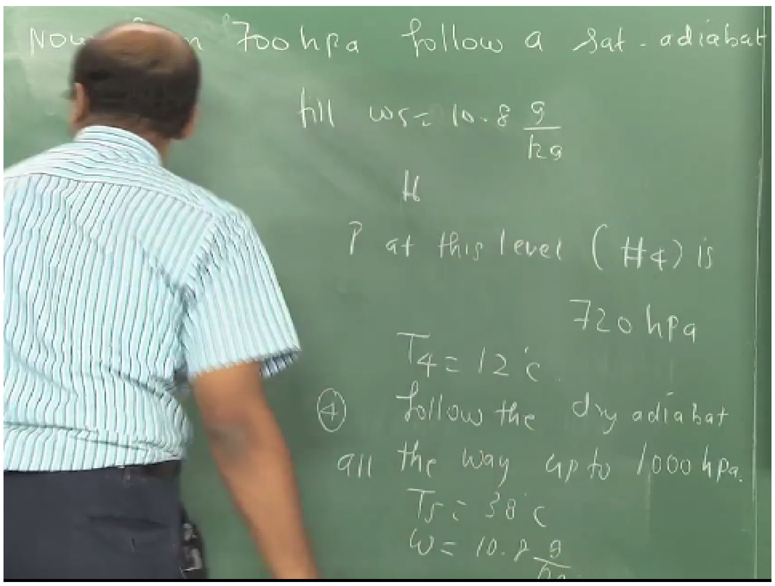

P at this level 4 is 720. So something like this you can expect in the quiz. It can keep you occupied for half an hour. You have to be systematic. No surprises but you have to do you have to be very meticulous. I will be able to test whether you know everything; wet bulb potential, dry adiabat, this thing and all these things. All the concepts which we have studied in thermodynamics will be put to test okay.

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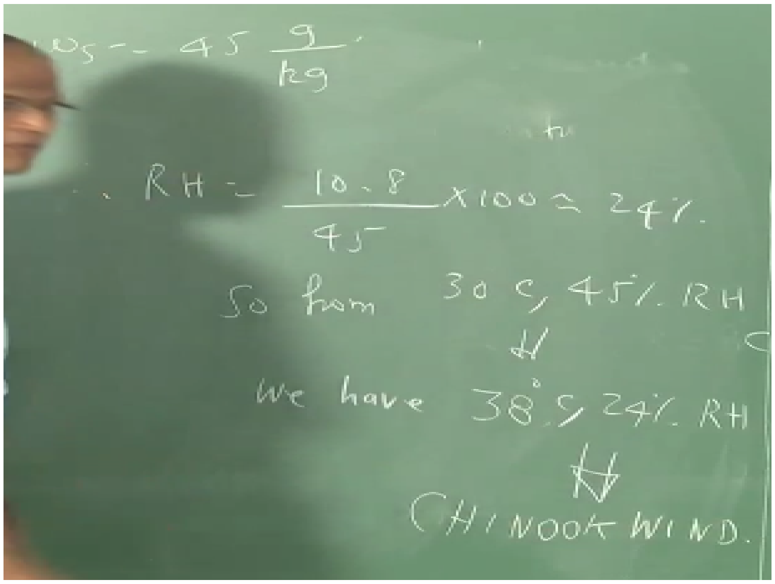

Omega, omega s okay. Such a wind is called a Chinook wind okay.

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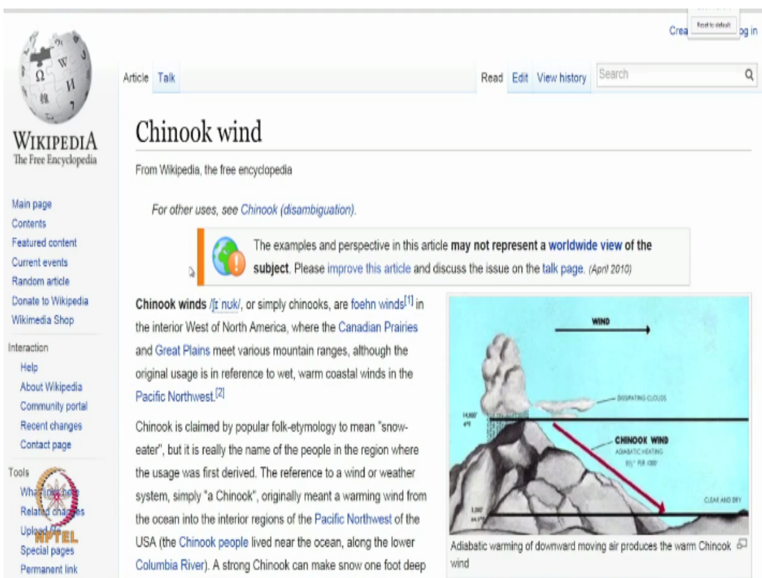

See that is the Chinook wind alright. Adiabatic warming of downward moving air produces the warm Chinook wind. So it is rising here. Then it is dissipating its moisture. Then there is adiabatic heating and you are getting a clear and dry air. So this is Chinook wind. Chinook winds are simply Chinooks or how do you pronounce this Marius foehn winds which are where the Canadian Prairies and Great Plains meet okay.

It is in mythology it is known to be in popular etymology it is known to be a snow eater because it can eat the snow on the other side. It is a snow eater okay. **“Professor - student conversation**

starts” You have foehn in Germany also right. Ya foehn. Ya you have experienced that. Have you experienced? Ha let us say ya. Okay. **“Professor - student conversation ends”.** So right so a strong Chinook wind can make one foot, can make snow one foot deep almost vanishing one day.

So it can remove snow right. The snow melts and partly evaporates in the dry wind. Okay and in Canada it takes place in these regions and then Calgary and so on. So these are the typical the cloud pattern when the Chinook wind happens okay. In Alberta in Canada. How Chinook occurs is basically rain shadow results and all that we have seen. We have seen the complete thermodynamics okay.

It is also in Chinook winds are sometimes cause sharp increase in number of migraine headaches suffered by locals and are often called Chinook headaches. They have conducted studies in department of clinical neurosciences and they they support the belief that this can cause headaches, irritability, sleeplessness and all that right okay. Do you have something Chinook wind in India, what is it? Your Andhi is not this right. That is not this, ya okay.

So Chinooks also occur in Denver. Denver is very notorious place in Colorado where always because rocky mountains are there. I have experienced this myself and missed flights and all that. That story I will tell separately. So Denver is a very dangerous region in the, it is a big airport DIA the Denver International Airport but till you climb 20, 25000 feet is all it is all dizzy. So alright. This is the Chinook wind. So let us go to Chinook wind and see some images.

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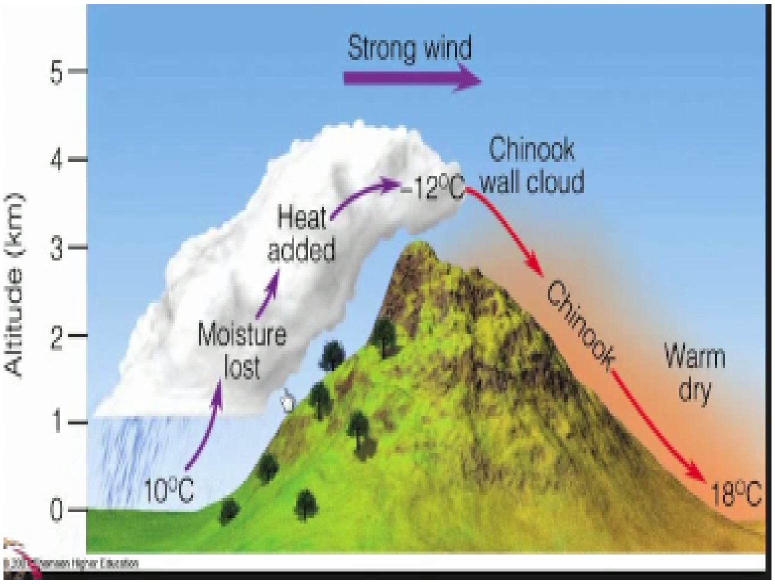

See this is good one. Get this 10 degrees, moisture lost, heat added, - 12 degrees, Chinook wall cloud, Chinook okay. Any doubts. So you will be able to solve problems of this nature right. I asked some more things, wet bulb, potential temperature, what did I ask? Determine the temperature, potential temperature, mixing ratio, wet bulb potential temperature. What is the wet bulb potential temperature? No change. Wet bulb potential temperature no change okay.

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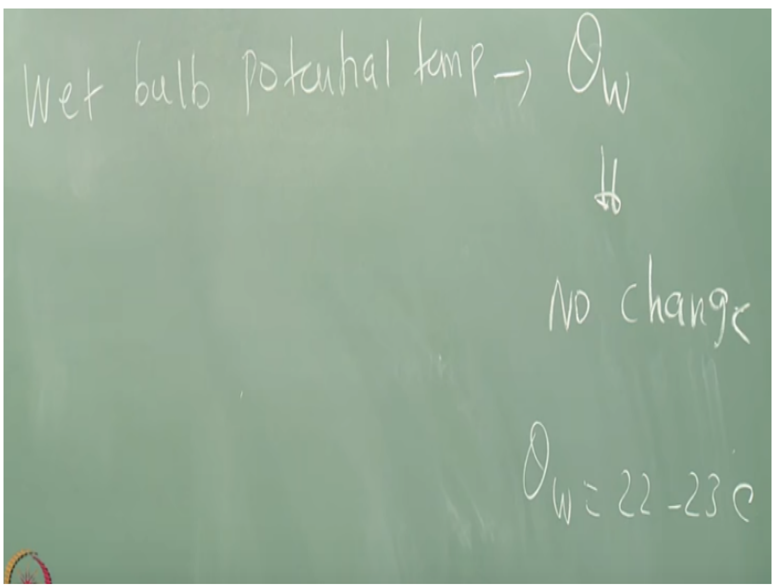

Theta w is 22 is it? Was it 22? Okay. Let us move on to the next topic. We have to look at a stability of an air parcel. If there is an air parcel which is rising, you give it some force. Will the air parcel continue to rise or will the air parcel return to its equilibrium okay. If it returns to its equilibrium we again give a force and if starts oscillating then is there a natural frequency of the system. So we have to get deep into the maths.

Then you have to do F = ma, then a = d square z by d t square and we will identify all the forces and then we get a characteristic frequency of this air parcel which is called the Brunt-Vaisala frequency. Do not worry too much about it. We will derive it in tomorrow's class. There is something called the Brunt-Vaisala frequency, name of the 2 scientists who figured out, the air parcel we need to oscillate.

What is the natural frequency depending on whether this frequency is small, high and this thing we can look at the stability and all that. But before that first we have to understand what we mean by stability. Stability, we have to see with respect to unsaturated air and saturated air. So we will start with considerations of static stability with unsaturated air okay. Let us start so this will take a couple of classes.

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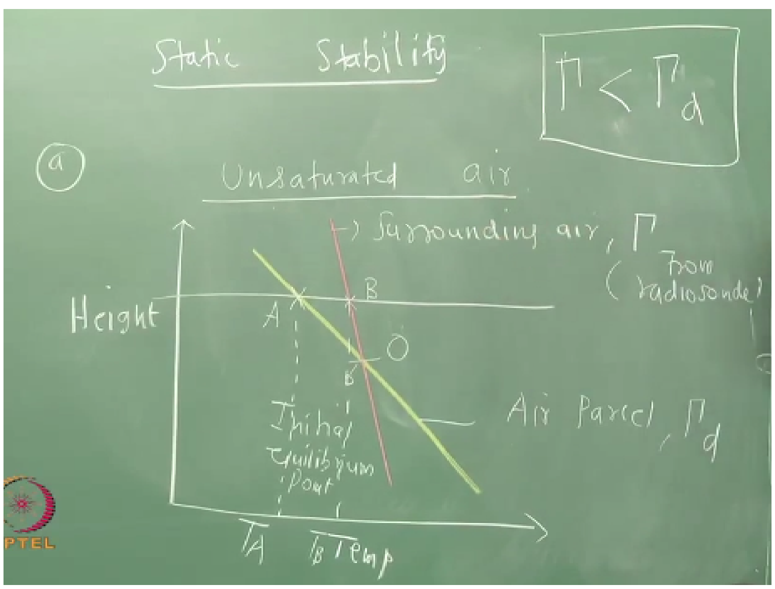

First we are going to look at unsaturated air. Please note that it is slightly funny curve because height is always our y coordinate in atmosphere. Temperature is not the y coordinate. So I am doing temperature versus height. How do you get the temperature versus height in the atmosphere? If you want how will you obtain? Radiosonde. You can put a balloon and get the values and then with that you have to find out how the temperature changes with z.

That is called the gamma lapse rate which is like 5 to 6 K/km correct? I have drawn 2 lines, 2 curves. What do you think they are? One is for one is for the air, one is for the parcel. Please note the parcel pressure is the same as the air pressure but the parcel temperature need not be the same. If everything is the same, no activity we have to, atmospheric science we have to close the show.

There is some difference in the temperature, there is buoyancy and then upward and downward force, some activity is there in the atmosphere. So I want to call this which one the steep one is the surrounding air. This one is the air parcel. If it is an unsaturated air, the air parcel will follow what? Gamma, what is its dharma. What will it follow? Gamma of dry air. It will follow gamma d. But what you get from Radiosonde measurements, if you put a balloon and the Radiosonde instrument you launch the balloon now at 12 o'clock, it goes up.

It will not detect air parcel. It will just detect, it will find out what is the temperature in the atmosphere okay. So what will be that, gamma okay. So this is from Radiosonde. Now, O is the initial equilibrium point. Now tell me gamma = gamma d, gamma > gamma d, gamma < gamma d. No, I am giving you the slope, how can it be equal. Gamma > gamma d surrender how? This is height versus temperature not temperature versus height.

Do not go, do not do too much research. Look at the 2 graphs. Which is steeper? Which is steeper yellow or pink? Gamma is greater than gamma d? What is the lapse rate? It is d z by d T or d T by d z. Then which, pink is steeper or yellow is steeper. Yellow is steeper. Yellow is steeper from the point of view of lapse rate. Basic funda is it not. So what do you want to write here? Gamma okay. Clear. If you keep on look if you keep on looking at it for 5 minutes you will get confused.

Just accept it okay. Now we are pushing the air parcel from O okay. Now give a gentle upward push to the air parcel so that it comes to a new level. At this level, the temperature of the air parcel is A. The temperature of the air is B. I am pushing it up okay. Come down, call it T A. Come down, call it T B.

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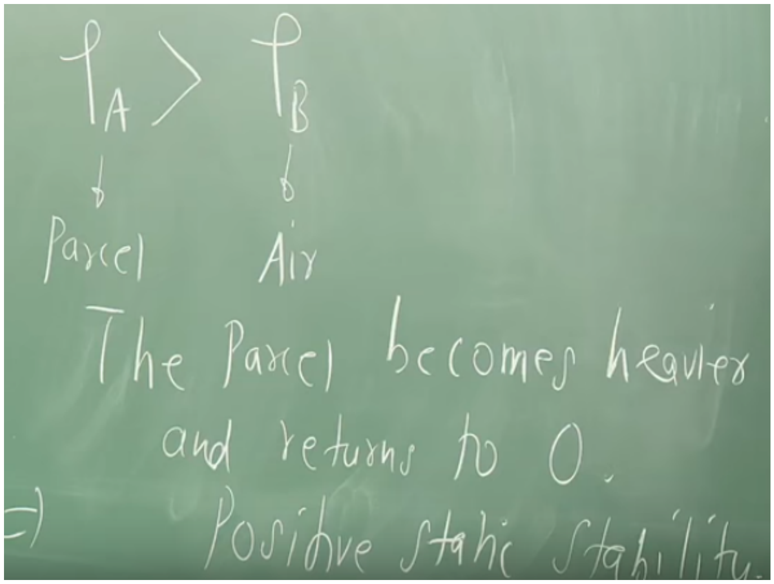

T A is but once you push, within a very small amount of time the air parcel gets, the air parcel gets its pressure adjusted to the pressure of the surrounding. That is the assumption. That is the assumption. So do not worry about the, pressure remains the same, but the temperature is different. So what will happen to the density? Very good. Rho A is A is the parcel and B is the air. If it is denser and I push it up what will happen? It will come back.

So is it a stable situation or unstable situation? Stable situation. So this is called, this situation is called positive static stability okay. This is called. I will give all of you 2 minutes. Please consider a situation where the parcel is pushed downwards, draw one more picture, the parcel is pushed downwards, take the 2 new points as T c and T d, argue out whether rho c, rho d is greater or equal and then find out whether the parcel will go down further or the parcel will come back to O.

Therefore, once you have done that analysis in the next few minutes can you conclude with reasonable confidence that if gamma is less than gamma d irrespective of whether you push it up or push you or you push the air parcel down it will always come back to O. Please get yourself convinced. Please complete that exercise.

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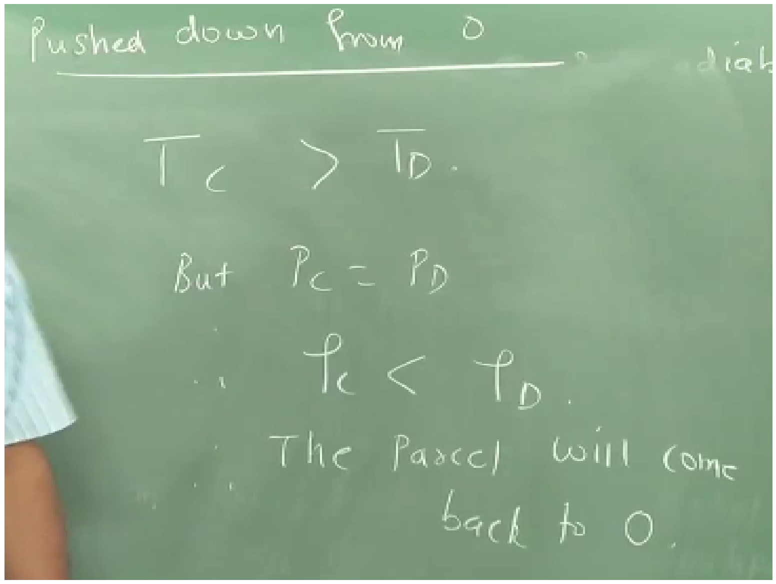

If it is pushed down correct? Therefore, the parcel will come back to O. Tomorrow's class what we will do is we will take up the situation where gamma greater than gamma d and prove that it is unstable or negative static stability okay. After that we will get an expression for the acceleration of the air parcel and then we will get an once it starts oscillating what will be the characteristic frequency. That is the Brunt-Vaisala frequency.

After that what you have to do is for saturated air it becomes more difficult. Then quiz 2 it will be too late for quiz 2. In the final exam, I will give you a Radiosonde reading. I will give you the pressure and temperature at various heights. You have to plot it on the Skew-T ln P chart, find out the LCL whatever and then you will have to see ab, bc, cd, at all the levels where the parcel is stable, unstable, convectively stable all that.

So that is going to be, that is going to be the tough question in the exam. That means you are becoming a meteorologist alright. So we are getting deeper into this thermodynamics. I thought this is an interesting part. So I am spending more time. After this chapter is over, we will look at radiation and climate change. Dynamics I will just touch upon 3, 4 classes. I will just give geostrophic approximation and the cyclostrophic approximation is relevant to us.

You can, I want you to be able to calculate the maximum wind in a cyclone okay; maximum wind speed in a cyclone based on pressure differences and all.