Introduction to Atmospheric Science
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Lecture - 28
Static Stability - Problems Using Radiosonde Data and Skew T ln P Chart

So, Good Morning. So in yesterday's class we looked at the stability of air parcels and all that. So we have been looking at it in the last few classes. Stability of unsaturated air parcel, saturated, and we went little deep and we looked at conditional stability and finally convective stability. The convective stability is lot more difficult okay.

So you have to first calculate the LCL and after the LCL you have to if the sounding crosses this when it goes to goes to the saturated or moist adiabat when these cross each other then it results in what is called LFC, level of free convection. After something the level reach the level of free convection it is unstoppable it will do some violent mixing and so on okay. So we are looking at this evaluating the stability.

So I thought like before if you have to understand this properly you have to solve a problem okay. So please copy down the sounding, please copy down the sounding data from a typical experiment maybe somebody sent a balloon and then from that instrument all these readings are obtained. It is called a sounding data okay. There are 7 stations A, B, C, D, E, F, G and 3 columns pressure in hPa, then the T temperature and then the dew point temperature okay.

I do not have we do not have time to solve this full problem. But we will just see how to approach this problem okay. So the idea is to find out whether each of the layers AB, BC, CD is stable or not and then if each of these layers is given a sufficient push from below whether eventually it will become convectively unstable or stable. So it is a long process. It is a long problem. For each layer you have to find the LCL.

Then you have to find the LFC and so this can, it is not possible to solve it in a quiz for example. End sem it is a good idea. Give it in the end sem because it is a test of rigor okay and you will have to put lot of points and you should put a rangoli in your Skew-T ln P chart. The problem

reads like this. Has everybody copied this down? I will give you 2 minutes. First copy this down, sounding data.

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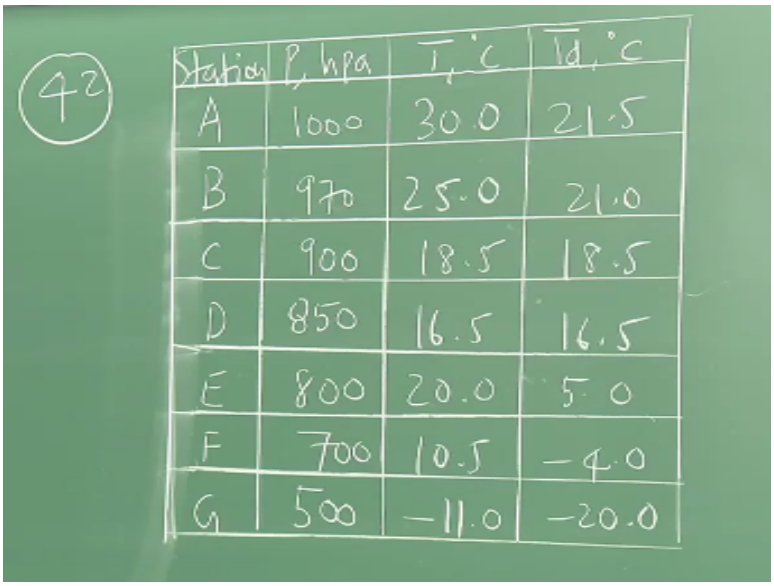

The sheets are in circulation. Sowjanya is having it okay, choosing the topic. Today you will have to finalize. Problem 42. Plot the following on a Skew-T ln P chart. Plot the following on a Skew-T ln P chart. A. Are the layers AB, BC plot the following on a Skew-T ln P chart. A. Are the layers AB, BC, CD etc. are the layers AB, BC, CD etc. in stable, unstable, or neutral equilibrium. That is conditionally stable right. We call it conditionally stable or neutrally stable?

Neutrally stable. Are layers AB, BC, CD etc. stable, unstable, or neutrally or in stable, unstable, or neutral equilibrium. B. Which layers are convectively unstable? B. Which layers are convectively unstable? Okay. Just do not start. I am going to give you the Skew-T ln P chart but listen to the logic. We will have to first see. Vishwajeet is it over? You have to first see which of the layers are saturated?

If it is saturated then gamma < gamma s, gamma = gamma s, gamma > gamma s that is the stability condition. If the layer is unsaturated gamma < gamma d, gamma > gamma d, gamma = gamma d. So for the part A of the problem you will have to first figure out whether the parcel is saturated or not. From the sounding itself except this point, except this point, the T is always greater than T d.

Therefore the gadbad is taking place only between this, is it 900 or ya so it is only between 900 and 850 okay. That is only in this layer there is trouble. In all the other layers it is unsaturated correct. So you have to find out so you have to once you plot you will have to find out so this is this is the gamma. Then you will have to find whether gamma is less than gamma d or gamma d you know what the value is. What is it? 9.8 okay.

So you have to plot that 9.8 so that gamma greater than or if you are too if you are too much of a stud then what you do is 1000 hPa - 970 you find out e to the power of - z calculate the height calculate the temperature and calculate the gamma layer by layer. Or you plot and then visually see is that visually examine okay. So the first part is you have to find out which of these layers is saturated or unsaturated.

If it is unsaturated gamma < gamma d = gamma d gamma > gamma d you can solve this problem. However, coming to this layer, this layer seems to be saturated because T is 18.5, T d is 18 point. So this layer CD alone you will apply the condition gamma = gamma s, gamma < gamma s, gamma > gamma s but now that is part A of the problem. That is over. Part B of the problem is very difficult.

Part B of the problem is each of these layers when it is pushed whether eventually it will become convectively unstable or not. That cannot be decided unless you find out the LCL, LFC this thing and so on. So you find out the LCL LFC and then find out whether it crosses correct whether the sounding crosses the other gamma s line that is a very tough way of doing. The other equally painful way of doing is for each of these level, attention please, I am telling you something which is profound.

For each of these layers for example if you take the layer AB you find out the theta here and using the relationship between theta and theta e get the theta e here. You find the theta here potential temperature and then theta equal to theta e is equal to theta into e to the power of l v omega s by C p into T. Using that relation get the theta e. Then between these 2 layers find out whether d theta e by dz is positive or negative or 0. Then take the condition.

So what I will do is what I will do I will open out one more column okay and then put theta. I will open one more column and then put theta e and then I will put d theta by dz whether it is positive, negative or 0 and then last column I will say convectively stable, convectively not stable unstable and so on. So this problem will take half an hour to solve okay. So in the interest of time what we will do is we will first plot T and T d on the Skew-T ln P chart.

We will just take 1 or 2 layers and see the normal stability of AB and BC okay and then we will take only AB and see whether AB is convectively stable or not. Once you know how to do it for 1 layer then please do it in your hostel and if you have any problems you ask me. Then I want to quickly move on. Now classes are limited. We got another 12 classes or so. You have to get on to the other chapters. Is it okay?

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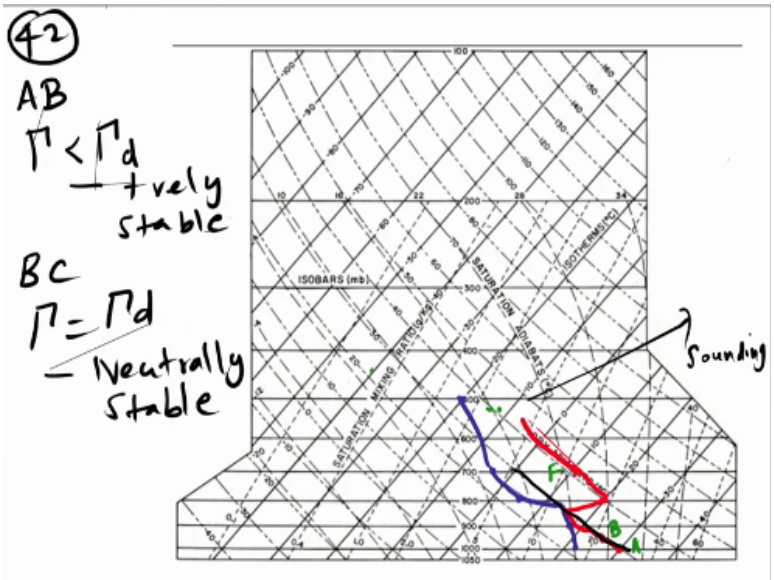

The first point is alright. First point 1000 and 30 okay. Next point 970 and 25. Next point is 900 and 18.5. Next point is 850 and 16.5. Next point is 800 and 20. No we cupped? How do I escape? Just click okay. Okay. Oh 820 it became again, inversion? Okay? That is a troublesome point. 820 what 700 and 10.5. 500 and -11. Okay I did not draw it properly. That is okay but. That is the sounding okay? Alright. Now, dew point. 1000 okay.

What is this F? Sorry, this is F right? Okay. So other points you can figure out. What is that? I thought I did it. 800 and oh okay. Where did you put the D? C is alright? What is C? Okay. D is 850 and 20? 850 and 16 let us do that wait. Ah now tell me 850 and that is okay. What is C 900 and 18.5. Okay this is okay. Then 800 oh like this then I can join this? Rohan is it okay? Alright. Now let us do the different colour and do the what is that dew point.

Okay A point is 1000 and 21.5. Then B is 970 and 25. 21 no? C is 900 and 18.5. D is 850 and 16.5. Same no? 800 and 5. 700 and - 4. 500 and -11. Which is - 11? - 4. Where is - 11? Ah - 20, here correct? Okay. So somewhere both are touching each other that is the point where you cannot put gamma < gamma d. That point require some special consideration okay. It is erasing everything.

Okay let us try to solve it on the AB what is gamma approximately? Or gamma is less than gamma d, what you want to do? What is gamma d everywhere? If it follows gamma d what will it be. It follows the, you cannot get it from the theta is it not. It dry adiabat, no. So what you do, you have to convert it into per hPa is it okay? Then what is per hPa for 9.8? How are you going to solve it? Air parcel will follow what air parcel will follow the theta no dry adiabat.

Why do you want to calculate the gamma? Where is the dry adiabat? Where is the dry adiabat for this? Dry adiabat is this right, correct? So gamma is almost equal to gamma d for AB. Little less, whatever you say. Less, more, that height versus that all that is fixed no? Those problems are not there right? Other people are also watching man they are going to watch this, whatever you say. Gamma is less than gamma d so it is stable or positively stable very good.

We will just do one more, BC. Gamma equal to neutrally stable correct? Shall we explore that gadbad layer. Which is the gadbad layer? CD okay. Is it CD or DE? CD is the problem? So then we will do CD and but which is the saturated CD is the saturated layer correct. So I will clear this okay. Nice now okay.

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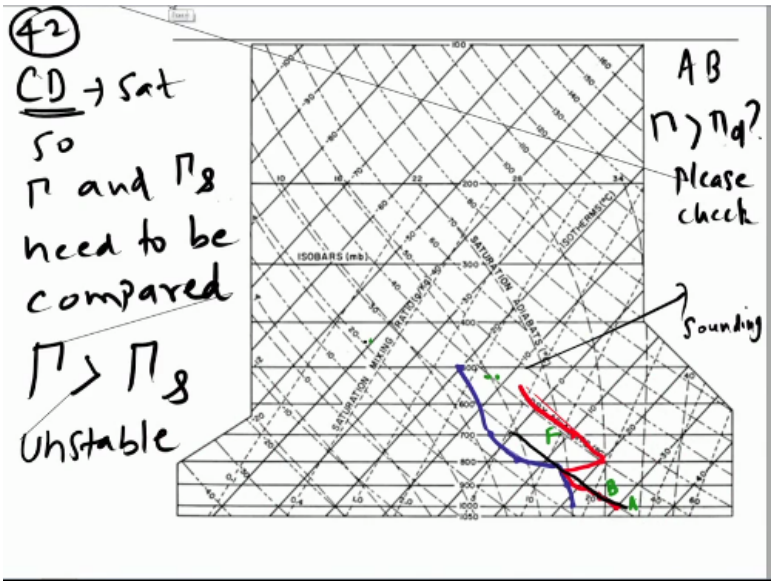

CD you please tell me. CD is saturated no. So gamma and gamma s need to be compared. Gamma s is basically the moist adiabat, saturated adiabat. So what is the story now. Anusha you are not comfortable? Are you able to follow? Gamma, please tell me. Saturation adiabat is coming in the right no this is gamma greater than okay. I want a few more people to. Fellow is unstable? Ya we are expecting that right.

Gamma greater than you only told me that gamma less okay AB, I will just say please check okay. Please check it. That gamma d and gamma s are basically the slopes of the saturation adiabat and the this thing so there is no great discovery or you do not have to solve a nonlinear P d. You have to just compare with the slope okay at that level alright. Now, let us ditch the DE. You know how to do it now right. Shall we proceed? Let us leave this.

Now the real trouble starts. So when you solve the problem it consists of 3 parts. If it is a 24 mark question first 6 - 8 marks I will give you for plotting the sounding and the gamma d. Out of 24 let us say 8 then the next or 6. The next 8 or 10 is for what you have done A, B, C, D each of these layers 1 mark let us say. Then coming to the important part is the part B which layers are convectively unstable.

So maybe I give 6 or 8 marks for the second for the parts where you are just looking at gamma < gamma d and so on. Some 12 marks for the other part where you look at the convective stability.

So if you have to do the full thing how long will it take? Half an hour. Let us say half an hour, 35 minutes let us say. So 35 minutes means 100 marks for 180 minutes. So it is a fifth 20 marks or 22 marks. That is a fair game right. Is it a fair game or not okay.

So 22 mark question will be there. So now let us go to now please let us go to see this problem is slowing us down. Anyway it is okay. So AB now AB.

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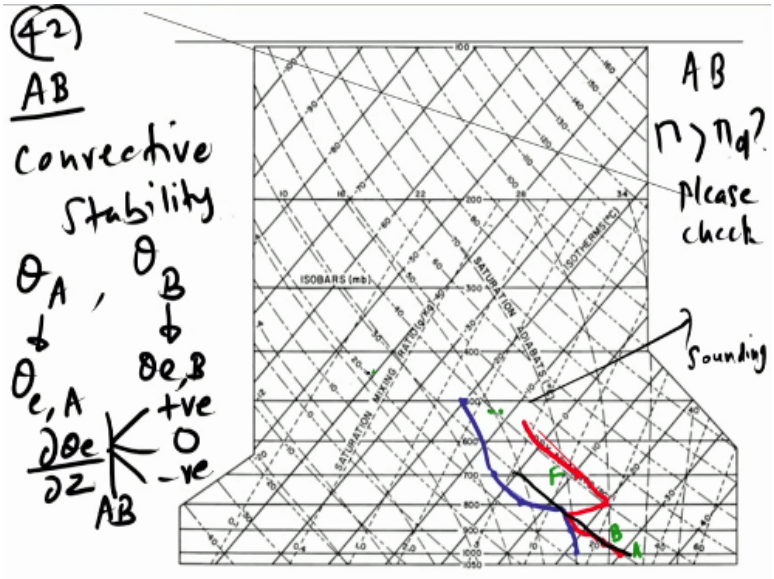

So you have to find this. Convective stability get the theata at A, get the theta at B, get the theta e at A, theta e at B, get doh theta e by doh z and doh theta B doh P whatever. Positive, 0, negative depending on that if it is negative it is unstable right. This is what we decided in yesterday's class. Now what will happen? In the atmosphere a potentially in the atmosphere a potentially unstable, now as you work on just hang on.

I will just explain some fundas then we will get back to the problem. In an atmosphere a potentially unstable layer has got the capability to form cumulous clouds and the cumulous clouds give heavy rain which is called convective precipitation. If it is not stable then it is likely to form stratiform clouds which may or may not rain. If it rains it will give light rain. So highly unstable layer will lead to that cumulous, dark clouds you see evening 4 o'clock 5 o'clock.

Kerala people will know every time so dark and this thing you know that ominous signs okay that you are going to have a downpour. In Chennai also sometimes in the evening 5:30, 6 it happens okay. That means some cumulous clouds are forming then there will be big shower for 1 hour it will shed its moisture and go away okay. So that is very much related to the, that is very much related to the stability of the air parcel okay. Now continue this AB.

Theta A and theta B can be found from the figure correct from this Skew-T ln P. So you have to get omega s and all that. Lv you can take it as 2250 kJ/kg. What is the relationship between theta e and theta?

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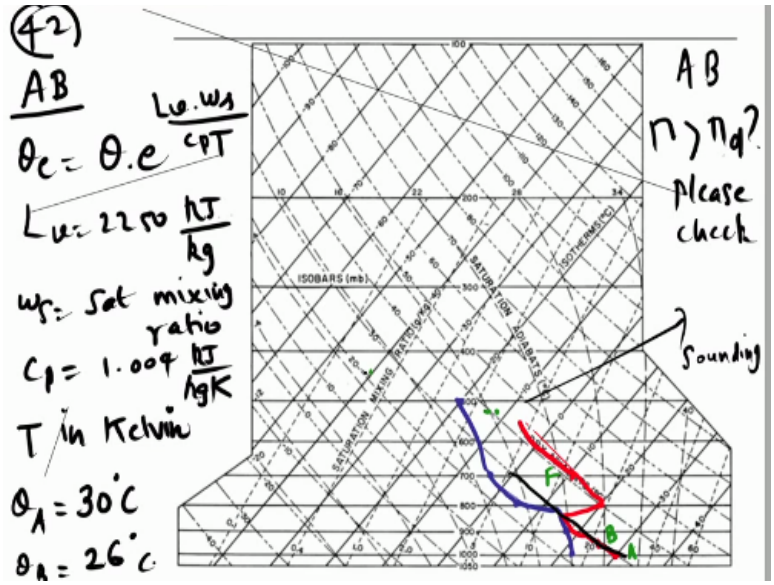

So plus. CP is how much? So get me theta A, 30 okay. Theta B, 26. Okay. So first get theta e and theta A and theta B from the chart from the sounding okay. Then use them in this equation. What happened it got erased, this one? Okay, now please tell me.

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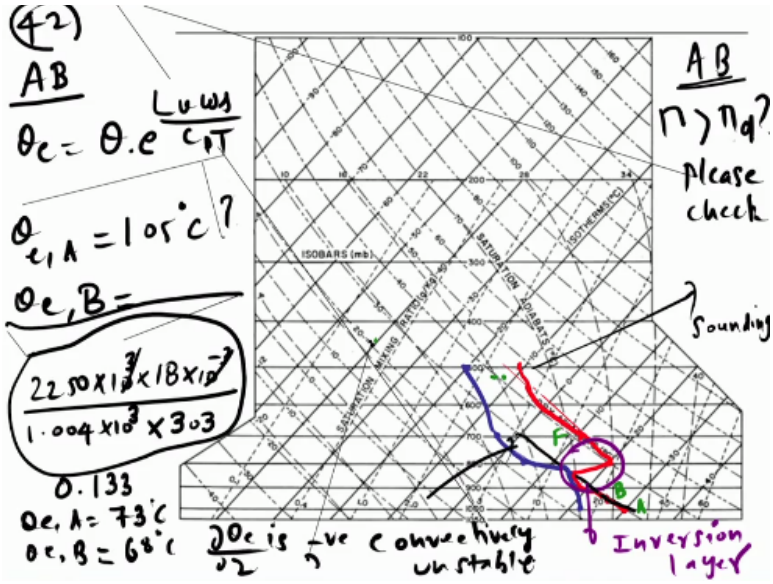

How much is theta e A. Omega s and all you can find out right. How do you find omega s. That dew point is given no. Marius how will you find omega s. Chart from the blue line. That blue line you find out the saturation mixing ratio corresponding. Please tell me. It is lower is it okay. Okay 17, 18 whatever. Theta e B. Other method is to use the LCL, LFC and all that. I think this is easier no. This is easier right? Vishwa what is the matter? So theta e B.

Anusha what is happening, not getting? Balakumar. Theta e B. So this is the inversion layer. Temperature is increasing with height. That is the inversion layer. Did you get the, you are getting 30? **"Professor - student conversation starts"** Sir, if the power is taken positive then theta s is greater than theta right. I thought so. 37 sir. Then let me check. Theta e is theta e plus Lv okay. So this is cupped? Okay so what. Omega is by C p T. Akil. **"Professor - student conversation ends".**

The funda is whether theta e has to be greater than theta or it cannot be from your thing it is less than. It is some theta into e to the power of some positive quantity which should be greater than 1. So it is already plain wrong. It is not correct is it not? How can it be? It is e to the power of something. A very small quantity also is more than 1. Therefore, in principle theta e is always greater than theta. So when you say 30 degrees and this is 18 degrees it is not correct.

Please do not make mistakes. Omega s will be in g/kg multiplied by 10 to the power of - 3. L v will be in kilojoules, attention please. L v will be 2250 kJ but omega will be in g/kg into 10 to the power of - 3. So that 10 to the power of - 3 and this 10 to the power of + 3 will get cancelled alright. So what is it Biswajeet what are you getting. You should get some decent value. Rohan. C p is 1004. If you take 1.00 it is kJ. Kirthika. 37.8 very good. At B we will complete this. Do not guess. Today one class we have solved the sounding problem.

"Professor - student conversation starts" theta should be in Celsius or Kelvin sir. Which one? Theta. They have converted finally. Temperature is this one? Theta will be in Kelvin will subtract 73 and get it man. Those things from childhood you are doing. When you are operating when you are operating on thetas you can. 100 and all. Theta and Kelvin it is coming around 100 degree C theta e is. 73.29. How? That is not correct no. T value is coming to 1.15 so theta is around 300 K. How much is it? Okay. Ya. If the water is condensed. **"Professor - student conversation ends".**

Let us not get into that argument now. We will assuming that that formula is correct let us finish this. I should have given this as an exercise problem. Ya how much is it 103? Is it correct? I am not sure. Okay theta e B 105 are you getting? I am not sure. Then theta e B? Ya that is alright. That T I have used in Kelvin right here. C p, L v is into 10 to the power of 3. Omega is 10 to the power of - 3. C p is I thought it will give small values. Omega is how much?

So 2250 correct into what is T. How much is this. Tell me how much is this? Please tell me how much is this value. No just this value. What is this value just tell me. 0.22. So what is T to the power of 0.22? Is this correct. Rohan just check the values no. Somebody told me it is 13. Come on. How can it vary so much? Omega s is the omega corresponding to the dew point. Omega s is the saturation mixing ratio. That comes only from the blue line. This is not L v omega.

It is L v omega s. Hare baba how will you find omega s at a point unless you know the dew point. What is it after listening to the whole Ramayana you are. How will you get the omega s unless you know the dew point you cannot know the saturation condition. Given a point A can

you find the saturation mixing ratio? It is not possible. That is why the sounding for dew point is also given. Please get your fundas straight. The omega at point A is not known. Simple.

The omega at point A at any point is not known. The saturation at all these points are known through the dew point. Please understand the sounding right. So if you take at A you will get 30, 40, 50 high values of omega. That is not correct. What is the omega corresponding to T d. 18. So that is the correct value. Let us use this. Then the whole thing is, this is 0.113, point how much this point okay. So theta e A is okay. Theta e B another 3 minutes we will finish this theta e B.

Get the omega s at B and then substitute and then you have the theta. Should be less, should be less correct. No we do not know. So it is stable. It is stable right. Ya check it. So you are using 26 now? 26 degrees which is like 299; 299 e to the power of 2250 new omega s will be lower because you have moved left. New omega s will be lower. T is also lower. Doh theta e by doh z is so it is convectively so it is convectively unstable correct. Very good correct.

Got it. What do you mean by, is there a contradiction? Is there a contradiction between the part A and part B. Part A I told you that AB. Also part A was also unstable. Then no problem because here the check no gamma is greater than gamma d. So left to itself, left to, attention please. Left to itself whether the parcel will be stable or not is decided by gamma > gamma d < gamma d and all that.

This elaborate calculation of theta e is if the parcel is pushed whether eventually it will become unstable it will lead to some cumulous clouds and rain by sustained vertical motion. If you just push it what will eventually happen to it. That so that study is a study of convective instability. Is it okay. Now you see you are struggling a lot. So for 8 levels it will take at least 20 minutes to find out the convective stability.

In 5 or 7 minutes you will find the normal stability and then another 5 minutes to do the plotting. So 30 to 35 minutes if you do not make mistakes and if you are fine with the kilojoules and grams per kilogram and all that you should be able to because you are not going to do it 16

times. Do not worry man. If you are doing AB for BC B is already there. For BC already B is there. For CD that C will be there. So you do not have to do double calculations for each of this.