Fundamentals of Environmental Pollution and Control
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Lecture No. # 31
Air Pollutants and Meteorology

Well, we today start a new topic as you can see is you know the topic is air pollutants. I'm so sorry.

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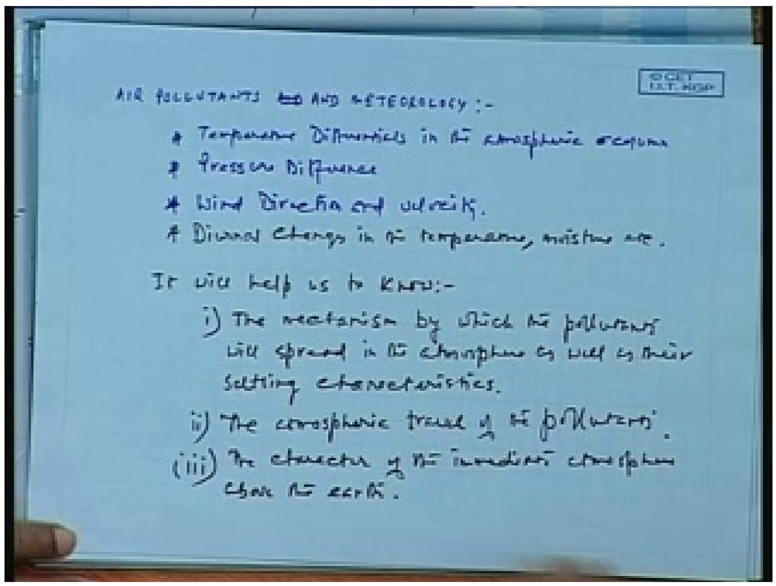

Air pollutants say this is we have known somewhat about this air pollutants as you know mostly the air pollutants that we have discussed are say all this gases like SO 2, CO 2 then NO 2 and then finally also we have discussed about the particulates RPM and SPM. We have also understood the standard of this. Here in this case you know it would finally it would discuss that you know what would finally lead to the dispersion of air pollutants, how this air pollutions actually disperse across a, across a, across an area or across a particular atmospheric column, so where what we would try to know is as you can see if you can observe now there are few things very important in this case of meteorology why this is, why this air pollutants are one thing the meteorology would discuss about say, say the temperature, temperature differentials in the atmospheric column, temperature differentials in the atmospheric column and secondly we can also find that is you know we can also observe say the pressure difference, pressure difference, pressure difference and also the third thing that we can find out this is a wind, wind direction, wind direction and velocity.

So, wind direction and velocity so where you can see this, this three important parameters apart from that you know you can also discuss about say this diurnal changes, diurnal changes, changes in the temperature, temperature, moisture, moisture etc. So, this diurnal changes in say day wise changes during the different times of the day and different times in the night, diurnal and nocturnal changes in the temperature that all these things actually influence, influence the flow, flow and concentration of the pollutants in the atmospheric column, in the atmospheric column. So, you know we would have to discuss so you know in cases how this air pollutants actually this would help us to know if we know about their the dependence of this air pollutants and regarding their movement of air in the atmosphere, it will help us to know the mechanism, the mechanism by which the pollutants will spread, will spread in the atmosphere as well as their settling, settling characteristics, settling, settling characteristics right.

Secondly, another important thing that we can find out is this the atmospheric, atmospheric travel, atmosphere travel of, atmospheric travel of the pollutants, atmospheric travel of the pollutants, atmospheric travel of the pollutants as you can see. So, the first thing that you can see the mechanism by which the pollutants will spread in the atmosphere as well as their settling characteristics, how they would settle and how they would travel. These two things are of extreme importance to us and we'll also see this you know atmospheric travel of the pollutants, atmospheric travel of the pollutants and also atmospheric travel of the pollutants you know you can very well see you know particularly if you can observe the situation like you know during a cloudy day, during the cloudy day if it is you know at the end of a, at the end of a cloudy day you'll find that the air almost doesn't seem to move. It is remains a very, the air seems to have stopped in situations like this, you know in an, the heat remain confined within the very short atmospheric column I mean within the cloud and between the cloud and the earth.

So, you know that is that gives to different kinds of discomfort. So, this discomfort and you know when the sky is clear, the comfort level increases. All this you know this particular this atmospheric changes has something to deal with the, with the travel of the pollutants at different levels in the atmosphere, okay. So, this atmospheric travel of the pollutants and also the immediate, the character of the immediate, character of the immediate atmosphere above the earth right above the earth. So, immediate atmosphere above the earth, it is of great significance, it will have great significance. We will try to see how and why these things matters a lot, okay. Now, before we further go on to this let me explain further on this you know about this what are the typical things that we generally observe is that you know with the one very important topic here to discuss about this adiabatic.

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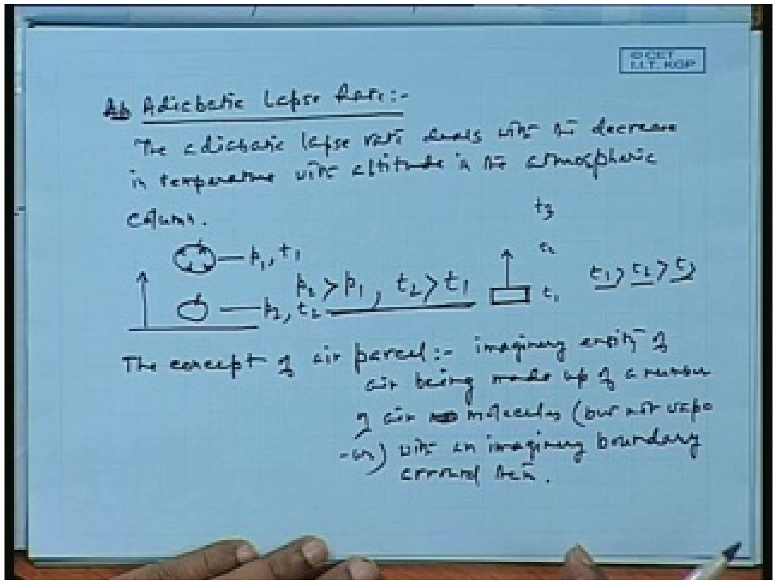

Sorry, adiabatic lapse rate, the adiabatic lapse rate. We'll also, we'll come back to this I am going to define this you know mathematically this is adiabatic lapse rate. The adiabatic rate deals with, with decrease with altitude, deals with the decrease in temperature with altitude in the atmospheric, the atmospheric column. The adiabatic lapse rate deals with the decrease in temperature with altitude, with altitude in the atmospheric column, in the atmospheric column. So, let us study you know we generally try to begin here to understand is that you know the typical phenomena that takes place, the typical phenomena that takes place is that as this as in the with the altitude if you just observe this, if you just observe a particular balloon here, if you just observe the balloon here and the balloon here at this point of time, you'll fine observe that the balloon would be generally what would happen is here there would be this in this case of the balloon as you can observe here there would be, this would be at a higher pressure.

So, you know you can this, if you can just observe this p 1 here and p 2 here we can see can find always p 2 becoming more than p 1, more than p 1. So, what it would happen is as this would make it to as you can see this p 1 it would make it to expand as you can see it can, it will begin to expand as the pressure would, pressure would be less, the pressure would be less as a result of which it would begin to cool down. As it will begin to cool down, as it will begin to cool down so there would be this particularly as on the other hand at here as you can see under remaining under pressurized condition this would be, this is, this is how this p 1 here under that. So, this here you can see the temperature here, here if you can see t 2 and t 1 you will also find that you know t 2, t 2 becoming this is p 2 is t 2 becoming more than t 1.

So, here as a result of which you know this is particularly so we would consider, we would just use this analogy we use this analogy to consider how this particularly the cooling and the how this so what we can observe here is if we just observe a particular column of air, if you just observing a column of air, so it would continuously it is, as it is going here you can see say t 1 t 2 t 3 we can see with altitude t 1 is t 2 is t 3 like this. So, you can see with altitude the temperature actually changing.

So, in the altitude as you can see in most cases as you can see within in a, in a, in a column of air, enclosed column of air we can observe that you know the temperature across along the atmosphere, along the altitude would this temperature would begin to decrease. So, this being a very typical phenomena but how this rate takes place, what is the change in the rate that takes place. So, we can observe here you know is a particularly as you can see here, so if you'll observe a, you know will consider the concept, the concept of, concept of air parcel, concept of air parcel is generally considered this is imaginary, imaginary, imaginary entity, imaginary entity of air, of air being made up of, made up of a number of, number of air molecules, air molecules but not vapour, not vapour.

Imaginary entity of, imaginary entity of air being made up of a number of air molecules but not vapour remember this with an imaginary, imaginary boundary around them, them means the particles this the molecules, the air molecules. So, here we can see this you know try to, trying to understand this from this adiabatic lapse rate that we can generally observe now how we can, how we can find out the rate at which this the temperature changed, temperature takes change in temperature takes place along the altitude.

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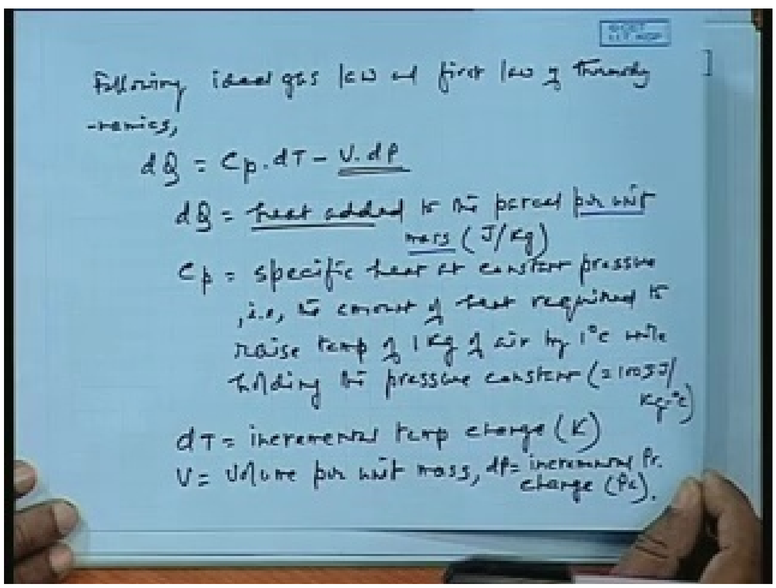

So you can see this, the particularly following ideal gas law, following ideal gas law and first law of thermodynamics, first law of thermodynamics say there is a thermodynamics that is you know a conservation of energy this is first law of thermodynamics. We can find out we can write an expression for this air parcel. We can write an expression for the air parcel which is known, which is equal to C p into dT minus V into dP where dQ, dQ will be heat added remember this heat added, heat added to the parcel, heat added to the parcel per unit mass. This is per unit mass, this in Joules per kg. This is important you know you must I try to underline this per unit mass. I'll tell you why you know per unit mass okay per unit mass is this C p, C p is a specific heat at constant pressure, at constant pressure, dT is so you can see that is, that is the amount, the amount of heat required, amount of heat required to raise, to raise temperature, temperature of 1 kg of air, of air by 1 degree centigrade while holding the pressure constant, holding the pressure constant and the Q is equal to for air we know it is about 1 0 0 5 Joules per kg degree centigrade okay, Joules per kg degree centigrade. So, this is C p which is nothing but specific heat at constant pressure okay, C p at a particular pressure say you know we consider this to be 1005 Joules per kg degree centigrade about this you know we can also find out here this is the dT is incremental temperature, incremental temperature change, incremental temperature change in Kelvin K, V is, V is the volume per unit mass, volume per unit mass and dP, dP is incremental pressure change, incremental pressure change, incremental pressure change you can say that incremental pressure change, incremental pressure change in Pascal's.

So, here what is observed here is as you can see essentially so, here as you can see this is a very standard equation. A equation as such what is essentially is a dQ plus V dP is equal to Cp is equal Cp into dT. What is this total heat added, heat added? The first equation is heat added in the per unit mass. So, you know this has to be basically multiplied by M as you know that, M into Cp into dT that is the temperature change. Isn’t it? So, is you know, so this mass has come down here so that is why it has become per unit mass. So, okay similarly, similarly as you can see this V dP volume per unit mass, volume per unit mass and this incremental pressure, incremental pressure change in Pa. so, there are two, two changes that would take place here, as the heat would be, the heat added to the parcel would be essentially Cp into dT but there would be some pressure that would be lost in the, in the volume per unit mass and the pressure, incremental pressure change. So, mass into volume so you can see here, so this would be, this is what is to be reduced from this Cp into dT total transfer of heat, total transfer of heat would be this minus this one, this would be observed as a work done and so this would be the net heat added to the process okay net heat added to the process. So, as you can see this this is a perfectly a non-adiabatic process.

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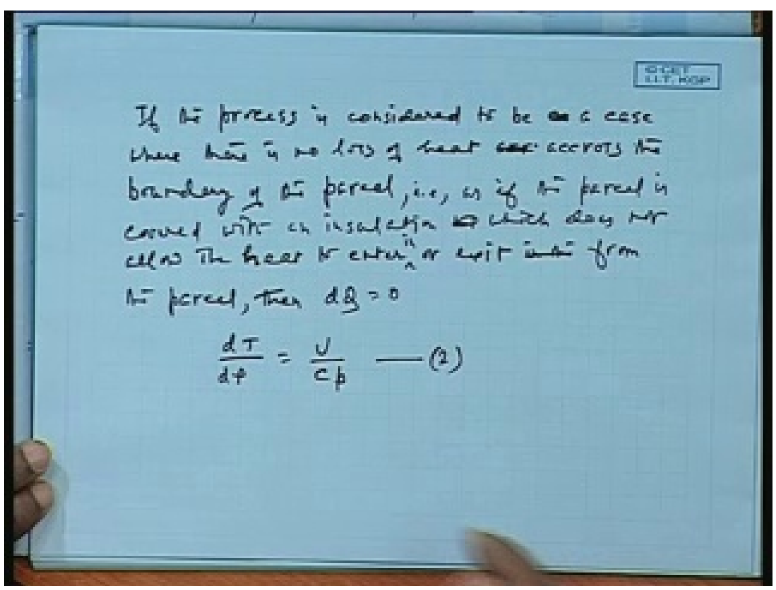

Here as such if you just can consider, if the process is considered, the process is considered to be a case where, where there is no loss of heat, no loss, loss of heat across, across the boundary of the parcel, as a across the boundary of the parcel, across the boundary of the parcel that is, that is as if the parcel is covered with an insulation which does not, which does not as you covered with an insulation which does not allow the heat to enter or exit, enter in or exit from that which does not allow the heat, which does not allow the heat to enter in or exit from the parcel, parcel. If the process is considered to be a case where there is no loss of heat across the boundary of the parcel that is as if the parcel is covered with an insulation which does not allow the heat to enter in or exit from the parcel then, then, then dQ is equal to zero.

If dQ is equal to zero, we can very well write this equation say equation if we just the above equation that is dQ is equal to Cp dT into minus V into dP that we can very well write as dT by dP is equal to V by Cp. So, if the top equation can be written 1, this one is 2, okay. So, now here now this is a condition you know particularly a situation when this is an adiabatic case, when there is an adiabatic case and we should consider that there is no this, this has taken place without any heat being, without any heat being entered into the parcel or exited from the parcel. There still this, this two work has been done, I mean complementing each other, complementing each other. In such a situation so you know there would be this if we just this can be explained like this okay. Having gone, having coming, having gone from this having gone from this now if we just try to understand the situation physically how it happens, how it happens.

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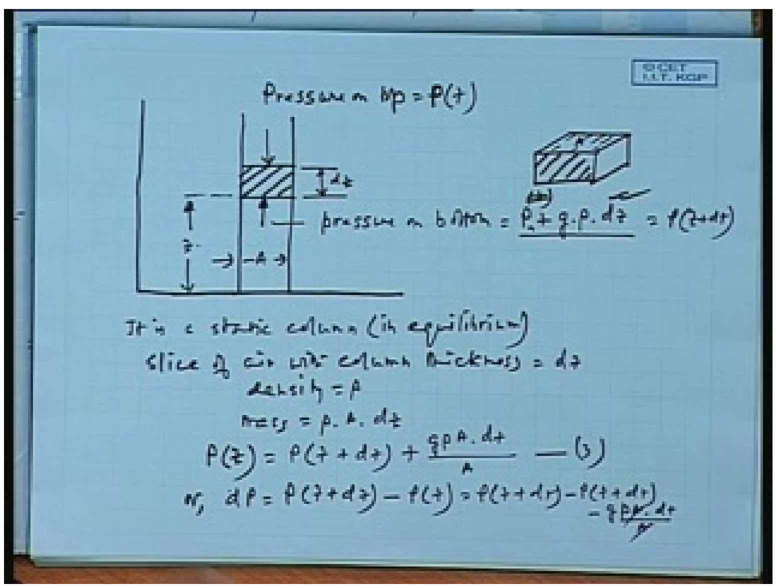

If you can observe things like this you know here if you just observe that you know this column of this particularly the parcel, the parcel I, if the parcel is in a perfect equilibrium say you know this parcel is in a perfect equilibrium that mean it is that is the parcel is in a perfect equilibrium there is absolutely no movement of the parcel at this point of time. We just consider that you know this parcel as you can see this parcel is a volume that I have said, you cannot see the volume as such here but what we are observing here now is this say its unit volume which is unit volume say you know we are seeing just a face of it. So, you know here if you are just seeing this face of it here what we observe is this one is say, this one is the area A. If we can say this is a, this is the area, the total area at the bottom, total area at the bottom, as you can see here this total area here. So, this is the, this is the area we are talking about this is A. This is the area we are talking about, this total area is this one is if you just observe this, this is A okay. If this area so what when it would be actually, so there would be as you can, as you have observed say the pressure on bottom, pressure on bottom as such you know to, since the pressure here would be, there would be always a pressure on top of this, on top of this you know this one is, this one is z, this one is z and this one is, this is pressure from the top, this is pressure on top is equal to P, pressure on top is P and the pressure on the bottom, on bottom is equal to say P plus P plus g into rho into dz, dz okay.

Here so as you can see this is the, g is the I mean this is excavation due to gravity as you know g is say rho is a density and dz is this, dz is this particular dz okay a particular part of, particular part of the column. So, here is you can see is that a, the a horizontal slice of air it is a, it is a, it is a static column, static column, static column, that is in equilibrium, static column equilibrium and this is this slice of air, slice of air with column thickness dz, column thickness dz, density rho, density rho and we'll be having and is this mass is as you can see the mass is equal to rho into A into dz of this mass. Having said this, having said this, one thing we can very well write here as you can see this one is P is a pressure on top is not rho. Remember, this is P, this is P, this is P plus g plus g plus g into rho into dz.

As you can see here, so if it is has to remain in the equilibrium, if it has to remain in the equilibrium what it should be you know this is Pz, Pz this is Pz sorry, this one is Pz and this is Pz plus dz, pressure on top is Pz and this one is pressure on bottom is P plus Pz plus dz. So, this one is if you can observe this as equal to P, we can write an equation as such as like this you know Pz is you can see this one is okay, I mean since it is multiplied by mass here as you can see this is mass so the mass into this is the, this is the weight divided by A. So, you know AA cancels here. So, in this is not necessary you can very well write this equation also here, so this one also can be written as like this. So, here so if this is just one minute this one is let me make this clear here, Pz plus no, no, no it's okay the pressure on top is this okay.

As you can right this you know you can see this Pz, Pz it has to remain in equilibrium, it has to be countering this plus this one, plus this column, plus this column zero A into dz divided by A. This one if you can just see this we can also write it like this. This is Pz dP is equal to change in pressure would be basically so if this can be, if these two things are you know if they are Pz if we are just changing it to say this one is P is P A dz minus Pz plus dz minus gp A into dz divided by A, AA cancels. So, we can find out this or dP or we can write this dP.

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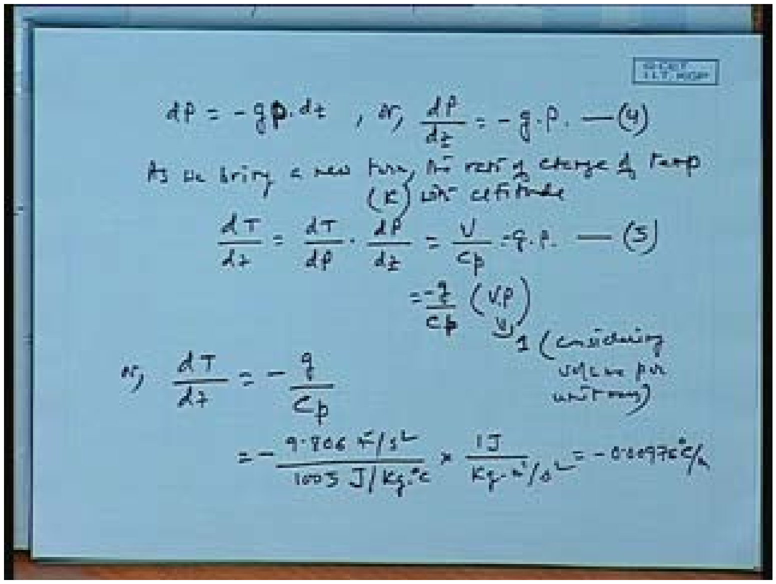

This is the dP is equal to dP is equal to this one is minus, minus gp dz or else we can write it at very simply as this or we can write dP divided by dz is equal to minus g into rho right, this one is rho I am sorry this is rho.

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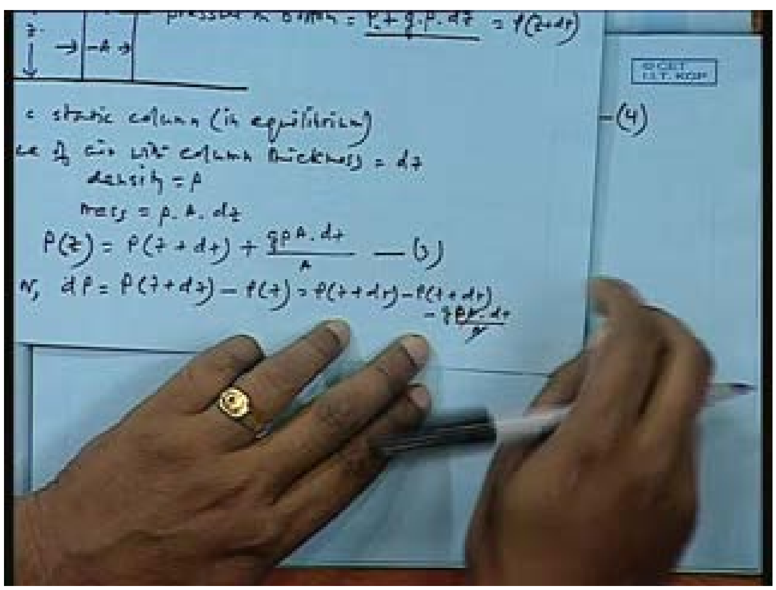

This needs to be you know just it’s not a I mean I am wrote it wrongly is p kind, it is rho essentially rho. As you can see this, so this is minus as you can see the minus is just to indicate that with a, with altitude, with altitude, the change in the pressure it would be minus so it would decrease just to ensure that.

So, this, these two things can be explained. We are as we bring in a new term that is about dT divided by dz, dT divided by if what is the a, what is a says this new term the rate of change of temperature, rate of change of temperature in Kelvin with altitude, with altitude we can very well write this as dT, dT divided by dP to dP divided by dz. You see here what we have just done is you know the divided and multiplied by the same term. What we have done? The simple operation that we have done is we have multiplied and divided by the same term. So, you can here itself we have found out, we have found out dT by, dT by dP, dT by dP is equal to V minus Cp under adiabatic condition and this one is equal to we have already found out g into rho, g into rho. So, this one is the equation number 5, this is equation number 5, so this is equation number 5.

So, this if it is now as you can see this is V into rho here, V into rho essentially this one is minus there would be a minus here, this is minus, minus, this minus gp, this is minus g divided by Cp because g divided by Cp because this one V into rho, V into rho is essentially V into rho is essentially 1. If it is for considering, considering, considering unit volume, considering volume per unit mass, considering volume per unit mass if you just see this volume per unit mass multiplied by mass divided by volume that is that rho. So, it equally cancels out is equal to 1, is that all right. So, this one is volume per unit mass V, since V is volume per unit mass, volume per unit mass and rho is the basically mass per unit volume, so each cancels out and this becomes 1. So, you can find out this if you or we can write dT by dz is equal to minus g divided by Cp, minus g divided by Cp. As you can see in the first case you know if we just give the value here say this g minus this g is equal, equal to 9.806 meter per second square that is typical value of g that you know of and this one is I have already said Cp is equal to 1000, 1005 joules per kg degree centigrade, kg degree centigrade is equal to, so you know is basically if you are just making a conversion here 1 Joule divided by 1 Joule divided by kg, kg mass m square by second square.

If you are just trying to this kg comes on the top, so 1 Joule, Joule in the gets changed. So, if you are just making a change in the unit itself it is taking place is equal to what we find out is 0.00976 degree centigrade per meter. What I am trying to do is we are just trying to kg degree per centigrade, this one is if you, if you just convert the units into Joules you know Joule if you change and if you can just you know if you just change these Joules into these values here, you can very well find out that you know all these things cancels out and degree centigrade this one is degree centigrade, this degree centigrade goes on the top and divided by meter, this meter, this remains. So, here in this case as you can see here, so what it’s says is one very interesting observation that it makes.

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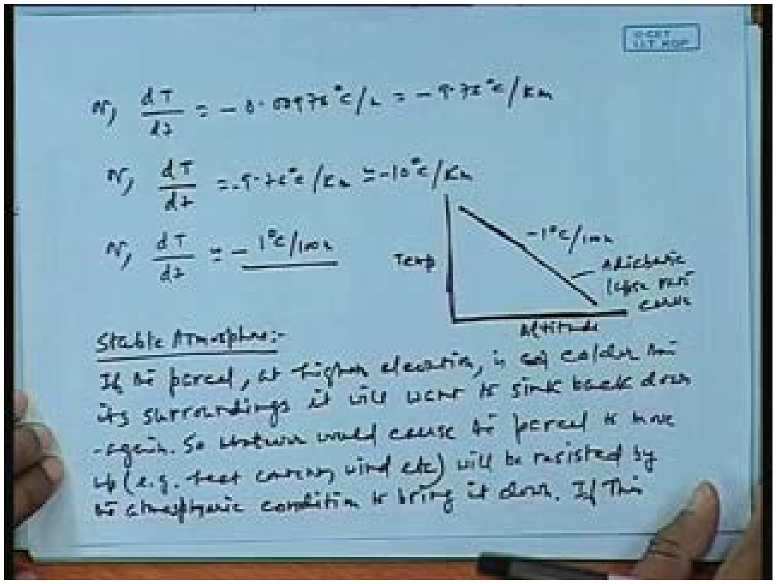

If you can just observe this or we can write as dT by dz is equal to minus 0.0976 degree centigrade per meter is nothing but if you are just is about 0.97, 9.76 degree centigrade per kilometer multiplying by, multiplying both by 1000. So, it becomes, 1000 meter become 1 kilometer, this one becomes minus 9.76 so or this is what is known as the adiabatic lapse rate is this is, this is adiabatic lapse rate is generally known to be is 9.76, minus 9.76 degree per kilometer or equivalent to we generally observe it as 10 degree, we generally say it is a minus 10 degree centigrade per kilometer or what is nothing what is or you can very well write that as dT by dz with a little bit of approximation, we can write this to be o1ne degree centigrade per, per 100 meter okay, this is the dT by dz.

So, what is interesting here is, what is interesting here if you just consider this, if you just consider this as temperature, if you just temperature and altitude, altitude, altitude under a perfectly adiabatic process, under a perfectly adiabatic process the curve would be like this, the temperature would continuously begin to go down. So, this is, this is about minus 1 degree centigrade per 1000 meter. So, under a, this is on this light we will now explain how this atmospheric changes essentially take place. So, what is happening here is in a situation like this, in a situation like this, if you just observe there are two situations, two conditions that we can discuss here this is, so this is, this is known as the curve of adiabatic lapse rate curve, adiabatic lapse rate curve okay which it signifies that with height, with the, with altitude there would be almost linear relation to exist in a under adiabatic condition when the, with the temperature would begin to decrease, when the temperature would begin to decrease.

We can, from this we can establish two important relationship, one is the stable atmosphere. We can this you know the stable atmosphere, the stable atmosphere. Just to explain the situation, if the parcel if the same parcel, if the parcel at higher elevation, higher elevation, at higher elevation is now, is now is colder, is colder than its surrounding, than its surroundings, it will, it will want to sink back down again, descend downward this is will begin to sink down again. So, there is if the parcel at higher elevation is colder than its surroundings it will want to sink back down again. So, whatever would cause, whatever would cause the parcel see this whatever would cause the parcel to move up heat content or so whatever would cause the parcel to move up will be resisted, will be resisted by the atmospheric condition, by the atmospheric condition, the atmospheric condition resisted by the atmospheric condition to bring it down. If this, if this so, what is, what I am trying to say here is if the parcel at higher, so what is happening is suppose a body of a, body of a parcel having a say some heat content in it, it is you know a, a it is a hot air suppose a hot air.

So, as we are saying is, as the hot air would begin to go up initially because of its buoyancy till at a point of time when it will not further like to go down it would, as it would be coming, it would be colder then it will begin to go down. This situation if the in the atmospheric column exists, the atmosphere would be called stable that means, that means whenever at, when the balloon or a particular, a particular parcel of air is moving up under adiabatic condition, under adiabatic condition that we have considered so far so when it is going up like this, there would be always a temperature change I mean the, the temperature reduction would take place and this temperature reduction would, whenever there is a relative difference between the atmosphere and the parcel, the parcel would go up because of the temperature being more and the air becoming lighter than the air on the surrounding, the surrounding becoming colder as we are, as it would take place over the column.

So, at after a certain point of time, after a certain point of time when there would be, there would be the temperature, temperature inside the, the inside the air parcel would come would be equal to the temperature outside in the atmosphere, it the, the movement would be stopped, it would come to an equilibrium and as such at that point of time due to mass it will come begin to come down. That is why all the balloons as you can see all the balloons after certain time you know due to hot air balloons, after certain time it begins to come down if the source of heat is stopped, the source of heat is I mean restricted.

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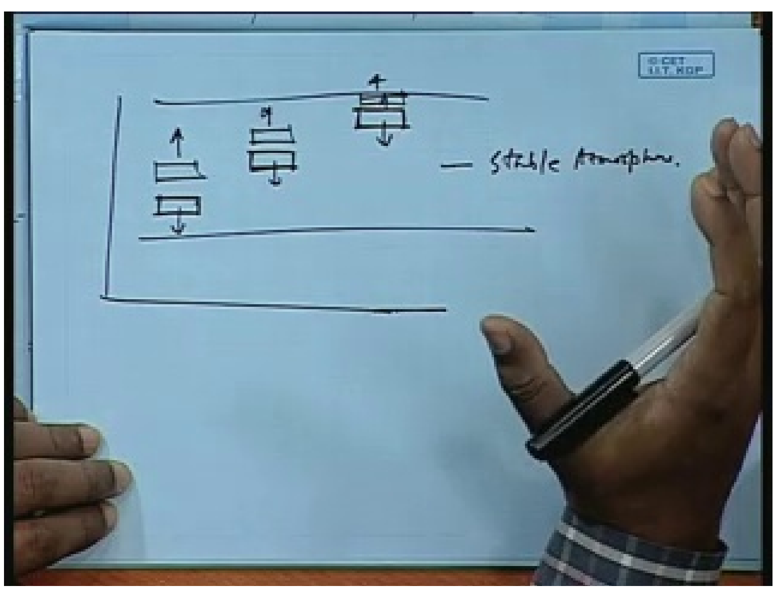

So, here if this happens in the atmosphere, it will be called as a stable atmosphere, it is known as stable atmosphere where it allows us you know see if you just its trying to understand this situation like this, if you see this in the, at in the, in the environment here say there will be a parcel the, the this parcels, this parcels depending on their, their, their thermal content, depending on their thermal content they would, they would undergo a, they would undergo a attraction below they would be, their upward movement would be restricted at a one point time in the altitude than this would be… If depending on the thermal condition at one point of time there would be a downward movement of the parcel but remember all this parcels would not add I am not telling that at all equal height it would happen, it would not happen because all of them are having different thermal contents. So, but if this phenomena across this atmosphere takes place, across this atmosphere takes place, this atmosphere would be known as stable atmosphere, this atmosphere would be known as stable atmosphere.

On the other hand if this situation does not prevail well, the parcel would continuously, this parcel would begin to go up, this parcel would instead begin to go up in the air due to different changes in the atmospheric condition, during the different changes in the atmospheric condition, the atmosphere would be called as unstable that means unstable means some atmospheric changes have taken place that has changed the way the atmosphere should behave, normally should behave, the normally should behave means you know it would follow an adiabatic lapse rate. Isn't it? It would follow an adiabatic lapse rate if there is no change but if there are certain changes it due to temperature differences during the day time during the, the different changes in the summer during the winter, there would be all changes taking place in the atmosphere and thereby when there was this situation of this adiabatic lapse rate following the adiabatic lapse rate and the parcels would undergo a situation when there they would be continuously raising, they would be continuously raising or they continuously coming down in such situation we would call the atmosphere to be unstable. We'll come back to this you know in the next class itself okay, so 5 minutes.

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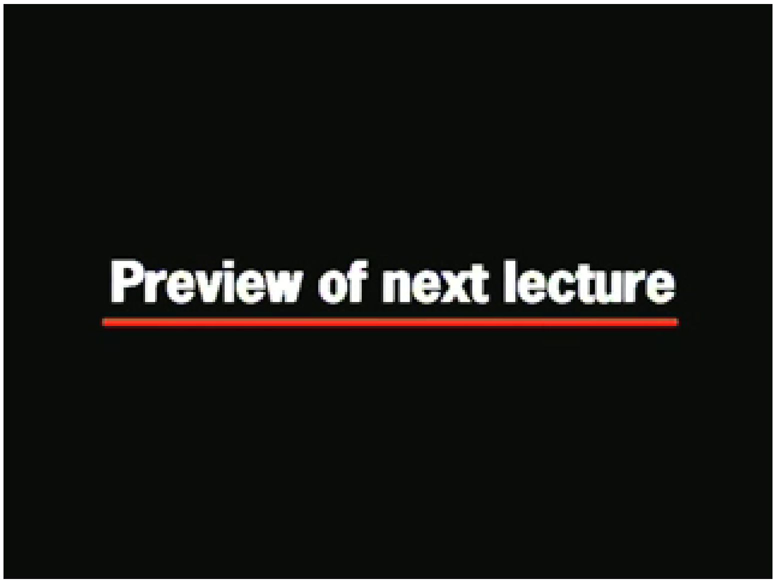

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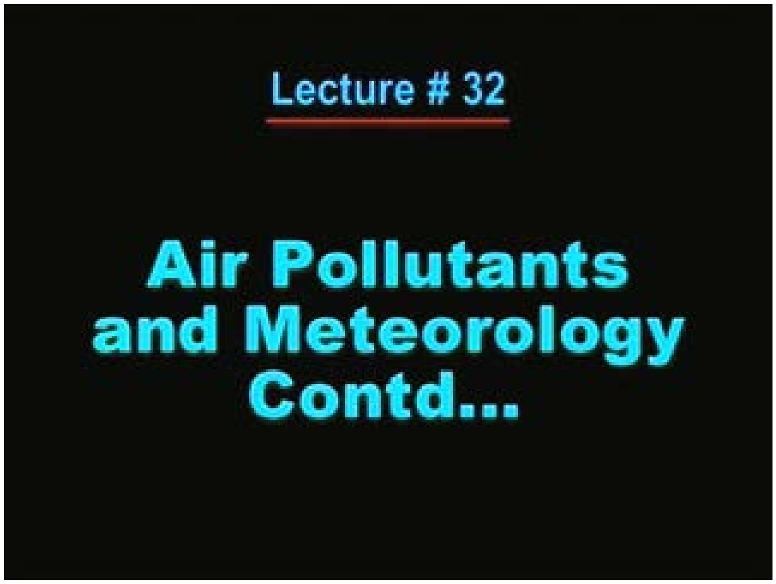

So, okay we were discussing about this stability in the atmosphere.

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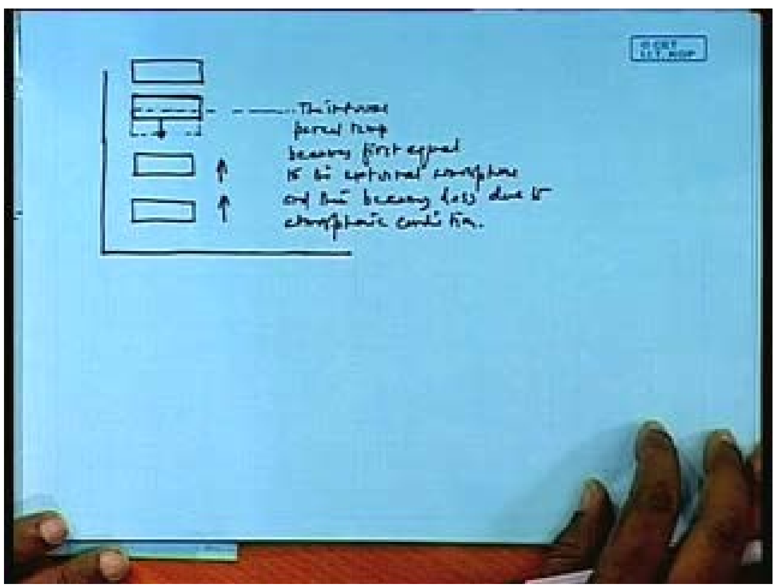

And so we can we are just discussed about one important thing that is I say that if we consider that you know the two situations that we have explained here say if is as you can see this is if the parcel as I have said that parcel begins to move, the parcel begins to move and then at one point of time, the parcel begins to sink down. So, if the sinking down as we can observe here this is how it would look like, the parcel would begin to sink, the parcel would begin to sink. So, you know you can see this instead of say having to go up there, so this, this is how the parcel is moving up, the parcel is moving up. At this point of time, at this point of time as you can see here at this point of time this, the internal parcel temperature, internal parcel temperature becomes first equal to the external atmosphere, to the external atmosphere. The internal parcel temperature becomes first equal to the external atmosphere and less due to the atmospheric condition becomes less due to atmospheric condition. The earth surface becomes cooler than that of the air on top of it okay but this one this reduction, this particularly this characteristics begins to change after 2 am, 2 am it becomes the most pronounced effect. After 2 am about 9 pm you know 9 pm, 6 pm, 3 pm we can observe this would remain, this would remain like this.

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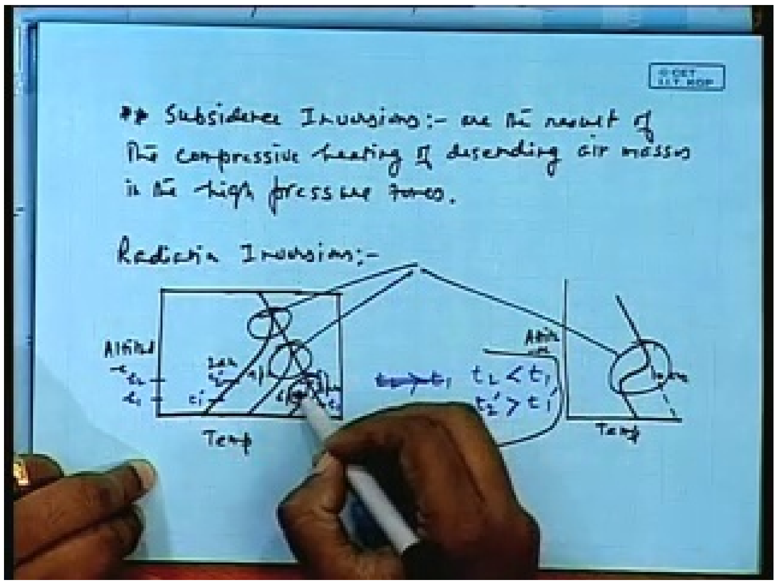

But on the other hand in the 3 pm side is you can see, we will observe that it would almost be close to adiabatic lapse rate. This is known as the radiation inversion. This radiation inversion, there is another kind of radiation inversion that we generally observe you know for your example here that you know is particularly in the situation of, in the case of say height this is altitude, this is altitude and temperature. If you see altitude and temperature we observe that at about 10 am, at about 10 am the inversion is like this, at about 10 am, at about 10 am whereas the adiabatic lapse rate, adiabatic lapse rate is essentially this one. This is what is these are, these are the things, these are things you know these are the things that take place the, these are the things that are known as the inversions.