Introduction to Explosions and Explosion Safety
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Lecture – 36

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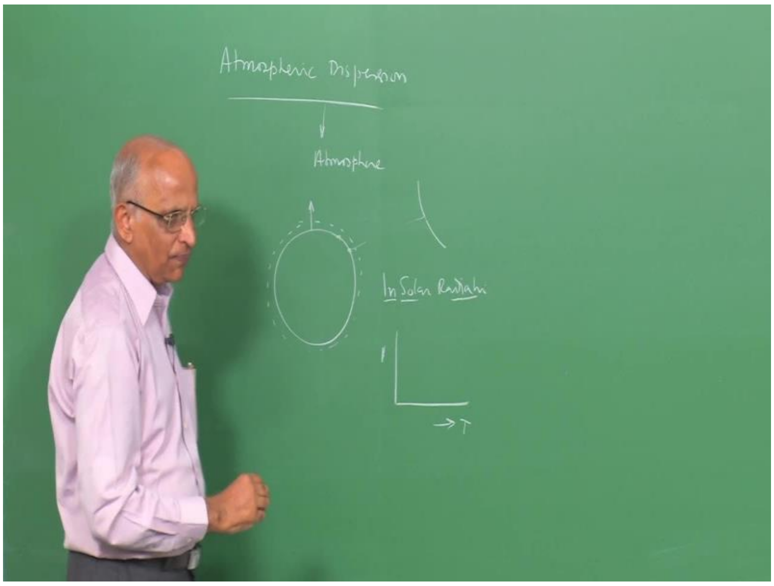

Good morning, you know in today's class we will considered the case of atmospheric dispersion, the dispersion of gases in the atmosphere becomes important in cases, were in we have some leak of either a vapor or a volatile liquid and this volatile liquid or vapor is carried forward maybe, at the point of the leak it gets mixed with a partially. And it gets transported by the atmosphere, maybe by the wind, by other means maybe due to the initial velocity, it get dispersed. And forms the explosive cloud and an exposition could occur, because of this particular dispersion of the fuel gas.

Therefore, to be able to get into atmospheric dispersion and formation of expositions due to the dispersion of the vapor, fuel vapor and also maybe the gases and also pollutant some existent. We need to understand what an atmosphere is about I will take a look at it, You know, you have the earth, you have maybe the sun far away and the heats from the sun, goes and heats the earth; that means, you have radiation from the sun coming on to the earth.

You have something like incoming solar radiation; that means, incoming solar radiation and this incoming solar radiation, is spoken of as insulation. We will, get into the details shortly and what this income solar radiation does is it heats the surface of the earth and the air about this surface of the earth gets into motion. And we let us try to take a look and what this atmosphere about; I show in a slide and in the in a slide I will start with showing the temperature on the x axis and on the y axis the altitude form the surface of the earth.

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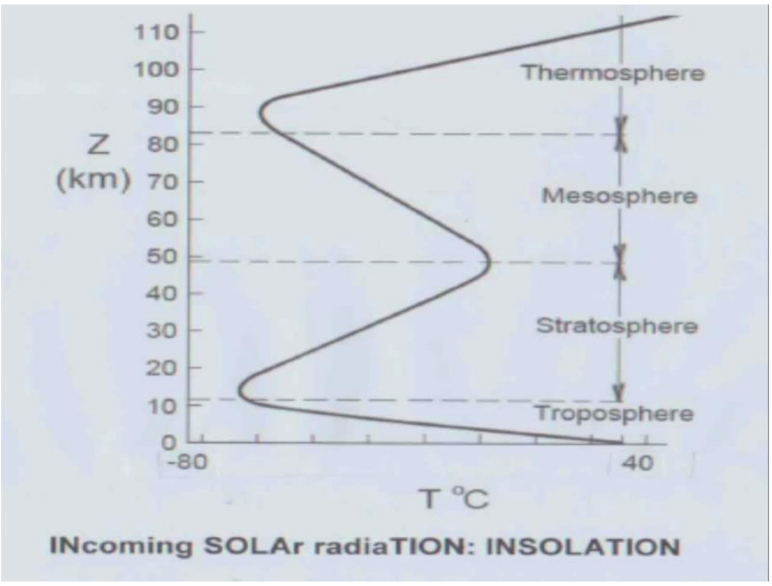

Let see, what the distribution of the temperature is, on the x axis as I was just telling, I show the temperature in degree centigrade and on the on the y axis namely, what is shown by is it in kilometers, I show the temperature. Now, the surface of the earth gets heated by the radiation from the sun and therefore, the surface of the earth is a little warmer. And it heats the lair adjacent to the earth by conduction with the result, maybe as we go higher above, the surface of the earth the temperature drops. This temperature drops till an altitude of around 10 to 15 kilo miters. See, this is just an indication because the temperature distribution changes at different place's, at different times. Therefore, if I say that, the surface of the earth is around let us say 35 degree centigrade.

So, maybe the air above this surface of the earth gets cool to height of around 10 to 15 kilo miter. And around 10 to 12 kilo miter is the height a witch, maybe a jet aircraft flies therefore, the temperature keeps dropping and till a height of around 10 to 12 kilo miters or 10 to 15 kilo miter. The temperature typically is around minus 50 to minus 60 degree centigrade. The air above the surface of the earth the pressure also falls and the region of the air, for which the temperature drops, is known as troposphere or the rotating atmosphere above the surface of the earth.

When we go to heights above let us say 10 to 15 kilometers till the heights of around 50 kilometer, well. The temperature beings to increase again, the question is why should it increase you have ozone. In this particular zone, observes sun light and librates heat and therefore, the temperature increases, and the temperature increases to approximately from something like, minus and minus 60 or minus 55 degree centigrade to around 7 degree centigrade height around 50 kilometers. The zone, in which the temperature increases, is known as a stratosphere. And the region of the distinguishing troposphere and stratosphere is known as.

Now, above the stratosphere that is above 50 kilometers the temperature falls aging this is because, there is hardly any molecule of air left and therefore, you know the radiation does not heat the medium through, which it travels. What only heats the earth over here and therefore, the temperature falls, and the temperature falls to an attitude of almost something like 92, 100 kilometers, but above this particular altitude, he have individual a small number of molecules of let say o2 and o or which absorbs some proton energy, which absorbs some radiation from the sun.

Now, since these things react and they have something like higher temperature, but this temperature is the notional temperature, because we are talking of something were in the mean free path is very large, is difficult to talk in terms of a continuant temperature, but if we view the this particular zone, from maybe places were the sky very clear. Such as in the very northern region and very southern regions we, will find that we can see the picture is display of these molecules getting heated something like aurora this in seen.

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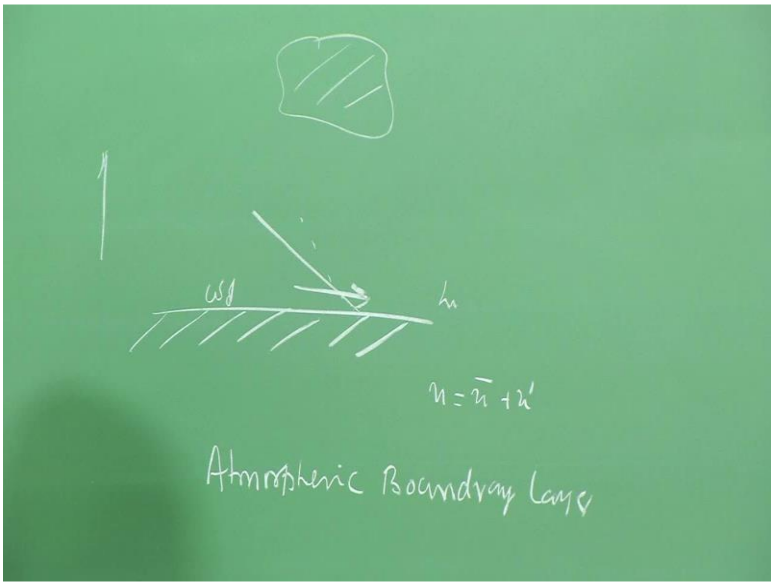

Therefore, we can say well the temperature distribution above the surface of the earth. Initially, the temperature falls to an altitude of around 10 to 15 kilometer in the troposphere, than is increase in the stratosphere, then again is fall mesosphere. The distention between mesosphere and stratosphere the region is known as stratosphere and thereafter in the region, further away well the temperature increases you have the irons over the here and this is also known as ionosphere. And this iron of here, this use for reflecting maybe the radio waves whatever it could be reflected from the ionosphere.

Therefore, this is the temperature distribution and mind you maybe all part the earth be are not uniformly heated with the result maybe same place in the earth more heated from the other. And whenever, same part is more heated we could also have wind well, this wind always be steady we could something gust of the be wind could available. And father in all at also possible, let me go back the board, you know, supposing I have something like be surface of the earth over here. Now, I show is the flat surface, we said well the temperature drop over here and we are really interested in, the region near to be surface of the earth; that means, we are looking at the atmospheric boundary lair.

You know, this region could something like maybe same 300 to 500 miter away. And maybe, because of the hinting earth the temperature drops and supposing, we have a could in the say what is going to happen it is going to prevent the income solar radius heating some parts. There for, maybe same part maybe cool, same part maybe hot and therefore I has winded because when, something’s is hot the air raises therefore I have a wind. This wind, we not will be studies it could be turbulent, will be u is equal to u plus u plant, it could be gust of and wind the cod be the sear.

There for the cloud in the heating the window also, when wind take place it also wind going to influence the heating. And therefore , the let take a look at effect of not only the incoming solar radiation, but also the cloud cover and the wind the fails. To be able to put that he know, in the slides I also talk in term of the incoming solar radiation that is I n, SOLAr t I o n and incoming solar radiation, it atmospheric dispersion is talked house has a in solution, in solution means incoming solar radiation.

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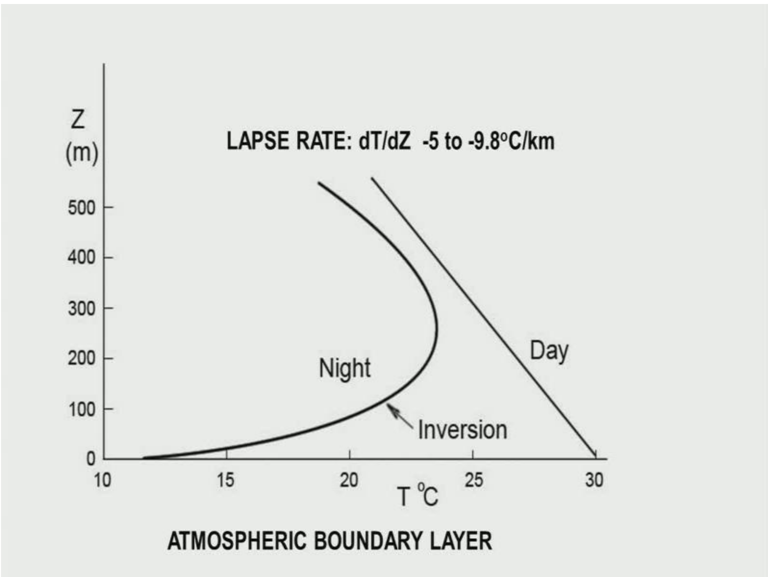

Now, in slide that let, take a look at how this temperature distributes. Like have a hot day let you say, during a hot day us we just not talked. And we are talking of maybe the lair adjusts in to the earth over the distention of 500 miters and to be ever to be. We talking in the region some were near the surface of the earth within the troposphere. And when I look at this particular region, when the temperature with dropping because the during the day time the insulation is the surface of the earth. And typically, the value of the gradient of temperature respects the hick, something like 529.8 degree centigrade per kilometer.

In the when the air is very dry the value of this gradient is larger when you have humidor, when what dish humidity do; see, humidity adjuration heat to the result that gradient degree dish. There for, when I am lot of humidity the gradient is small; when I have, less humidity the gradient is the large and this gradient spoken of lapse rate by lapse rate the menace the temperature gradient, this is how the temperature changes because of the radiation, but supposing I write to thinking terming night.

Let say a cold winter night; see, when I talking trams of the night there is no insulation and supposing like say, air is cold. The surface the earth gets weight cold and therefore , it is cools the lair of the air adjusts into the earth with the result. The temperature gradient, the temperature no long a drops as a height increase, but the temperature increase tell maybe at same distance away it marmoset with the rotten way of temperature discrete with attitudes, but near the surface the earth well the temperature increase.

In other worlds, issued of the having a gradient which is negative; I start getting a possible gradient. And this particular humeral of temperature increasing a pureed along the pureed to the surface of the earth is spoken of us temperature invasion. Well, all the sing are within the of atmospheric bounder lair. And therefore , it was possible during to have day time well the temperature decreasing above the surface, from the surface of the earth and during the night time expressly on the cold winter night well; that temperature a increasing.

Now in now, in auditions to maybe we have this radius form the sun maybe absents of the radius at night. We now, we also have we just know set cloud cover, we could also have wind and what could be in effect of the wind? Say, during the day time and there is no wind at all. This is the gradient when there's the wind go decreasing gradient all the to gradient come down. And at night if I have wind, I will not well such a gradient maybe the gradient will be little less over here. Let a see the possible gradient the influence just the say positive gradient will be inversion just the same way us the negative grease inversion.

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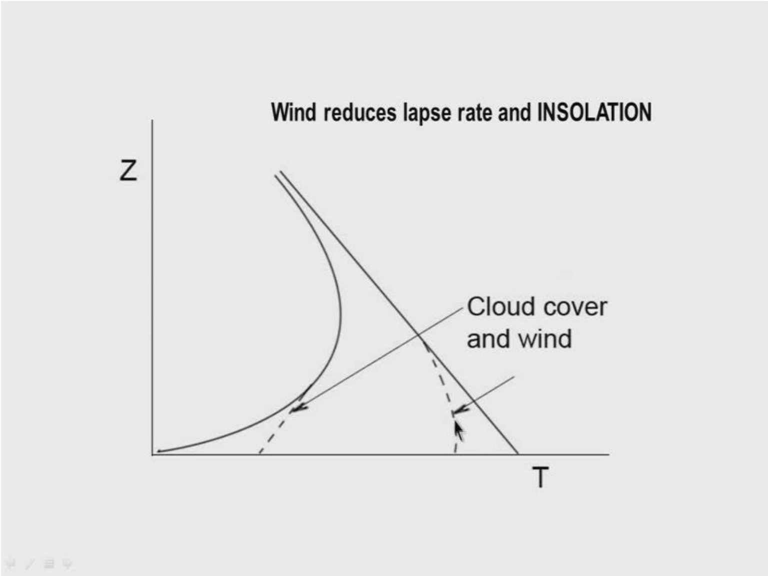

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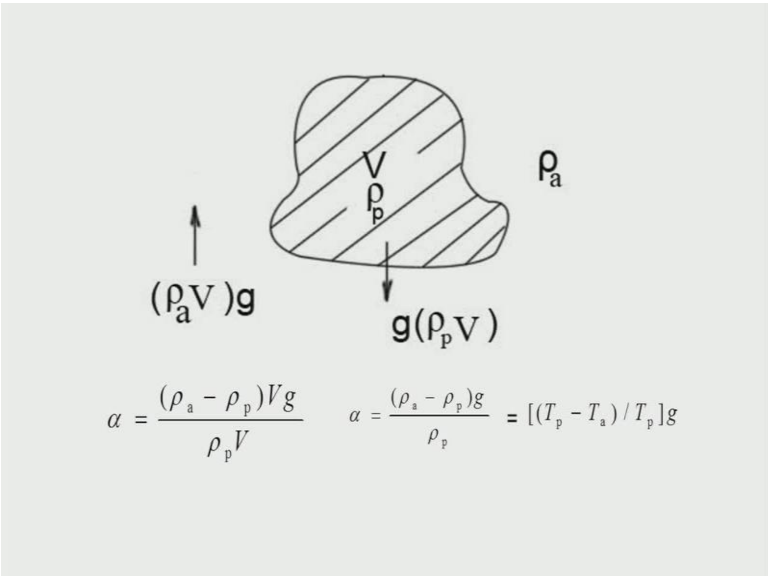

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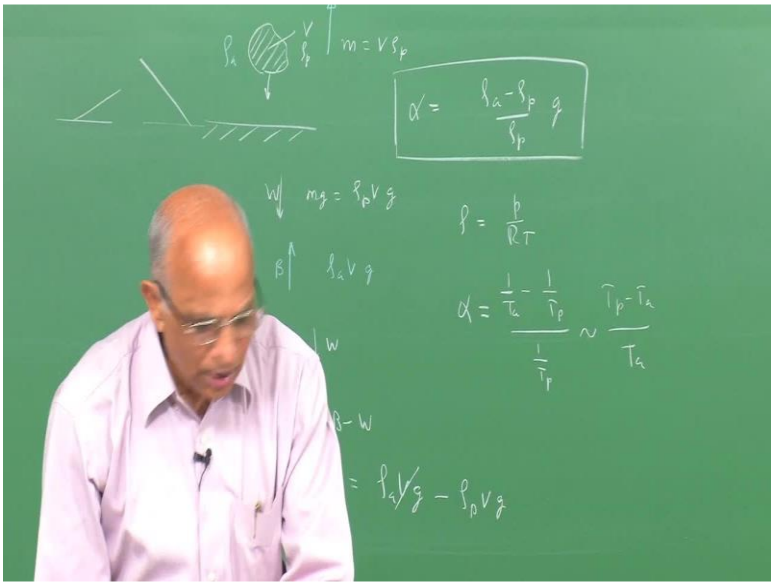

If I have the cloud above as will; the cloud during day time a changes this temperature and therefore the gradient to be going effected. If I have at night cloud above this surface of the earth what is going to happen? Well the cloud misdirection and the effect maybe the temperature at the surface going to the out on the ingredient going to come down. Therefore, less could down they effect of the cloud and the wind the effect on the temperature distributions. And if I by the do that well the effect of cloud and wind on the negative gradient that it a negative lapse rate.

So, the lapse rate as it is to make it by to do it line issued of have being the street line. And also issued of having temperature inversion well the amount of inversion street changes over here. There for, both the wind and the cloud cover reduce the lapse rate and not only that it is reduce the lapse rate during day time, it also reduce the insulation because, the cloud paralyses gross this radiation which come on the on to the surface of the earth. Well this are the critical of let say the temperature distribution, but what is the we are introduction.

So, we want same out Corneille the temperature distribution, the cloud, the wind with respect to the distribution. If I have same thing like leak on the surface of the some gases found, in some exposing; how does it mix to what existence dish a cloud of an exposition gases mixer as a form, and that form we want to do. To able to do that let now, a focus on the problem of something let a parcel of gases. Let us considered I go to the broad and work out this particular issue, at us that this is the surface of the earth oral here. Let a say, I have a parcel of a gases and that what I show in this sailed. The parcel gases is the value we it as a density ropy, and just interested in motion the this parcel of a gases due to the temperature gradient above the surface of the earth. We said all the temperature gradient could had the be negative, just above the surface of the earth our it could also the positive. In case we have, temperature incarnation taking place. Now, the max this parcel of a gas that is max is equal to value density and this max aerated by the gravitational force; therefore , I have a downward corresponding to mg which is equal to p into v into g.

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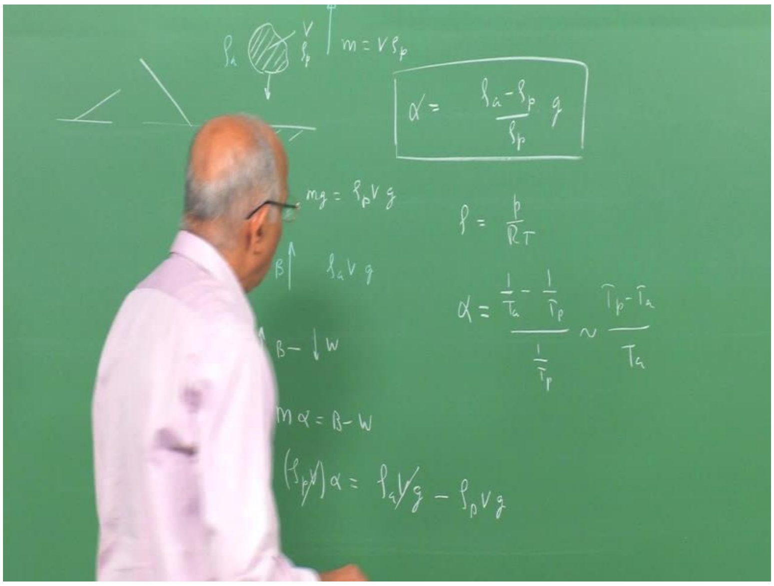

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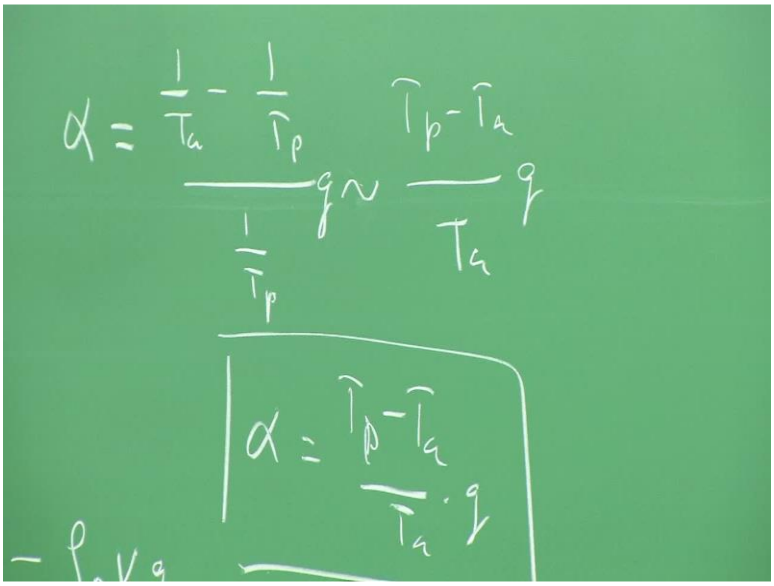

Now, in this parcel of a gases is going to display same amount of air and denoting the density of air by rho a. Now, the value of air this place is v rho a is a, b density and therefore , a have a posing force corresponding o rho a into value into g which is the bossing 4. I have this which maybe the parcel of gases started to the earth is w. And e now, if I resume this parcel of a gases is going to the mood by bounce.

Let at the resume that maybe the density air is grated than this arum ingredient the parcel; well, I have the bounce e force excised may gradation force the excel reaction and parcel of a gases is corresponding max into excel reaction. this parcel of a gases is equal to the bounce force mice the whit of this particular parcel of a gases and max of the gases is equal to rho p into v density the parcel of a gases into value of gases in to alpha is equal to the bounce force this is equal to rho a into v into g; this is the bounce force minus the force which with the parcel is attracted by the gravitational field.

Namely; mg this the whit this is equal to rho p into v into g; I sloe this for the excel reaction and mind you I am thinking of on excel reaction, which is being posh the because I have take on the rho a corresponding to bounce c over here and the rate rho p corresponding to density of you parcel on the with the negative our here. And what is it I get I get alpha is equal to, I get v and v get cancel on the both the side I have rho a mice rho p divided by rho p into g over here. This the excel reaction upper excel reaction of the parcel of a gases when I have the density of the air exuding the parcel ore sponging now, I considered of particular case, considered the case where in, I am in the region near the surface of the air. And is happened rho is equal to p v is equal m a RT our rho is equal p by RT and therefore , in the region very near to the of surface the of earth veneration fresher this not that, I ore taking the fresher us constant.

This upper excel reaction us equal to since the fresher is the near constant; I can write is the 1 over temperature of air minus 1 over temperature of the parcel of gases divided by 1 over temperature of the parcel of gases divided by 1 over temperature of the parcel of gases. And this gives me the value us maybe the temperature of the parcel of gases minus Ta divided by is the value of the upper axle reaction. And therefore , let take a look at this particular 1 and this not I show here; I have to, I toke alpha as multiple by g and therefore , I will have the g over here this is g over here and therefore , I get alpha is equal to TP minus ta divided by Ta into the value of g upper.

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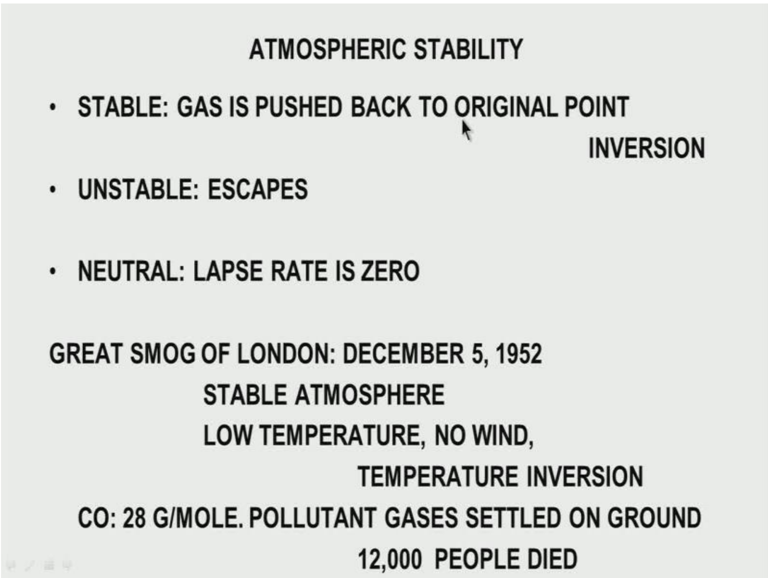

There for, we find that well, when I have parcel of a gases it can dist upper when I have the temperature. Let take a look at temperature, but before that be take look at density when the density of the air, is grated than the density of this particular parcel of gases movies of and accordingly, when the temperature of the parcel of gases is higher than the temperature of the air well it is get pushed upward.

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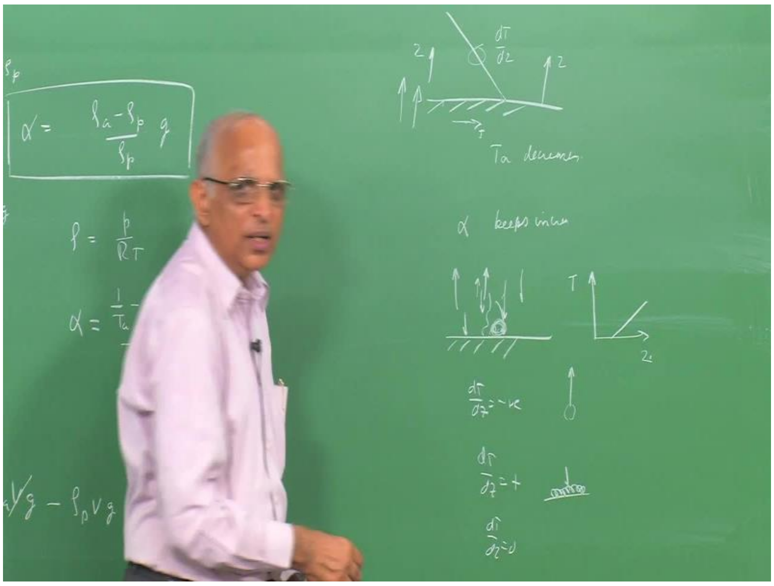

Now, let take 1 more look at e now, we took in tram this parcel of gases being push up and push down. Let take a look at this particular problem, first we alliance a supposing we have the surface of the earth, I have the temperature gradient which is let say native dt by d is a d native; that means, us I moo v up in the is the detraction Ta temperature of air discretion, then what is going to happened to this particular axle rations, in a axle rations depend on the parcel of gases minus Ta.

As I move up the temperature discretion therefore , the alpha keep is incursing that is, the axle rations parcel of gases keep is (( )) us it move up because of the native temperature gradient, but supposing I am talking in tram of temperature inversion, where in issued of having native gradient; mind you, there here I have maybe I show temperature like this. This may attuned is that I show this particular case, supposing I talking tram of the positive gradient that menses, I have temperature long this we attuned here, I have positive that is it the temperature increasing.

What is going to happen; well, the temperature increasing therefore , what is going to happen; we know, if the temperature is increasing over here well; it if happened to heir then the temperature parcel of a gases well. The parcel can no longer move up its push down. There for, where we temperature inversion what is happening is the, upper axolotl rations of the of the parcel of gases when our I have, during day time; I talking tram of the dT by dz discretion. That is, temperature discretion upward well the parcel of gases excels rates of, where as if I have temperature inversion and the temperature above the surface of the earth.

Let say here, this temperature well is z temperature is positive. If temperature is positive well, the dowered the parcel of gases ones it shift up it is push down and therefore , gases cannot leave the earth surface, but it is push back on to surface of the earth. There for, we find that, whenever we took in in tram of dT by dz being native. Such us, it happened when then surface heated by the sun well. A parcel of gases on the surface of the earth accelerates up and it is goes up and up, and it gets loss.

When I have, dT by dz is positive such as when I temperature inversion. Well a parcel of gases eve 1 effect initial move up, all they parcel of gases can just not mover, it is always push back to the ground; that means, think ground itself. If I have dT by dz is equal to 0; well, there is no monition to the parcel of gases. There the temperature ingredient above the surface of the earth, within the atmospheric bender lair, decide whether of parcel some leak, our some parcel of gases which is found. Well, it get loss to the ore it will come back and this is was mainly use to be able to say whether the atmospheric is table un table.

We say the atmospheric is table when gases us push back to the original point, because I have temperature inversion. They say, the temperature is unstable the atmospheric is is unstable when the temperature ingredient is native; that means, the earth is heated by insulation the temperature keeps discretion alone the surface. And therefore , we say well it is the parcel of escapes in the surface of the earth and when, I have material, well the lapse rate of gradient is 0 and therefore, there is no movement of this. Therefore, the atmospheric stability is depend when, is depend stable, unstable our neutral. According to whether mick the gradient let go back and see what it is.

If I have a negative gradient, we atmospheric is unstable; if I, have temperature invasion ore positive gradient the atmospheric stable. And this is mainly what this sides, whether there is going to be sun leper on the surface of the earth. Let us take 1 topical example;

we know, behind the great smog London on December 5 1952. This was the very clear cold month in London and what happened is; we now, being very cold people wanted keep them self warm and therefore , barn more clue more cold to generate heats and they neap them self warm, the wind of all most 0 with the result.

You know, you had is something lake very stable a atmospheric; let us go back to this well; you had a large temperature gradient and the wind was slow that menace, I have who is temperature gradient around the surface the earth. And what is did was since there no wind and low temperature, because of the temperature inversion, the carbon monoxide and other gases which got grated, could just not live the earth. The keep collecting live the air the keeps colleting the ore the surface of the earth maybe carbon monoxide us the monocular max of 28 gram per mole, which is all most similar to what nitrogen ore air has around 28.8 gram per more, with the result.

The pollutant gases settled on ground and this pollutant gases inter the parole and something like 12000 people died because of the particular great smog of London. There for, find well. There is the collation of the gases on the surface of the earth, whenever we have something like a stable atmospheric. We would like to use this stable, unstable neutral atmospheric to be able to see the dispersion gases in the atmospheric.

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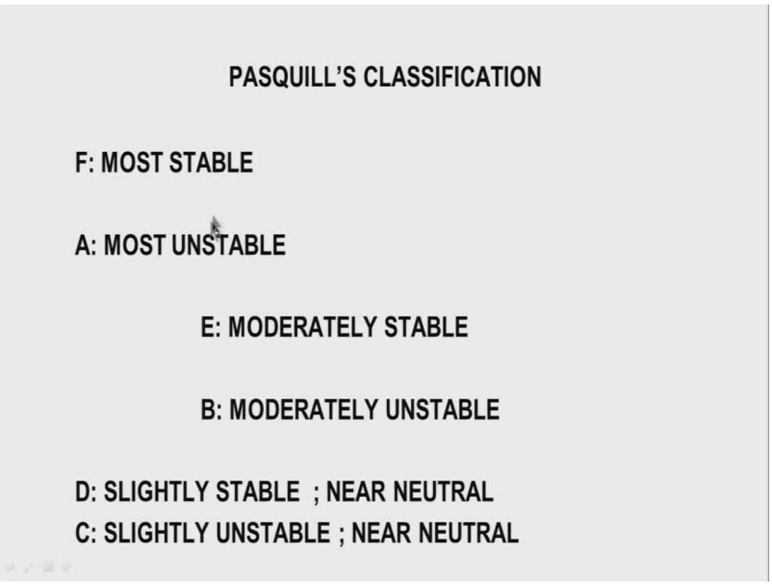

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PASQUILL'S CLASSIFICATION OF ATMOSPHERIC STABILITY

Surface Wind (m/s)	Insolation			Night	
	Strong	Moderate	Slight	Overcast with cloud cover > 1/2	Cloud cover <3/8
<2	A	A–B	B	E	F
2–3	A–B	B	C	E	F
3–5	B	B–C	C	D	E
5–6	C	C–D	D	D	D
>6	C	D	D	D	D

TO WORK OUT DISPERSION ?

Let us go further; you know, a very frames metabolized by Pasqual's, what he did was classified the atmospheric into different categorizes. And this classification again becomes important; let us take 1 particular example of it. We said well; the wind fetch the insulation, wind fetch the g radiation even if we have something like we have temperature inversion the wind effects. And therefore we know, whenever we talk about atmosphere, is very difficult to work with the precise number we cannot say well the gradient is so, much.

What Pasqual did was he said earlier, any way I can talk in terms of stable atmosphere. I can talk interns of an unstable atmosphere, unstable means; I have succession which are able to escape out I am also able to talk in terms of neutral atmosphere, which stable atmosphere can I talk interns of very stable atmosphere. Like, we had in the case of the gray smoke of the London temperature inversion and everything settling on the surface very stable.

Similarly, unstable I can talk in terms of very unstable may in summer months, may be in Chennai we have, very hot sun midday, striking on us with the result. Well, temperature gradient about the surface about the earth is quite negative, or can I talk in terms of neutral can I talk very stable I can also talk of moderately stable, I can also talk in terms of let us say, little less may be may be slightly unstable. Similarly, I can talk of may be moderately stable, which means it is not that hot may be the sun is at inclination, when I have the surface of the earth. The sun is directly above my head well.

The insulation is the largest, if I have the sun at an angle well the insulation is less over here and the effort may be I can talk in terms of moderate and also I can talk of slightly unstable. Well the slightly stable, slightly unstable corresponds to near the neutral zone and in hydration to the insulation may be at midday, if I have a cloud above the surface of the earth well; the insulation does not affect me directly and the effort the cloud cover makes the makes my unstable characteristic into moderate.

Therefore, whenever we can characterize the atmosphere in terms of highly unstable, highly stable and these are the 2 extremes. What he did was, he said that, the very stable highly stable he calls it as very unstable, he calls it as a very stable he calls it as F and in between A and of you have 4 other category and a and 5 other category is are those could be well could be modeler stable he called it the E, it could be stable strictly calls it has be well. It has very un stable I should have renter go here very un stable called has a modeler stable has B modeler unstable has a well B and C, which are slightly stable and slightly unstable are very near to neutral.

There for E catalog the atmospheric in something like A categorizes, B categorizes C categorizes, which your unstable maybe D E F which were stable, F which were stable, a is highly unstable. And this is classification, and therefore it I look at the classification I fine well, F is most stable, A is most un stable, E is moderately stable, B is moderately unstable and D and C are slightly stable and unsightly stable and this are near to neutral.

Why is the classification in the point us we know, is very difficult to as our saying, work out our number. There for, maybe I could example, if the condition of many systems our may is most unstable and bound to renter the gas on the surface of the earth. Where as if most unstable well, if may out; therefore , let diffuse therefore want studies. before that, let me put down the effect of the wind and cloud coverage also, like for the distance surface wind which is the very small wind of the order of less than 2 meters per second have a insulation their midday sun is vertical above me, will have very and stable because I have very strong dT by d negative whereas, at night when I have low wind and may be, could winder night, there is hardly winder night there is hardly any cloud cover cloud cover is less than 3 by 8 by the total au region above me; I say well, it is most unstable.

If I say when, the insulation is such that the sun is at an angle I have moderate 1 between A and B; if the insulation is slight here, because I am very cloudy day not much heat not much installation is there I have B. Therefore when, I have no surface wind, I could have well a strong in solution leading to very unstable A atmosphere A at night cold winter night I could have F; if the sky is over cast well the infra red radiation from the cloud each smile au and therefore, it becomes slightly less stable at E. similarly lets go to the opposite is very nice I have very high wind speed and what does the wind speed do as we saw wind speed, changes the laps rate above the surface of the earth well.

The un it becomes an C moderate becomes D it becomes almost D over here; that means, the in solution is so, small, au that it is something like almost something like slightly stable over here and at night when I have large wind well, it is almost like slightly stable because I m not able to get the decreasing gradient over here therefore, when I have high wind conditions have something like almost near neutral or slightly stable and for the intermediate cases in between 2 to 3, well A changes A to B o A changes to B that is it is between A and B for moderate it now, becomes B for slight it becomes C and so, on.

We have this particular case. So, once I know what is my surface wind conditions, I know what type of the insulation that is whether the sun is vertically above, me whether there are clouds above me I can fix the category of the atmosphere, as either A B C D E or in between A and B, in between B and C or in between C and D using these particular pacification between, A and F and the regions A B, B C that is the border zones I want to work out what is the type of dispersion be taken practice. I think we want to find out how an explosive gas disperses and that is what we do in today’s class.

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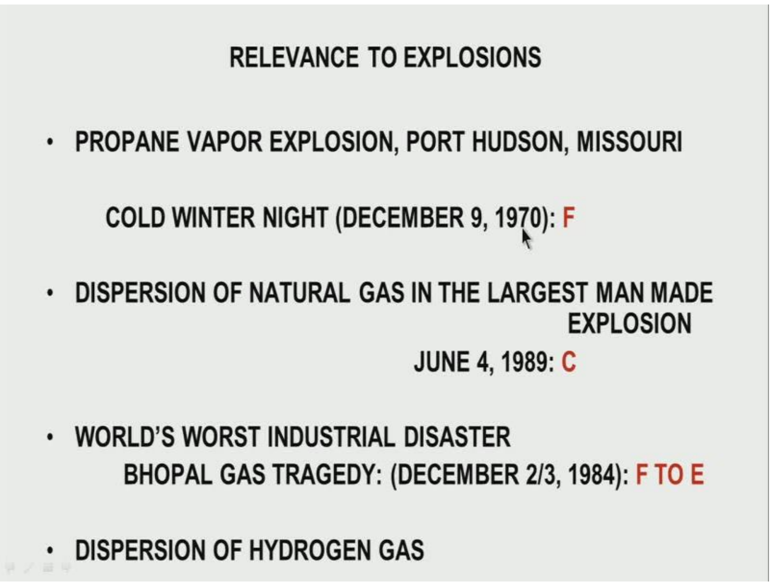

What we have done is we now know how to represent the stability of the atmosphere as being highly unstable or being highly stable and what are these different categories of these stable and unstable atmospheres? Then the applied you know, people keep asking; what is the relevance to explosions, of this atmospheric stability. let us take 1 or 2 example: You know, when we had the propane air explosions; that means, liquid propane escaped from a pipe at port Hudson in Missouri it was a cold winter night, it was something like December 9 1970; December is a cold month, the wind was quite low at around 2.3 meters per 2nd and therefore, the cloud of propane collected over the surface of the earth and it got drifted with the rain.

The stability atmospheric, stability was F, when we talk in terms of dispersion of natural gas, in the largest man made explosions, because this was a neural mountain and this was in 1989 it was in June, a summer month. Why you know, this again given atmospheric stability, it is not a it was a cloudy perhaps the atmospheric stability was C; that means, at unsteady atmosphere compared to the steady atmosphere in this col cold month. If you talk in our own country the world's worst industrial disaster country, mainly the Bhopal gas tragedy, it happened in the month of December 2 to 3, just after midnight 2 to 3 1984 cold day well not much wind the atmosphere has stabled between F to E and therefore, being stable. While the methanol is cyanide leaked hugged to the ground and it got transported by a wind.

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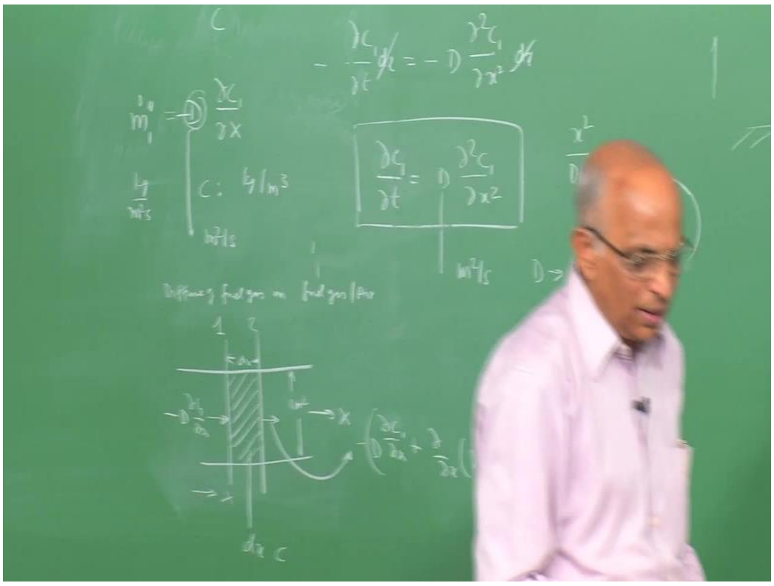

So, it led to a number of deaths over here; you know we are interested in dispersion of hydrogen gas formation of explosives and therefore, yes indeed atmospheric dispersion and the atmospheric stability characteristics will influence it and therefore, let us move further classifications of the atmosphere into categories from a to f; well, be looking at the dispersion problem.

Therefore, let us get back to the dispersion problem and to be able to do that, well we are interested in gas dispersing; that means, we are looking at the concentration of the gas due to some gradient or due to some moment; well it keeps changing rather I am looking at concentration and what we say, l when I talk in terms of concentration gradient dC by dx; let’s consider 1 dimensional geometry, then I have something like a diffusion coefficient D; because of a gradient I have a mass flux; that means, I have concentration of some substance, in a mixture, let us say 1,1 because of this gradient there is a mass flux.

Therefore, I am talking of concentration in terms of kilogram per meter cube, mass flux over here in terms of kilogram per meter square second and the unit of D, which is a deficient coefficient, is meter square by second. You know when, we talk of diffusion of gases its essentially due to gradient, but the turbulence and convection and all that modify D to give it to be a turbulent and AD diffusivity, but let us just consider the molecular diffusivity, and then extend it out we want to find out well, I want to find out diffusivity of let us say, a fuel gas in a mixture of a fuel gas and air; that means, 1 corresponds to fuel gas maybe, the mixture is 1 plus 2 over here, which is the and we are considering the diffusion of 1 in the air mixture as it well.

So, therefore, let us formulate out a first dimension problem. So, that we understand it, let us presume I have 2 stations here this is my 1 jet my 1 dimensional geometry align x, I have 2 station here station 1 at distance x over here, in which may be some gases diffuse in and the gas which diffusing well. You know the gradient should be negative and the mass which is moving must be negative therefore diffusion coefficient into something like dC 1 by dx, which is entering section 1, let us say section 2 is a small distance dx away.

The thing which is leaving now, is well it is equal to let us write it out this becomes equal to minus d of dell C by dell x, dell C1 by dell x. Now, I have In a small thing some additional changes are taking place therefore, dell by dell x or d of dell C1 by dell x, in to dx well. This is what is moving out and therefore, I find something has moved out and therefore, in this particular volume; now, I am considering only the flux therefore, my area of cross section is unity 1 meter square or it is a unit cross section and therefore, this volume corresponds to unity into dx, in dx what is going to happen, well the concentration. So, much C kilogram per meter cubes. What is going to happen well, this is going to change because something has moved out?

So, therefore, what is it I get I have dc by dp in the particular volume this is the rate of change of mass over here, is equal to let us say d C1 is equal to what has moved out and now, this is decreasing therefore, d C1 by dT into dx well; I have x also. So, let us make it partial doe C1 by doe T of dx is equal to what has moved out is minus d because this minus this gives me the value I have d into d square C1 by doe x square into dx, rather this gets canceled I get my equation for diffusion as equal to Dc by dT is equal to d into d square C by dx square this going to be my basic which says how, the fuel gas 1 diffuses in a mixture of air and fuel. Where d is the deficient coefficient I again repeat concentration is in kilograms per meter cube, d is in meter square by second, which is the diffusivity, I need to solve this equation to be able to get how it diffuses and I want to solve this at a different atmospheric conditions and this what I want to do, to be able to solve this.

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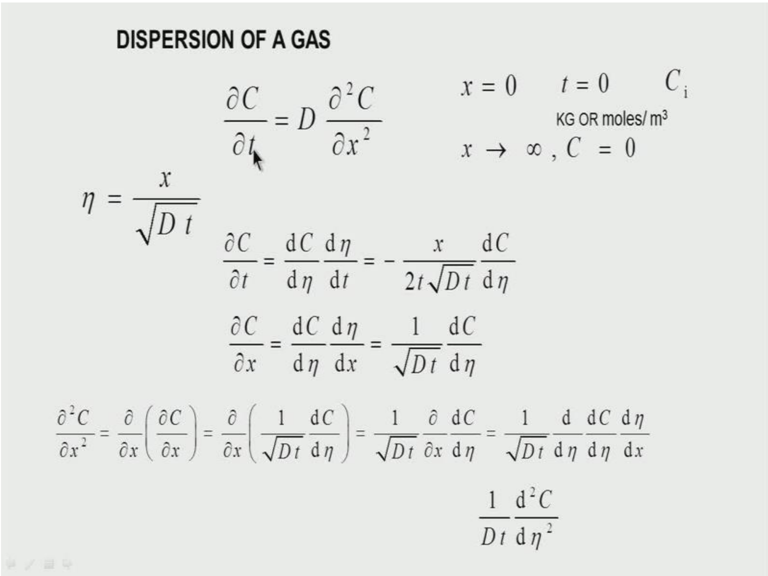

Now, unfortunately I find it is not a single variable dx involved, it is also time involved and therefore, I just fed dimensional considerations I would like to make this equation, as function of a single variable. Well I find d has units we just now, said d has units. So, we just got by second concentration, as units we said is equal to kilogram per meter cube; x has units that is diffusion in 1 dimension as units of meters.

You know, if I take a look to express x and t as a single variable; I will find well if I have d; that means, meter square by second multiplied by time gives me seconds hat means; I am talking of dt as units of x square, x a meter square, x square has units of meters square therefore, I can consider a from dimensional considerations a unit like let us say x square, by dt is something which the way I express the variation of x and t to be included in this particular equation.

I can define a new variable eta has x by under root Dt therefore, I introduced this variable because form the dimensional consideration I expect the relationship between time and x to be of this particular form I introduced this eta in this equation and I quickly solved this equation, this is what I do in the next few slides, which I show here. Well we have the diffusion equation dell C by dell t is equal to d dell C square by dell x square. And we are not the initial conditions well at x is equal to 0; I have initial time concentration. At time t is equal to 0 at the initial concentration and this concentration gets diffused and very far away from x well the concentration of the particular substance which I am interested is 0 may be a fuel gas substance.

therefore, I want to solve this equation and as I just now, said well I have both x and t in this equation I relate them as eta is equal to x by dt and therefore, I write x by dt as equal to now, dC by dt can be written as dC by d eta into d eta by dt. Now, d eta by dt, I can write in terms of, this is the variable over here therefore, d eta by dt is equal to x divided by under root d into 2 to the power with the negative sign t to the power 3 by 2. Rather it to the power 3 by 2 that is minus 3 by 2, I bring t here, I bring t half over here it becomes minus x divided by 2t under root dt dC by d eta is a value of dC by dt on to the left hand side.

Similarly I get the I want to determine dx C by dx square dC by dx is equal to dC by d eta into d eta by dx is equal to 1 over under root Dt and again, if I try to dx C square into dx square is dou by doe x into dC by dx, which is equal to d by dx of 1 over dt into dC by d eta and that becomes equal to 1 over dt into d square C by d eta square.

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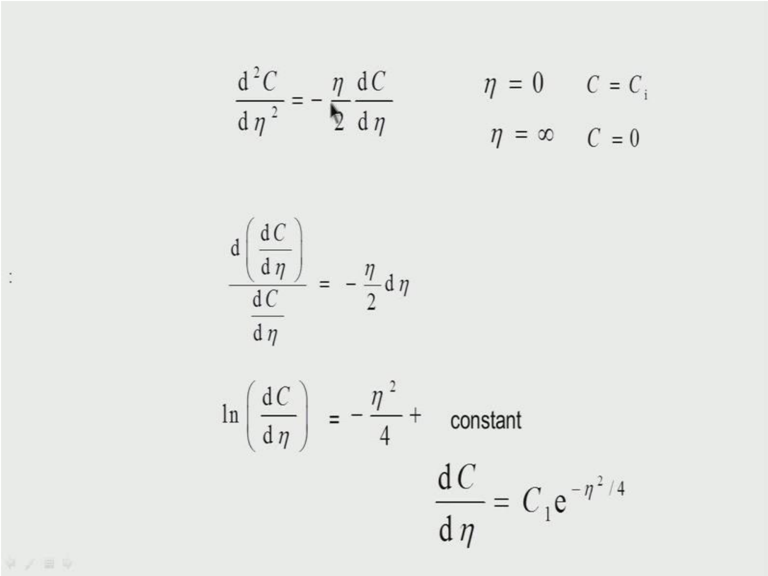

Therefore, this particular equation can be written in terms of a single variable, instead of having t and x over here, can be written in the form d square C by d eta square is equal to minus eta by 2 how did minus eta come we go back. We find yes d square C becomes 1 over dt into d square x by d eta square. I have in this particular equation dC by dt is equal to 1 over x over 2t into this into dC by dx a and now, substituting the value of dC by dt over here, in terms of dC by d eta. I substitute d square over t by dx square as equal to 1 over dt and d gets canceled I have 1 over t into d square f C by d eta square this t and t also gets canceled and left with only x by 2 eta t and that is the region I get; this particular equation, dell square f C by dell eta square is equal to minus eta by 2 into dell C by dell eta.

I am putting these conditions, initial conditions at x are equal to 0, and eta is equal to 0. The initial concentration and far from the surface eta equal to infinity, the concentration is 0; I have to solve this equation, I immediately observe I can write dell square f C by dell eta square as equal to d of dC by d eta over here, that thing is d square C by d eta square. Now, what is it observed d of, I have eta by 2 into d eta; that means, what I do is I again write this equation d square f c by d eta square divided by d c by d eta is equal to minus eta by 2 and then you know I have d by d eta giving me d square fC by d eta square.

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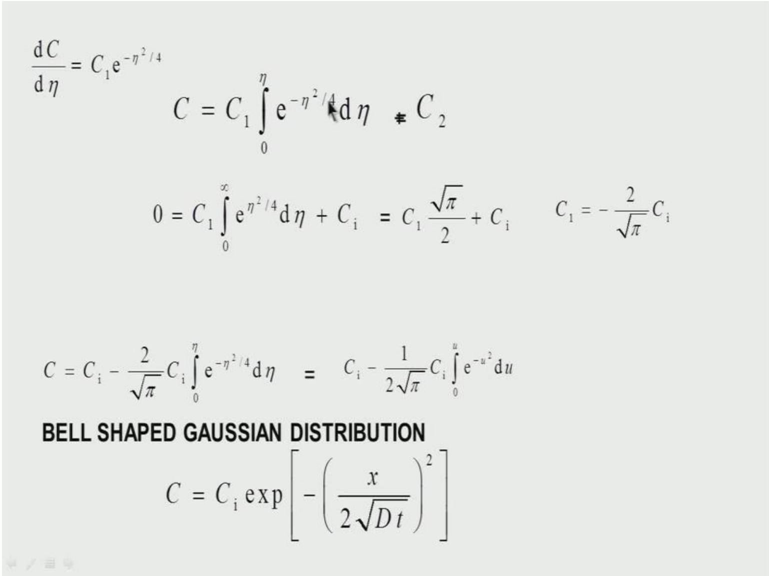

Therefore, I have d of dC by d eta divided by dC by d eta is equal to minus eta by 2 into d eta which came from the d eta over here. I integrate this and I find this is a form or of dC by d eta this particular expression is equal to minus eta square by 4 plus or constant and the rather I get dC by d eta taking exponential on both the sides is equal to constant gets up with this; I have c 1 minus e to the power minus eta square by 4; therefore, the moment I get C1 eta square by 4 well I need the concentration how the concentration of the fuel gas changes, I integrate this and I get C1 into integrate eta square by 4 d eta and I have plus C2 over here.

The constant of integration over here and what happens is, I put the boundary conditions at eta is equal to infinity, I have the concentration is equal to 0 and therefore, the integrate 0 to infinity e to the power eta square by 4 d eta is equal to under root pi by 2 with this constant C1 and I get C1 is equal to minus 2 pi by Ci. And since I get C1 and I now, write the concentration C is equal to I get the value Ci plus minus the value what I get here; that means, 2 over pi; that means, C1 is equal to minus 2 over root pi into Ci;

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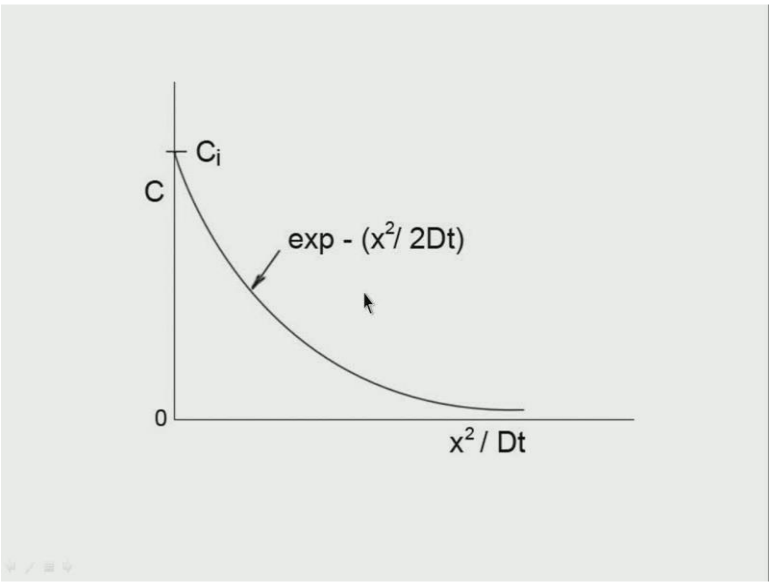

Therefore, minus 2 pi over Ci this is equal to the value of C1 into this particular value of the concentration is equal to Ci minus 1 over 2 root pi Ci into the integral 0 to u into e to the power minus e square d u. In other words, the concentration follows the law; C is equal to Ci of exponential minus. We know eta is equal to x over 2 under root dt or eta square is equal to x by 2 or x by under root dt square we have 4 here therefore, it becomes 2 it becomes x by 2 under root dt square. Now, this is the type of distribution you get for concentration or rather, the initial concentration is Ci as x ward by dt increases it follows.

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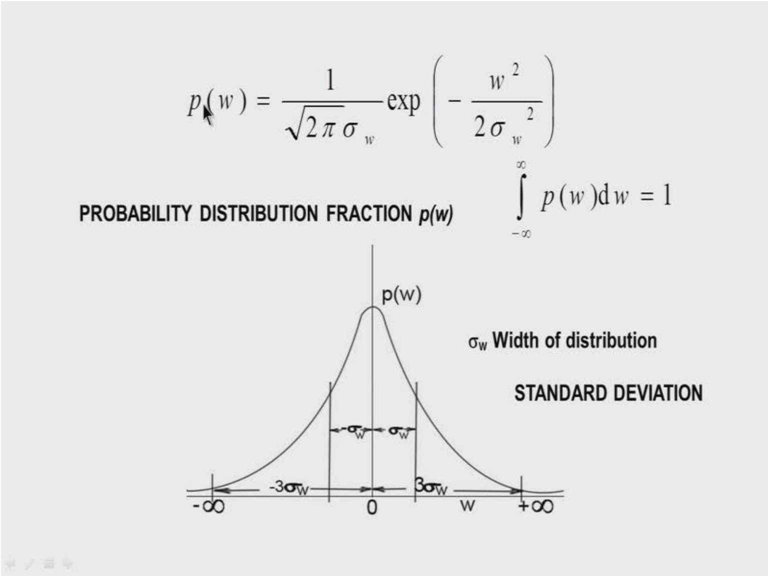

You know in other words if I have a bell shape I will have a bell shape like this and exponential distribution shape like this it follows the right hand part of the bell and this is the exponential distribution. You also know that if I talk in probability distribution; you know, there is a probability distribution pw is equal to 1 over root pi into the standard deviation sigma w per sigma into exponential minus w square by 2 sigma square. This is the probability distribution fraction pw and what is this probability distribution, I ll show it in this particular figure.

I have the dummy variable w on the x axis, the probability distribution fraction pw on the y axis and what does it denote well this is the type of distribution and the area under that distribution from minus infinity to infinity of the dummy variable, is equal to 1 that is minus infinity to infinity of the integral pw dw is equal to 1 and therefore, this area is 1 and what does the standard deviation denote. Well, it denotes what is the width of this particular distribution may be the whole area is 1; if it defuses more well the curve could be here, the standard deviation could be more .

Therefore, standard deviation to some extent, whenever we are talking about of probability distribution, tells us you know what is the peak value of pw; I could have a distribution which is like this, for which also the area is 1 therefore, the standard deviation tells us, how much is it the dispersion is taking place or rather, if I were to just take a look at standard deviation.

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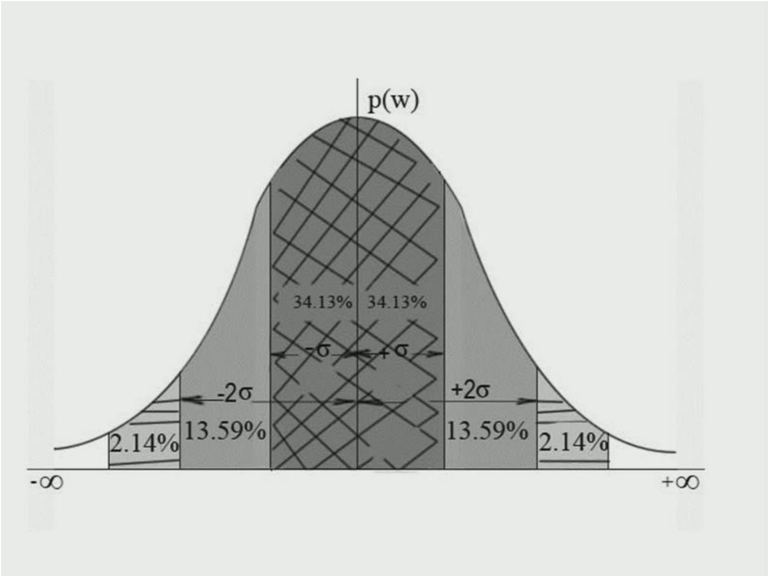

I say well I have from minus sigma to sigma the area under this cure is something like 68.3 if I consider something like minus 2 sigma 2 plus 2 sigma the area under this cure is something like 95.7 percentage of the total area and if I consider from right from here that is 3 sigma minus 2 sigma 2 plus 3 sigma the total area this is the cure is something like 99.7; therefore , I have several that is 1 sigma, 2 sigma, 3 sigma and that this show what is the area under this cure. Now, if I had to take look at I go back to the previous line; I go back and take look at probability distribution and compare it with something like the bell shape distribution what I get on this portion, what is it I fine.

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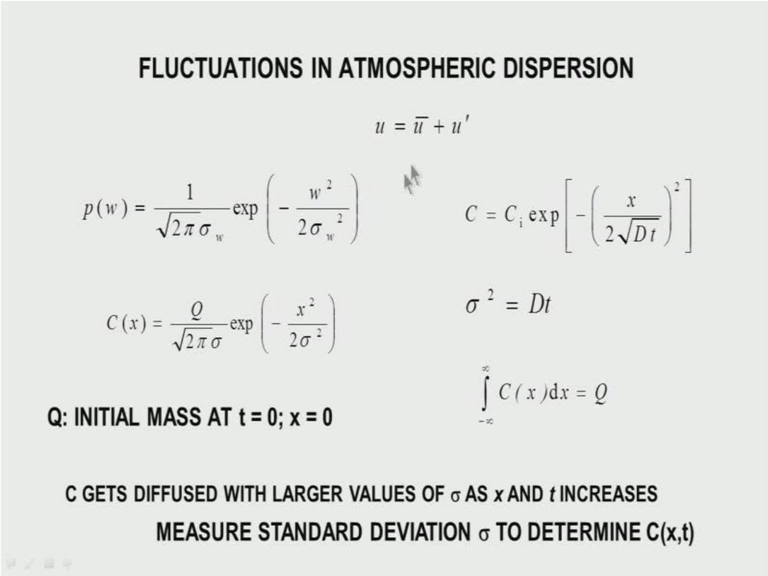

Well, I finem well in atmospheric I have fluctuation just like I have fluctuation of the dummy variable and the dummy variable that is the value of if I were to say the probability distribution fraction pw is given by 1 over 2 pai in to the standard deviation explanation. What did we get, when we had diffusion of the wafer I had see, I exponential x over to dt; if I can take the value of sigma square is equal to dt over here, well this becomes x by 2 sigma square; that means, and I am talking of exponentiation minus x square by 2 sigma square. And maybe you know, the dispersion of the gasses is able to tell me that is the standard deviation what I get, is able to tell me how the dispersion of the gasses is going to take look, because the movement I can get the value of my standard deviation, I know how the diffusion take place.

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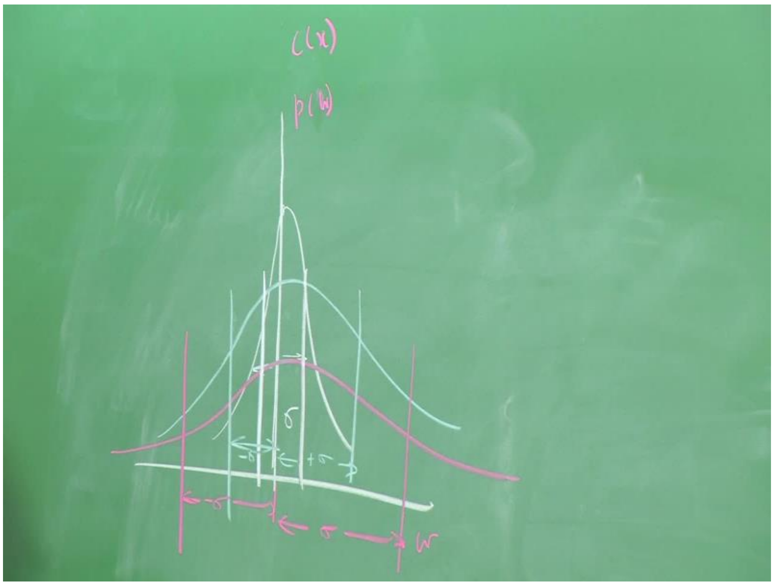

Let me slightly quantifier this before I go for word saying is, we trying to say well there is the gas which defuses in the atmosphere and if something is defusing in atmosphere what is happening is may be, initially the gasses, I let say gasses all this particular point after some time, the gas defuses out when it defuses out still for the after some time well defuses out like this. Well after still longer time well the gas defuses of still for the you know, when I am looking at the this particular probability distribution that I say, p of w with respective w; I find well p of w is very similar to what I am talking in terms of concentration has the function of the x valued over here.

Now, in this case well the standard deviation for the for the curve which corresponding to initially time well, this is in the dispersion what I get standard deviation, when it is defuses out still for the well. This is my value of minus sigma over here this is my value of plus sigma over here, when it defuses still for what is going to happened well. Thus this becomes minus sigma above the mean and this becomes so, out of plus sigma about the mean, the fore, if I can evaluate the value of sigma well, I can sort of evaluate my concentration and this is how we evaluate concentration.

Therefore we find that if I have something like at initial mass at t is equal to 0 x is equal to 0 has Q; and we find well you know in this case of well that total mass is conserved with mass is Q then Cx dx for minus infinity is Q.

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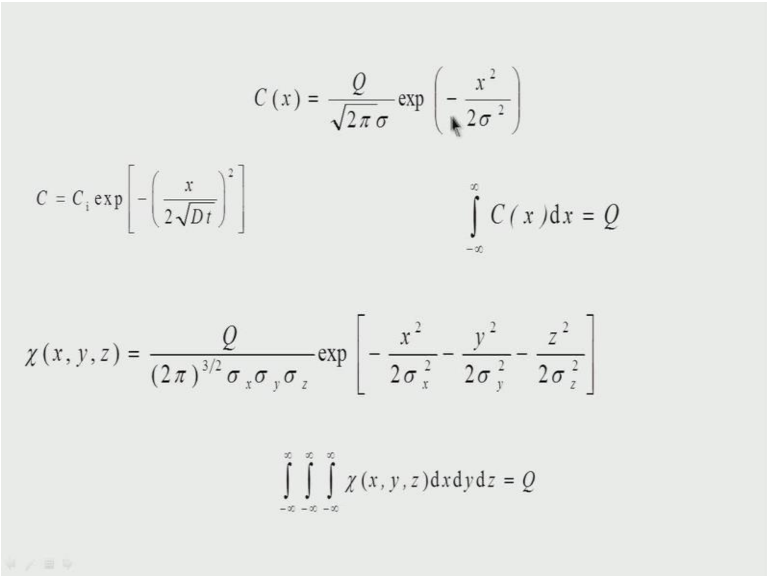

We have corresponding to minus infinity to infinity of pw dw is equal to 1 we have this equation and therefore , we find if I can experimentally measure standard deviation, then I can determine the value of concentration has function of eta, has the function of x and t; well. This is what is don therefore you have, concentration has function of mass relies, has function of deviation this standard deviation and these standard deviation are measure and this is for 1 die mention, if I just extra pull it to 3 die mention well. I have 3 die mention know I have standard deviation long x name the sigma x, standard deviation long is sigma, y standard deviation long is sigma is it into exponential of in addition to x have y square and 2 sigma y square with result that the concentration at any x, y, z into dx, dy, dz is total mass. This is what we used to solve the dispersion relations in different atmosphere.

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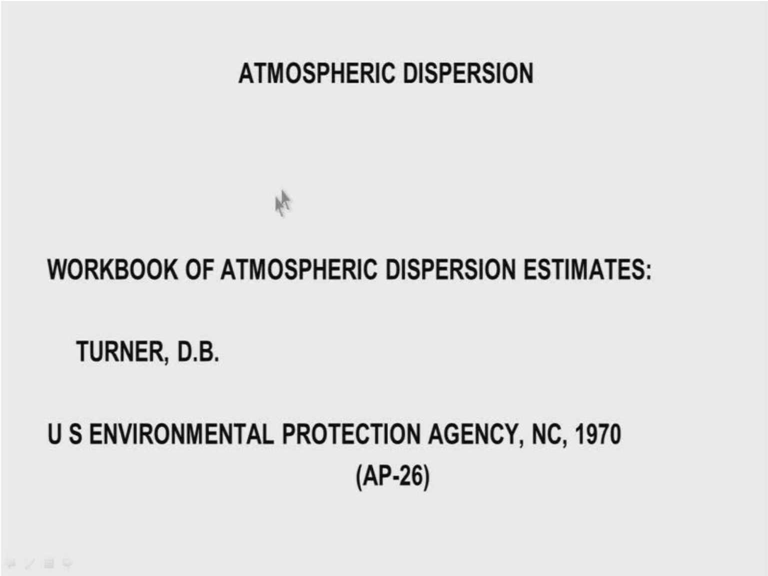

What I do in the next class, having said that it is possible to use the probability theory to be able to solve the diffusion under different atmosphere conditions and having specified the atmospheric stability criteria. Now, all what we are take look out is we will tried to take look at leek which keeps happening an constant rate in which ; that means, we will we will take of gas in which I have constantly crate. We will see what is the concentration which is form will take some the like of or constant volume of gas, which is realized, which gas dispersion into the atmospheric.

The reference have used, for getting in to all atmospheric dispersion is there is the nice had book mean namely work book atmospheric dispersion estimates, this was by Turner, D.B. and it is publish by the us environmental protection agency the report number is at 26 it is from in 1970; therefore, I will I will get in to the details of the all we work of the values of the concentration in the next class.

Thank you.