Introduction to Atmospheric Science

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

Lecture-02
Atmosphere-A brief survey (Pressure, Temperature and Chemical composition)

Okay. So, welcome back. So, we started looking at this atmospheric science, we introduced the subject to you in the previous class. So, we will just complete this introduction and then we get down to chalk and talk.

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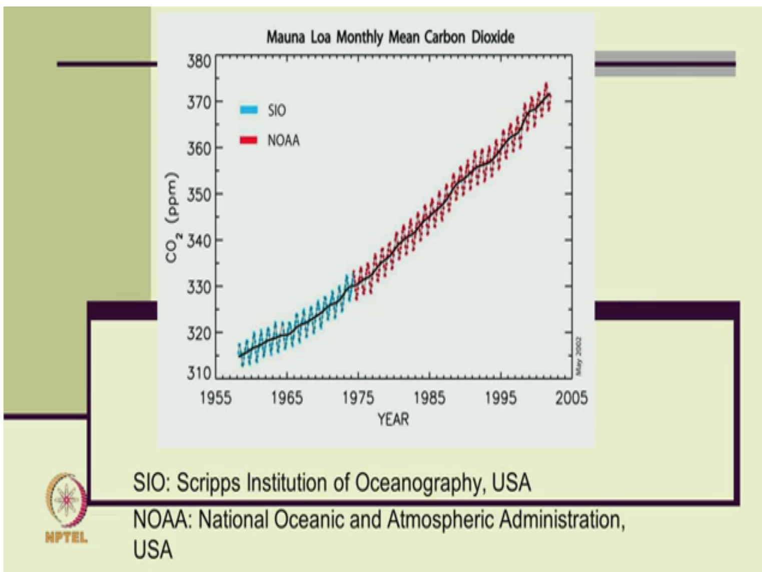

So, this was an important slide which I discussed in the previous class. So, the y-axis is the global mean concentration of carbon dioxide in PPM parts per million versus the time so recordings are available probably from recorded data is there, probably from 1960 onwards. Of course, you need 2005 you can plot up to 2013, right. So, the first 20 years we have from SIO that SIO is called is the Scripps Institute of Oceanography.

The Scripps Institute of Oceanography in San Diego, California, USA, right. And then, from 75 onwards you also have satellite measurements and so on. So, you can see that it is increasing very nicely. But there are so many consequences the graph looks alright now. I mean it is an increasing curve and there is a peak and a dip corresponding to the summer and the winter which is related to the photosynthesis, okay because the carbon dioxide uptake the release and uptake will be controlled by this whether it is spring time and spring, so spring summer autumn and winter, all right.

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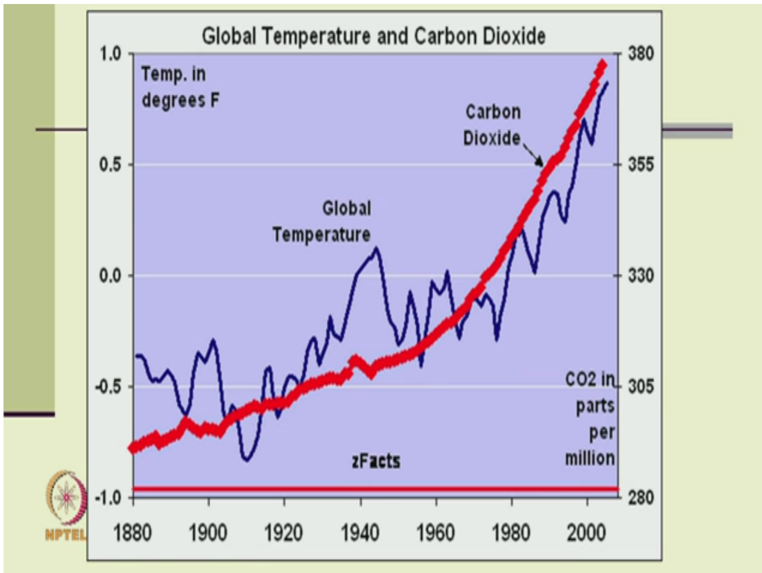

So, why is this curve very important because if you superimpose the global temperature, okay along with the global carbon dioxide measurements and carbon dioxide is fairly well dispersed in the atmosphere which means if you make measurements in carbon dioxide in Chennai, it will be the same as what you measure in Hawaii and all and so on within limits, okay. So, the red line is a carbon dioxide for which you have to read from the right hand side, okay so, parts per million that is a red, red line.

Then, the global temperature increase is or which is called as the anomaly okay that is on the y axis that is also on the y axis but the scale is you have to read it from the left side. So, you can see that generally there is a global temperature anomalies increasing. And now you can see that there is a strong correlation between the two. So, there is enough reason to believe that this increase in carbon dioxide, if you put it into radiative transfer model, it will tell you how much the temperature will increase and so on, okay.

That is scientifically established, but of course, there are several people will say no, no, the sun's radiation is increasing or decreasing; it follows a cycle it is not because of this and this, this. So, but there is there is highly light there is a high likelihood that the global temperature rise is caused because of the carbon dioxide. And the time has come for us to take stock of this and do some mitigating measures, okay. Even if the Curie, there is some certain level of commitment because of the economic progress the world has made, so, the carbon dioxide will continue to rise.

But at least we, we need not make the curve even more steeper okay. So, if you had this mitigating technologies because the Earth's system has got high thermal inertia it will respond slowly only. So, if you start making corrections, you will see the effect after a couple of decades, is it, okay. Now, that mass into specific heat is so high. Yeah, if you have a forcing we can estimate you can get the mass of the atmosphere and this.

If you have a forcing for example, if you have a stainless steel ball, it will respond to one centimeter in the respond very fast but the earth will take a long time to respond that is what I am saying, okay. The Mauna Loa are the measurements are from Mauna Loa in Hawaii the Mauna Loa in Hawaiian language means, long mountain.

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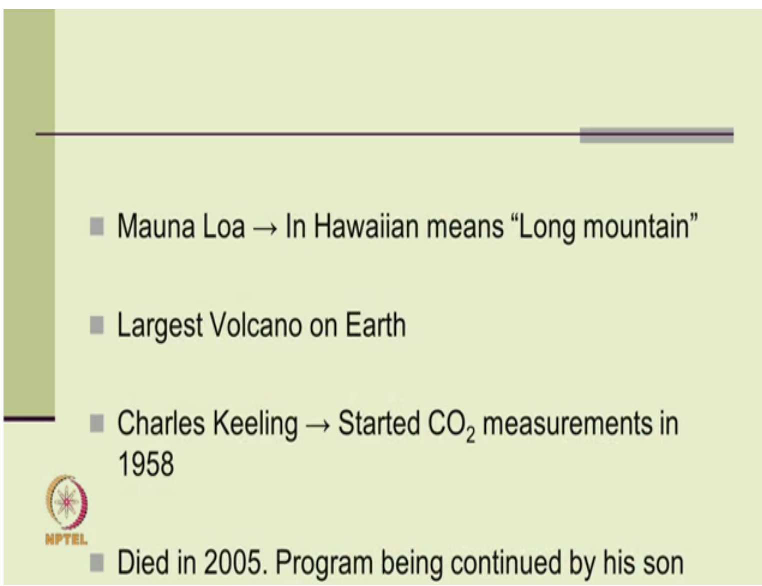

It is the largest volcano on earth the carbon dioxide measurements are from on Mauna Loa, okay. So, it was started with Charles Keeling who started the measurements in 1958 long before people looked at climate change. But for some reason, he wanted to have accurate measurements of carbon dioxide, he started measuring, okay. And it is well documented. He died in 2005. The program is being continued by his son. I think his son is also Prof, okay. So, the measurements are continuing. So, one more important thing is the so called Antarctic

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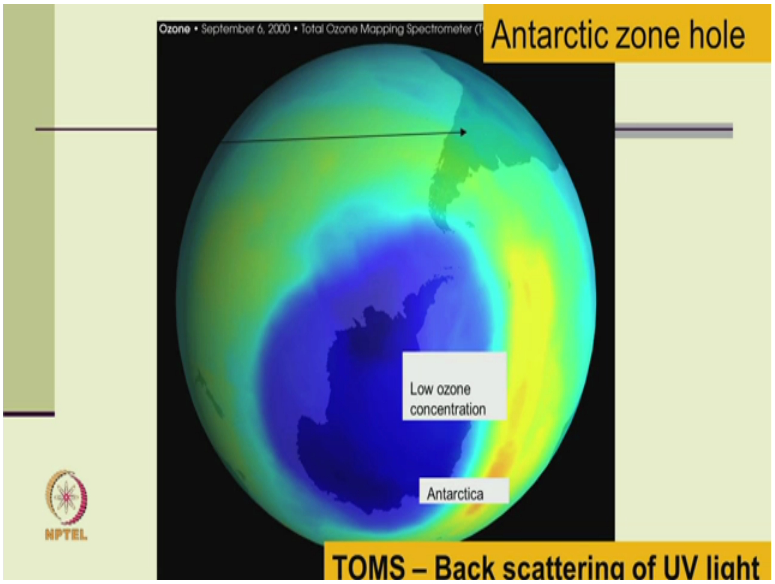

There is a typo there it should be Antarctic ozone hole, okay. So, you can see Antarctica here okay. So, this blue color shows that the there is a low ozone concentration in the Antarctic region, okay. So, last few decades this has been a subject of intense scrutiny people wanted to measure this. So, there are various ways of measuring this concentration of ozone in the atmosphere.

One is to have balloons and balloons you have some potassium iodide. Potassium iodide will react with ozone and it will discharge some electrical current. So, you just have a, you have a way of measuring the ozone concentration. As the balloon goes up, we can find out what is the concentration in the troposphere and the stratosphere. The other is to do the same thing by flying, using aircrafts. You can have aircraft measurements of this ozone.

The other third technique would be do you satellite, okay. So, if you use a satellite and find out what is the radiation which is received by the satellite, which is a back scattering, you can have two kinds of sensors on both. You can have a sensor where it will send out radiation and find out what is a reflected component. Usually if it is a radar or something it is also used for military detection of vehicle. Surface to this thing, right you have radars.

And the other is to just take the radiation which is coming out of the Earth's surface, the back scattering, okay. If you use this back scattering principle then, you have you get what is called the Tom's okay. The tom is the total loss in the, total ozone, Total Ozone Mapping Spectrometer. We just put on some American satellites and it gave very, very reliable readings okay gave very reliable readings. And it was conclusively established that there is a destruction of ozone because of which harmful ultraviolet radiation enters earth and which leads to so many other complications which we will see in the next slide, right.

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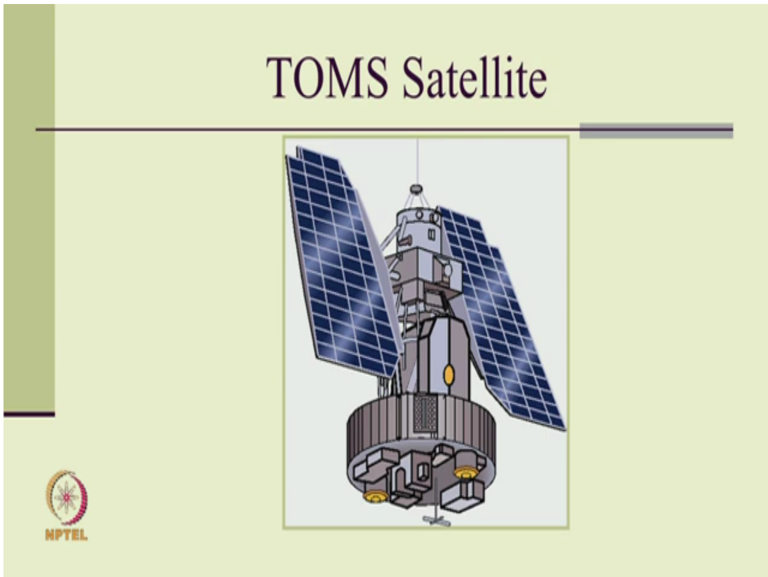

So, this is just a picture from the internet. So, this is the TOMS satellite typical this thing. So, the sensor, the sensor is placed inside and this will hose out depletion, right. So, the ozone depletion and other reasons is caused by you know these chlorofluorocarbons, CFCs which are widely used in refrigerators, right.

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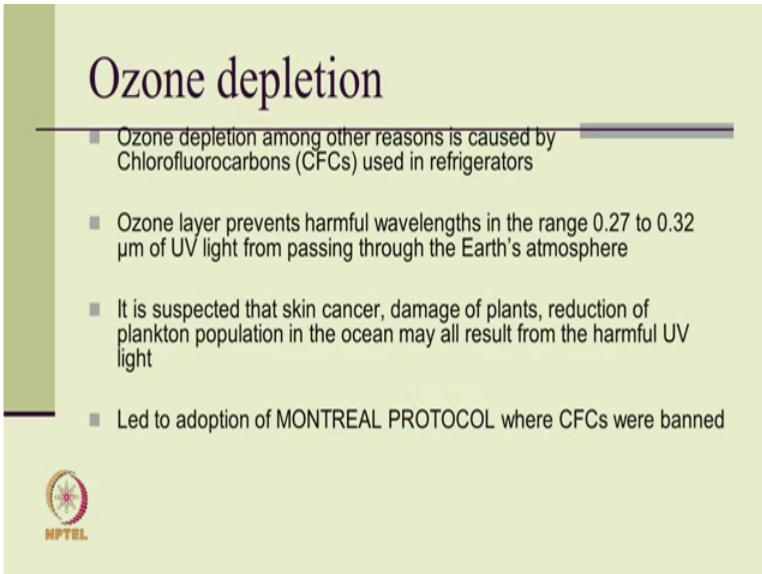

So, the ozone layer what it does is, the ozone if it is available in good quantity, it prevents the harmful ultraviolet radiation in the range of 0.27 to 32 micrometers from passing through the Earth's atmosphere. So, it is actually a protection. The ozone is a protection from UV light. So, but then, it is already suspected that skin cancer, damage of plants, reduction of plankton population, may all result from harmful ultraviolet light.

So, after an intense scientific debate then the community finally agreed that we will have to do something. We have to face out the CFCs in refrigerators. This led to what is called the Montreal Protocol where everybody agreed to remove CFC some refrigerators and banned CFCs. Now, we don't use R11, R22 and so on. These are 134a or CFC free refrigerants, okay. Yes, so now, we will get back to the blackboard.

What is up okay? I want to get back to the board. So, let us go through a brief survey of the Earth's atmosphere, okay. So, we look at the basic definitions and start solving some simple problems.

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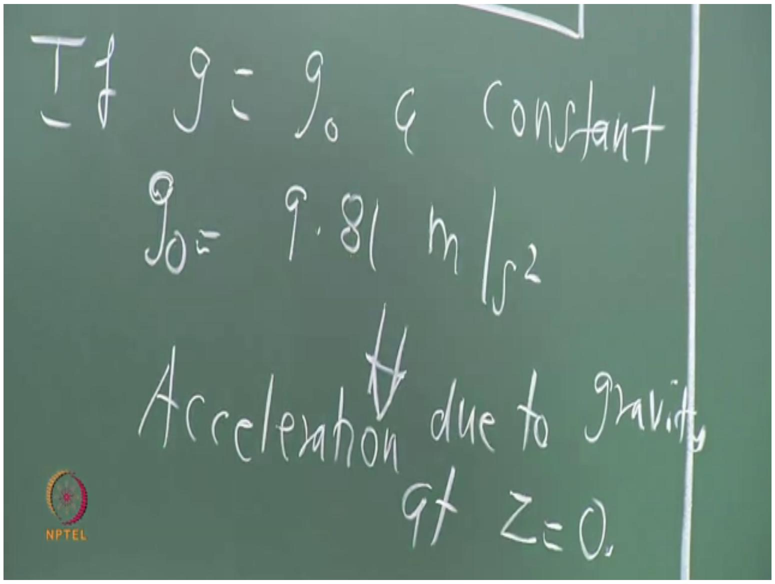

So, we will divide into 3 this is, okay, here. So, let us start with a brief survey of the Earth's atmosphere. So, what is the first quantity you would like to know? We are talking about the atmosphere. Before that, composition very good, even before that; size density, right, correct. So, the first is weight of unit volume of air, okay. So, the weight of air exerts a downward force. This is = M into V into g, right. Per unit volume, here you go. There is a Rho into g all right? What will be the atmospheric pressure? Force per unit area.

But this density is changing with height. The acceleration to gravity may also change with it. So, now give me a reasonable definition for pressure mathematically, the surface pressure, the pressure at the surface of the atmosphere. Ps = integral 0 to infinity Rho g dz where z is the vertical coordinate, all right. So, the z is very important in atmospheric thermodynamics or atmospheric science.

So can we make a reasonable assumption now? To make it simpler, g is a constant. What is it, I am trying to say? If g is a constant, = g naught means what? g naught why am I saying g naught at z = 0, exactly. So, at the surface of the earth if the acceleration to gravity is g naught which is agreed upon as 9.8 over 9.81 meters per second squared, okay, okay.

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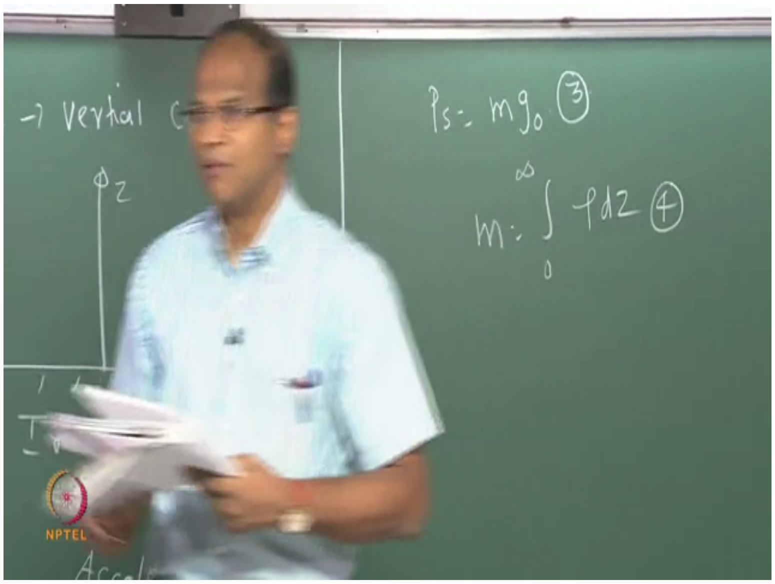

So, then, Ps = where m is given by Rho dz, very good, that is it. If I know how Rho varies with z I am home. I will be able to calculate the mass of the atmosphere, okay. So, please take down problem number one. Please take down problem number one. If the globally average surface pressure is 9.85 into 10 to the power of 4 Pascal's and the radius of the earth is 6.37 into 10 to the power of 6 meters, because write within brackets average value. Why? It is flattened at the poles and all that right? 6.37 into 10 to the power of 6 meters. Estimate the mass of the atmosphere; okay. So, I will enter the data here.

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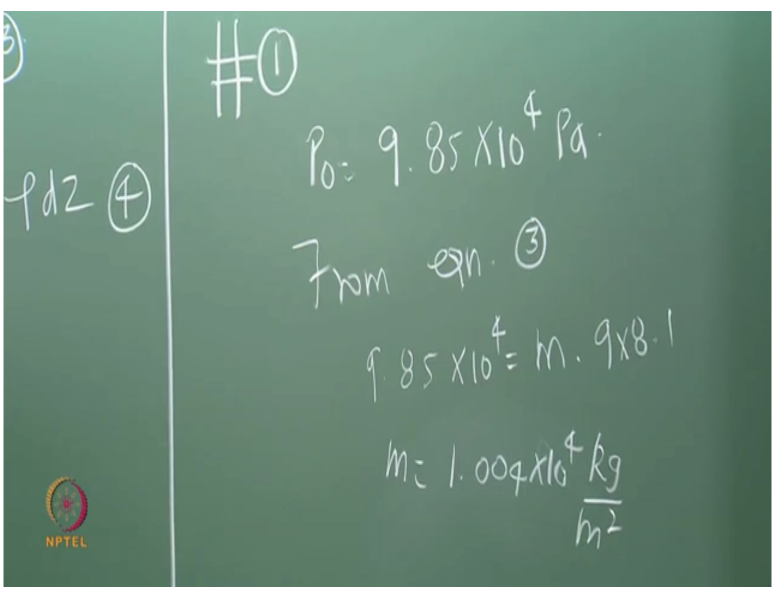

What did I give? Globally averaged surface pressure that is P naught is 9.85. So, which equation we use? Third, yeah please watch out the units of m. What do you get? 1.004 into 10 to the power 4 kilogram per meter square per meter square, okay. 1.004, go ahead and complete the Part B of the problem. Use the radius of the earth this one so what is the total mass of the atmosphere.

So, this is per unit area. What is the area then? Assuming the earth to be a sphere 4 Pi Re square so multiply this by 4 PI Re square. So, kilogram per meter square into meter square, meter square meter square will get cancelled; you will get so many tons, gigatons, whatever tons. This just gives you an idea of how big the atmosphere is. So, I go back here.

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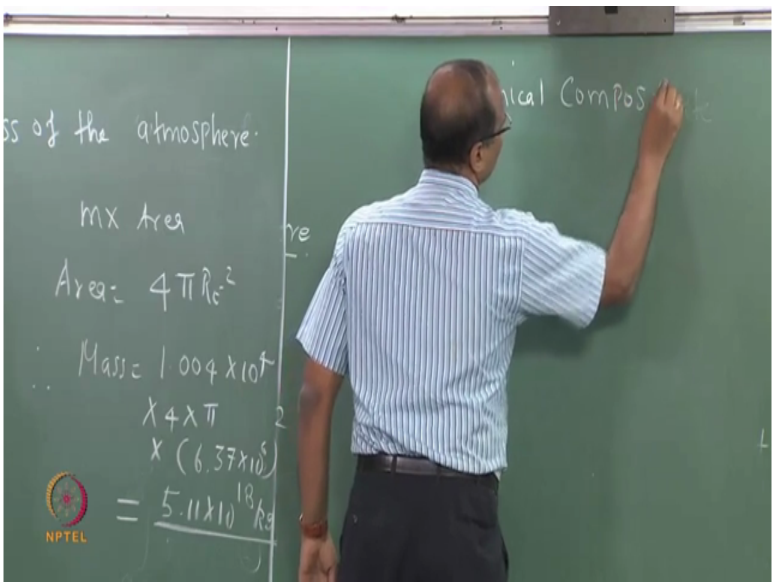

How many is it? 5.10 to the power of 18 kg. So, this is the amount of air above us, okay. Okay a huge number. Okay, so you got an idea of the total mass of air out of the 23% is oxygen. So, it is good for us right but this carbon dioxide is increasing and all that. That is the source of trouble. But now let us look at; somebody said what are the important quantities we want to look at? Somebody said the chemical composition. So, the next will be the next thing to look at will be the chemical composition of the Earth's atmosphere, okay.

Please note that we are not doing planetary atmospheric science. It is Earth's atmospheric science okay. We can do complete study we can do a Venus, Mars and all that, okay. But data and all is not available you have to use telescopic data some other data a spectroscopic data and figure out and we are interested in our lesser models. We are interested in only in our earth’s atmosphere, okay. So, we will concentrate on the Earth's atmosphere, okay. Is this clear? Now I will give you a table that gives you the chemical composition of the Earth's atmosphere.

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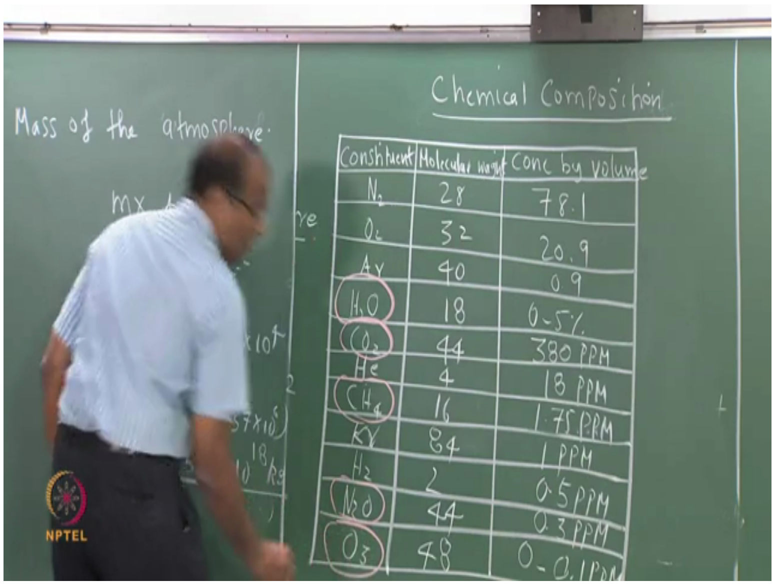

I have to use this. So, you can avoid PowerPoint we can just use 1, 2, 3, 4, 5, 6, 12, okay so, constituent, molecular weight. Then it started, okay. So, the various constituents we are listed nitrogen, oxygen, argon, water vapor, carbon dioxide, helium, methane, Krypton, hydrogen, nitrous oxide and ozone, okay. So, the molecular weights most of this you know. Nitrogen is 28, oxygen is 32, argon is 40, water is 18, carbon dioxide is 44, helium is 4, methane is 16, Krypton we'll have to see 84, hydrogen is 2, nitrous oxide 44, the same as carbon dioxide know. O3 is 48.

So, let us look at the concentrations. These are all trace gases, so in parts-per-million, okay. Please take down this table. Then, we will start looking into this, okay. What can you infer from this? First point: the nitrogen is dominant and all that is obvious. It is our dump, something little more. Sir, nitrogen is 78, oxygen is, okay. It is there from the table. What can you read what can you read between the lines?

The Earth's atmosphere is dominated by diatomic, diatomic molecules. Point number one: there is too much of nitrogen the inert gas there is too much of nitrogen all round. But the saving graces there is about 21% oxygen which is required for the systems of life, photosynthesis, whatever, okay. Now I have circled a few with pink color chalk piece. What are these? They are all greenhouse gases, very good, okay. All these fellows okay.

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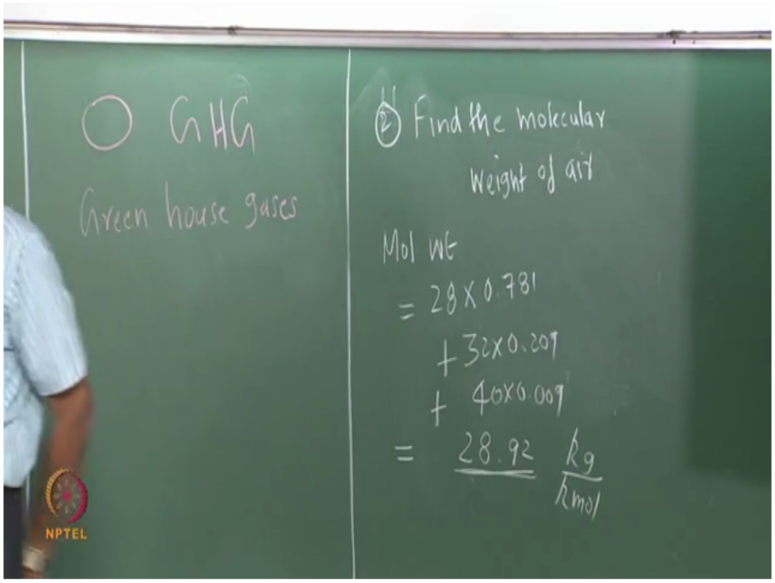

Problem number two: please take down problem number two. Based on the chemical composition of the Earth's atmosphere, given in the table, determine the molecular weight of atmospheric air. Based on the chemical composition of the Earth's atmosphere given in the table, determine the molecular weight of atmospheric air. So, you may choose to drop, you may choose to drop irrelevant gases, okay. Please do, please start. Is the problem clear? So, that will be problem number two.

Say that again 29.2, okay. It depends on which gas, first 3. Water 0 to 5% then it will give you. So, this 0 to 5% you will say 78.1, 20.9, 0.9 is exceeding 100. So, all the others so what does it mean? So, this chemical composition on these is on the basis of dry air. The chemical composition is on the base of dry air 0 to 5% it may be there, if you are to that means you have to consider moist air.

So, in Saudi Arabia it may be 0% somewhere it may be 4% in Singapore. So, that 0 to 5% is a normal concentration or atmospheric whatever this. It is not dry air basis okay. So, forget the water vapor. Do not use it, alright. So, if you do that what do you get? So, molecular weight = 28 into 0.781 + okay, so I am just converting it into fraction 0.781 into 28 +, we include is argon fellow also, right; 40 into 0.009, 28.91.

Actually, we in thermodynamics we learned it at 28.97, 28.92 kg per kg mol. That is what I study, is it correct? kg per kg per kilo mole, okay fine. So, it is about 28.97. So, it is between oxygen and nitrogen molecular weight. It is between, it is very close to its closer to nitrogen than oxygen possible basically because this nitrogen is too much, okay.

Problem number 3 convert the volumetric analysis of the chemical composition of the atmosphere of the earth and all the time; convert the volumetric analysis of the earth's atmosphere to a gravimetric analysis. There is the instead of volume bases, you are, you have mass basis, okay. Can you do this? Please do it. That is problem number 3.

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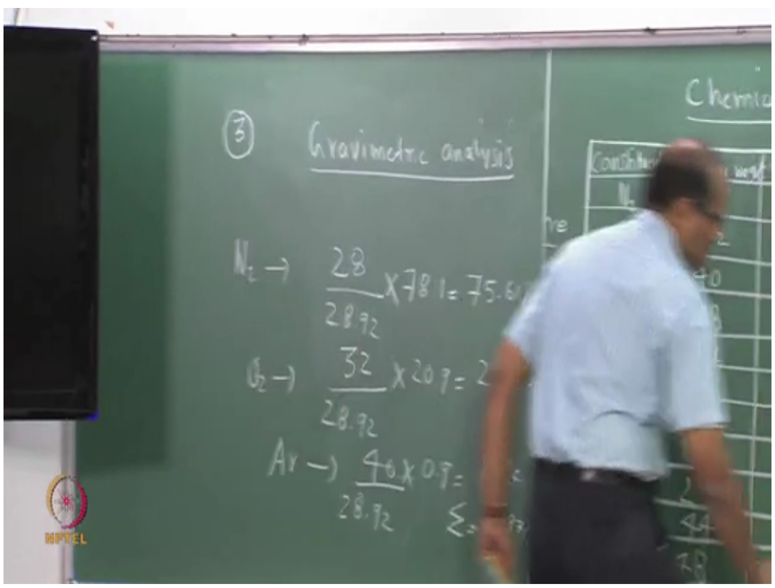

So, to do gravimetric analysis what is the first part, you have to get the molecular weight which I already got in problem number 2. So the driller you gave up, is not it? Yeah. Please tell me nitrogen, we will make it 78.1. How much is it? 75.61, O2 somewhere you read in school it is 23% you have to get it now. Then it is safe, 23-point how much are you getting, okay. We will take argon also, 40, .9 someone find. What is Sigma? 99.9, okay, Sigma should not exceed 100. Then we are in trouble, right. He is back Sigma 100, 99.9, 100, 99.97, okay.

So, this is basically the concentration this is the chemical composition. The water vapor is highly variable ranging from 10 parts per million in a desert region it can range up to 5% water vapor in a very, very you know your tropical region and so on. N_2 and O_2 are diatomic molecules which basically determine largely this is molecular weight and all that they are the dominating this thing. And gas molecules with certain structures interact with the radiation okay.

That is they are capable of absorbing radiation and because of which it leads to the, they absorb radiation selectively. That is their ability to reflect radiation and their ability to absorb radiation varies with the wavelength, okay. So, this leads a lot of disturbances which means they are allowing the solar radiation which is shortwave radiation, incoming shortwave radiation, they are allowing to come; so, this heats up the earth. But whatever is going out of the earth is a long wave radiation.

It is because of the planet means this means displacement law which will study later. Atmospheric radiation I will teach you later. So, this is outgoing shortwave radiation these fellows block and they are not able to get pass the atmosphere because of which there is a continuous buildup of this radiation. They act like a heat shield and therefore the global temperatures are increasing. Is it okay?

So, as the carbon dioxide concentration increases this will this will have a positive feedback but will continue to increase, right. So, they keep on there will be a feedback okay 2i = whatever. You will have a feedback and you keep on increasing all right. Now, the next will be the vertical structure of the Earth's atmosphere it is clear up to this stage.

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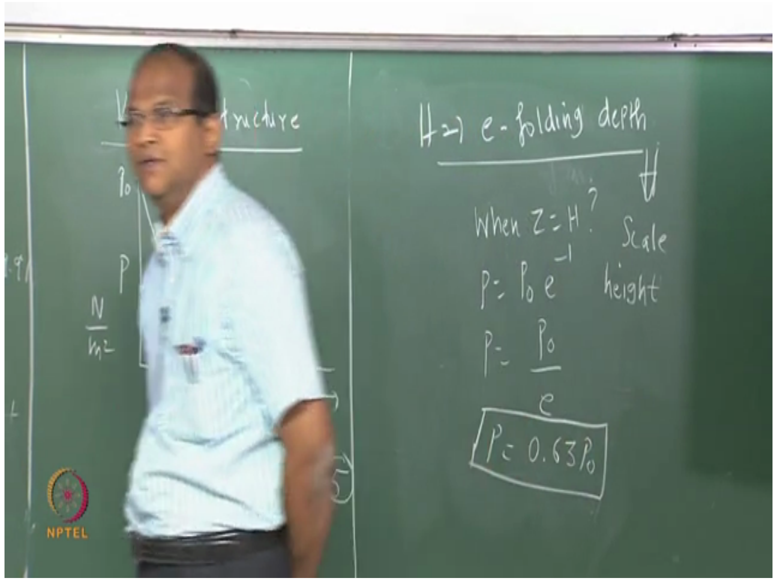

So, the pressure decreases with height, okay and the mean surface and the surface pressure is about P naught and to a large extent this can be calculated using the simple relation. What is it? Let us follow a global equation number, at least for lecture wise what will be the equation number for today's class, 5, okay. Okay so the pressure decreases exponentially with depth okay and H is called the e folding depth. When Z = H what happens? P = please use your calculators and let me know what these values is yes 0.63.

So, the e folding depth is the depth at which or the height at which the atmospheric pressure reduces to 63% or the pressure at z = 0 or at the surface. So, the H is something. H is basically a scale height for the atmosphere. It is a scale height just like you have if you put a mercury in glass thermometer in a patient's mouth, the doctor waits for 2 minutes, because he has to be reasonably confident that 99, it is close to 99% of the true value, okay.

So, there is something called a time constant for the thermometer. Like this the earth has got a scale height which is given by H is usually in kilometers, okay. Problem number 4: So, this will be the style in this course. It is okay. We will solve simple furnace slowly it will become more difficult but it will not get as difficult I said heat transfer. We would not solve nonlinear partial differential equations and all.

But through problems we will learn the science, all right at approximately what height, problem number 4, at approximately what height above sea level.

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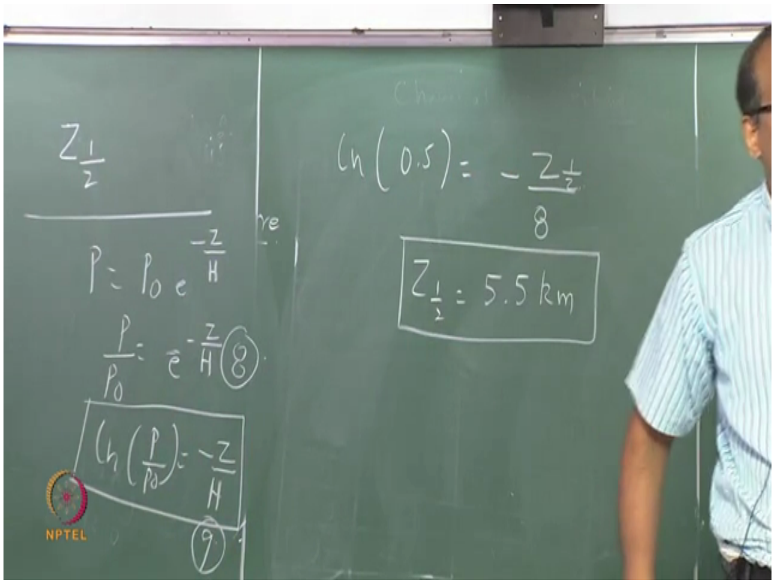

And approximately what height above sea level here it is given by Z half. I call this as Z half. But approximately what height above the sea level Z half that is half of the mass of the atmosphere lie above and half lies below but what height of Z does half of the mass of the atmosphere lie above and below it correct?

Assume H to be 8 kilometers and g is 9.81 meters per second square, assume H to be 8 kilometers and g to be 9.81 meter per square throughout. Do not try to integrate and make it make life difficult for you, okay. Please solve it, so we can work on that further. So, the pressure itself is a proxy for the mass right so you can take Lon of 0.5 right, that is what you are looking at, right.

So, the solution to this problem is: What is this? So, this is very interesting. We worked out the total mass of the atmosphere is 5. Earth's atmosphere is 5.11 into 10 to the power of 18 kg, okay. So, 2.56 into 10 to the power of 18 kg is within the first 5 and a half kilometers of the atmosphere and from 5 and half kilometers to infinity is the remaining 2.5 into 10 to the power of 18. So, the atmosphere is very dense in the first few kilometers.

This is the important concept you have to understand, so most of many of them; so your thunder storm, cyclones, or all these analysis we are restricting only to 0 to 20 kilometers more than that and about 10 or 12 kilometres generally you do not expect weather, only cumulonimbus storm. That is why commercial aircrafts fly at 12 or 13 kilometers. There will be severe thunderstorms but you will have a chance to navigate around the thunderstorms, okay.

When some aircrafts cannot pass through the thunderstorms also generally why that a civil aviation that 12 kilometers is fixed is, most of the clouds are below the 12 kilometers. They are really dangerous ones which lead to the typhoons and those things are extended up to 14 to 18 kilometers. But they will have a tower like this so it will be 100 or 200 kilometers the pilot has a chance to navigate around that.

If his radar is working properly and he is interested in, okay. So, we will stop here. So, it is quite interesting. So, we look at other; in tomorrow's class, we look at what is the vertical structure of the temperature. This is a vertical structure of the pressure. What is the vertical structure of the temperature? We look at troposphere, tropopause, stratosphere, stratopause, mesos mesophere and all that after all these discussions. Then, we look at the other important components in this namely the ice which is the cryosphere, the earth's crust mantle.

This will be a couple of classes that will complete the introduction to the various systems of the Earth's various players in the Earth's climate. Then, after 2 or 3 weeks we will get into atmospheric thermodynamics which will be the mainstay of this, which will be the main course of this course. So, we look at atmospheric thermodynamics, try to study everything from thermodynamics angle and then we will go to radiation and atmospheric dynamics.