Soil Science and Technology
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Lecture – 20
Tutorial

Welcome friends to this new lecture of Soil Science and Technology. And in this lecture, we will try to finish the soil temperature, which we started in our last lecture and we will also try to solve several, you know, couple of problems related to soil aeration and soil temperature.

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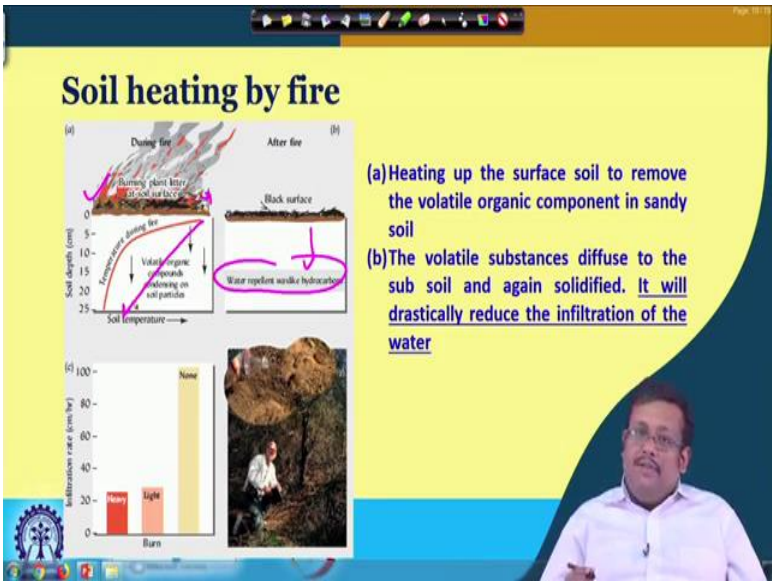

So, in the soil temperature, we discussed about how soil temperature is affecting different soil as well as microbial and other process. So, let us see some other examples. So, let us see: what is the implication of soil temperature in soil heating by fire. Well remember that, when heating up the surface soil to remove the volatile organic component in sandy soil and as a result of heating up of the surface soil. So, as a result of the heating of a surface soil, the volatile organic compounds, you know, diffuses the volatile organic compound diffuses to the subsoil and get there solidified.

So, you can see that, you know, this is a burning of plant liter at the surface. So, this is the reason and as a result of that, soil temperature increases with the soil temperature, you know, the soil temperature increases. As a result of that, whatever volatile compounds were there at the top of the surface, they will diffuse to the subsoil and again solidified. So obviously, because of that, there is a temperature gradient from surface soil to the subsurface soil as you can see here. So, this volatile substance will diffuse into the subsoil and again solidified and it will drastically reduce the infiltration of the soil because, there are water repellent in nature. So, that is how soil temperature by forest fire affects the soil, you know, water moment as well as different other soil physical and chemical properties.

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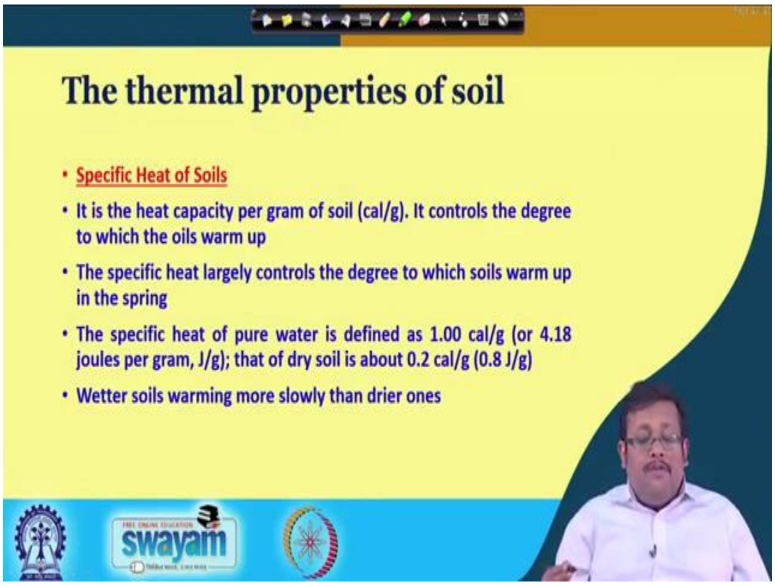

So, let us move to the next slide, you see: what are the important thermal properties of the soil. So, we all know heat capacity. So, what is the specific heat of soil? Now specific heat of the soil is the heat capacity per gram of soil, which is measured in terms of calorie per gram and it controls the degree to which, you know, the soil warms up. Sorry, it should be soil warms up.

So, the specific heat largely controls the degree to which the soil warms up in the spring, it is the very very important soil property. And the specific heat, you remember that this specific heat of pure water is defined as 1 calorie per gram or 4.18 joules per gram and that of a dry soil. So, the specific heat of dry soil is about 0.2 calories per gram.

So, you can see the specific heat of, you know, pure water is 5 times more than that of specific heat of a soil. So, as a result of that, wetter soils, you know, wetter soil warms more slowly than that of drier soils. Because, when there will be water in the soil, as a result of high heat specific heat more amount of heat will be required to raise the temperature. And as a result of that, the dry soil will, you know, will warm more faster than that of wet soil.

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So, this is a specific heat. And what is heat of vaporization? Well it requires a large amount of energy that is around 540 kilo you know kilo calorie for every kilogram of water to be vaporized and their and this use of energy for evaporation has major effect because, it cools the soil.

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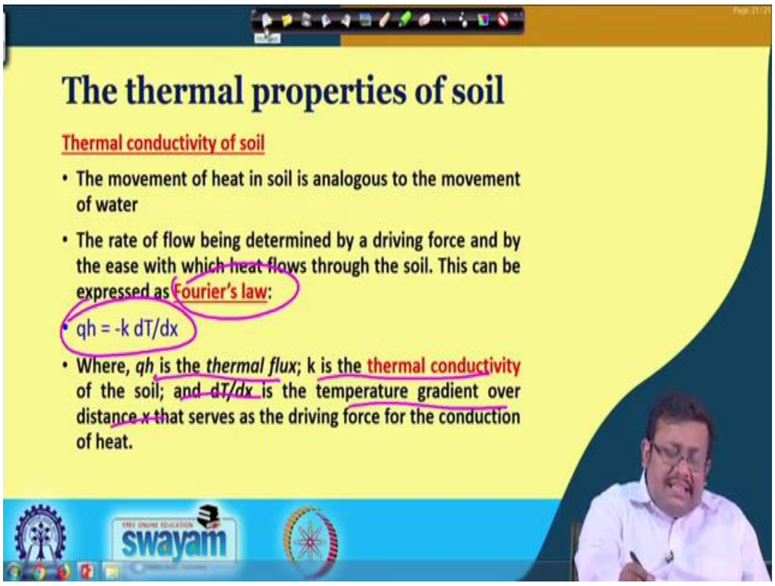

So, what is thermal conductivity? It is very very important aspect remember that, the movement of heat in soil is also analogous to the movement of water. So, we have discussed about the movement of water in case of saturated soil, in case of unsaturated soil. In case of saturated soil, we discuss about Darcy's law and remember that. So, the movement of heat in the soil is analogous to the movement of water and also the rate of flow being determined by a driving force and by the ease with which heat flows through the soil and this can be expressed by Fourier's law.

So, this is important remember that this is called Fourier's law. Now, what Fourier's law states? The formula of Fourier's law is qh is equal to minus k into dT over dx, where qh is the thermal flux, k is the thermal conductivity of the soil and dT over dx is the temperature gradient over distance x that serve as the driving force for the conduction of heat. So, this k is basically called the thermal conductivity.

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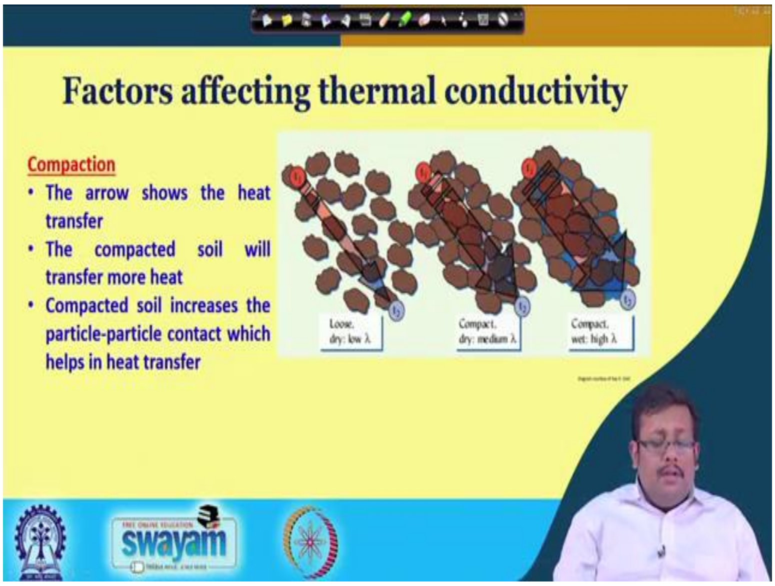

So, let us see some factors which affects the thermal conductivity of the soil. The first important factor is compaction because, you can see the soil when the soil is more compacted; obviously, the heat flow will be more. So obviously, the arrow shows the heat transfer as we can see this is the loose soil loosely aggregated soil and this is the, you know, compacted soil. And the compact soil will transfer more heat and compacted soil increases the particle because, this compact soil increase the particle-particle contacts which helps in heat transfer. So, you can see here; obviously, in between the particles there are air molecules. So, as a result there is no, you know, particle-particle contact, but as you are going from loose to compact soil; obviously, there will be more particle to particle contacts and as a result of this particle-particle contacts there will be more heat transfer.

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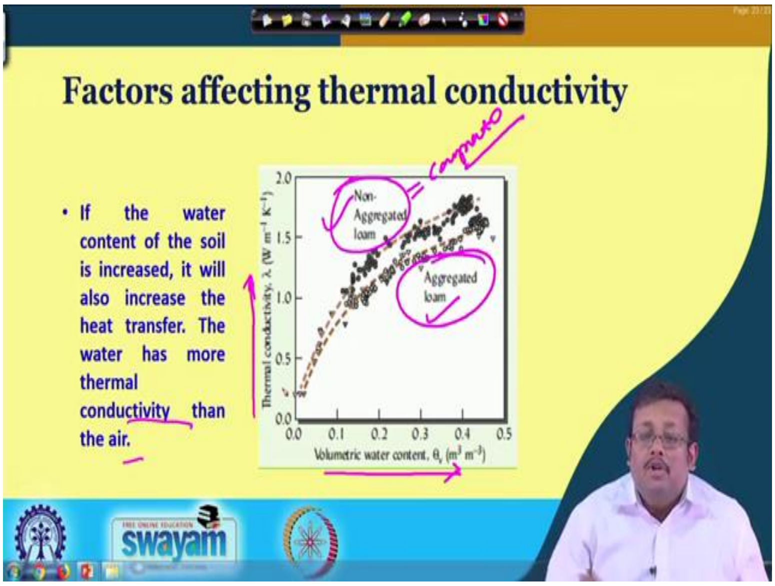

So, compaction, we know, increases the heat flow in the soil. Another important aspect is, you know, the volumetric water content. So, you can see this as the interplay between volumetric water content or in the words water content with the thermal conductivity. So, as we are increasing the water content in the soil, thermal conductivity is also increases.

So, if the water content of the soil is increased, it will also increase the heat transfer and the water because, the water has more thermal conductivity than that of air. So, if the pore spaces are filled by water they will; obviously, replace the air. So, the water the presence of water into the pore space will increase the thermal conductivity because, the water has more thermal conductivity than that of air. So, you can see there are 2 types of soil, one is aggregated loam and another is non aggregated loam soil.

So, in case of non aggregated loam soil or another words, it is a compacted soil we can say. So, the in case compacted soil; obviously, the thermal conductivity rises more as compared to well aggregated loam, where there will be more amount of macro pores. So, this is the implication of volumetric, you know, water content in thermal conductivity into, you know, in 2 types of, you know, aggregated soil. One is compacted another is aggregated.

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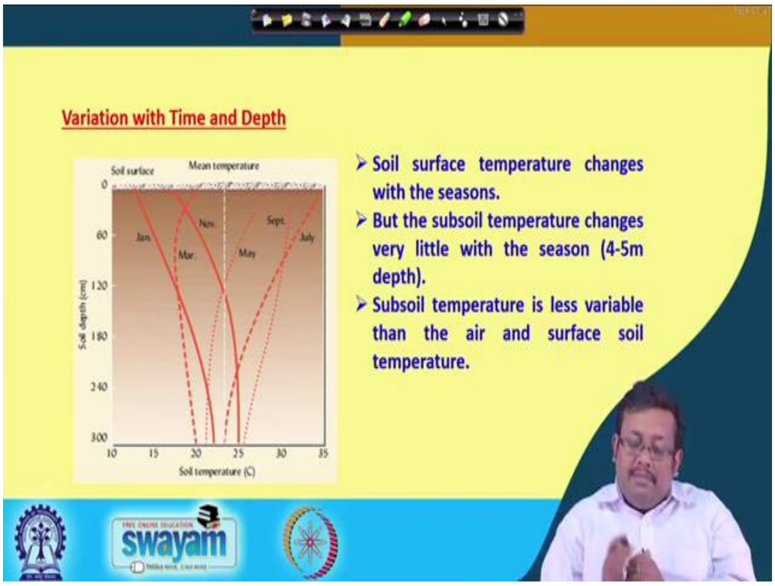

And also, temperature also has shows variation with time and date; obviously, soil surface temperature changes with the season, as we can see in this in this picture and subsoil temperature changes very little with the season, that is 4 to 5 meter depth and subsoil temperature is less variable than that of air and surface soil temperature. So, the surface soil temperature changes more rapidly than that of subsoil temperature, because at the subsoil temperature is more or less, you know, almost constant.

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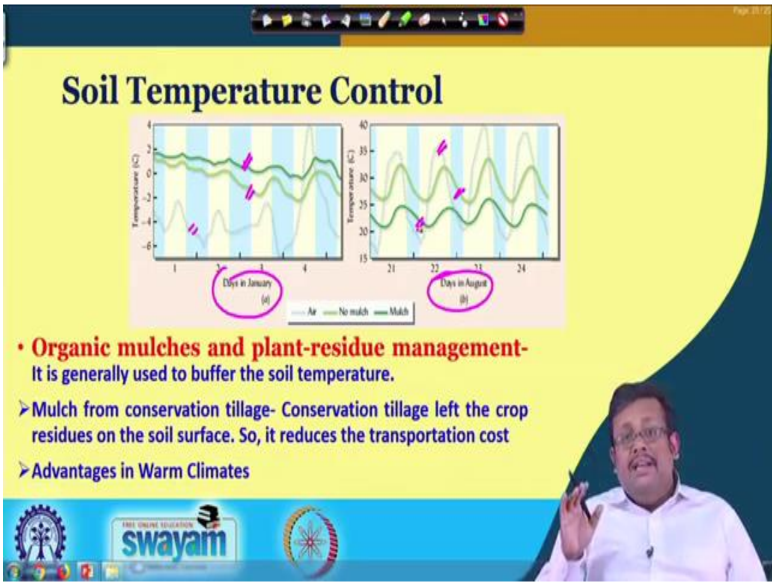

So, how you can control the soil temperature? Well there are couple of ways to control the soil temperature, some examples of, you know, management strategies for controlling the soil temperature are organic mulches and plastic residue management. So, it is generally used to the buffer temperature. So, as you can see in this in these 2 graphs; obviously, this green this line shows the mulch condition, this is no mulch condition and this is years, you know. So here, also, you know. So, days in January, the temperature in year is quite low. So, if you go for mulching, it will raise the temperature. So, it will protect the soil temperature from going below a certain temperature so that, the germination and biological activities and all other nutrient transformation can be maintained.

So similar, you know, the opposite can be found in case of, you know, August because, in case of August or in other words in case of drier months; obviously, their temperature will be higher followed by the no mulch condition. And finally, you will see lower temperature will be get, you will get in the mulch conditions. So it will conserve the temperature of the soil. And it will, you know, it will prevent the soil temperature to go beyond a certain limit, thereby, you know, preserving all the soil biological as well as physical, all the soil biological as well as chemical activities.

So, this is, you know, importance of mulch for soil temperature control. Remember that, mulch from conserve, you know mulch from conservation tillage let the, you know, so;

mulch for conservation tillage is also important. Because, in the definition of the conservation tillage it says, the conservation tillage must let the crop residue on the soil surface. So, when we leave the crop residues in the soil surface, it acts as a natural mulch or organic mulch and reduces the temperature, it reduce the transportation cost. And in another word, it helps in maintaining soil temperature and; obviously, it is helpful in case of warm temperatures.

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Plastic mulches, plastic mulches are used to increase the soil temperature. So, organic mulches in case of conservation tillage are helpful in warm climate, whereas plastic mulch are helpful in the cooler climate. Because, plastic mulches are used to increase the soil temperature in the cold region and there are 2 types of plastic mulches, one is called clear plastic mulches, another is black plastic.

So, clear plastic has greater heating effect than that of black plastic and generally it is used in cool climate for growing crops or for pest management. The major disadvantage is that it is non renewable, but some nowadays biodegradable plastic films can be used as a mulch.

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So, as you can see, these are the some biodegradable plastic mulches farmers are using nowadays for mulching purpose in the cooler climate region.

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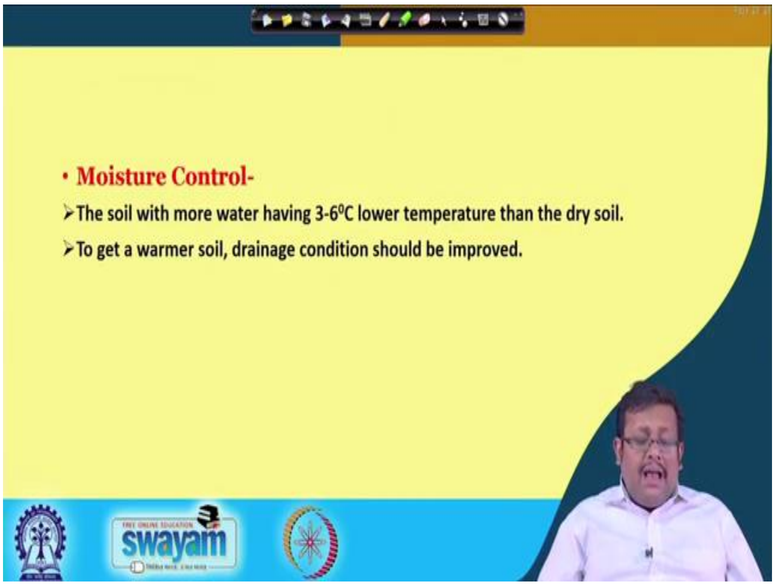

So, another important aspect is the soil with more water having 3 to 6 degree lower temperature than that of dry soil and to get warmer soil; obviously, you need to improve the drainage condition. So, you we know so; obviously, we have already discussed, why the temperature in dry soil is higher than that of wetter soil. So, moisture control is also and other factor to, you know, to control the soil temperature.

So, guys we have finished this soil temperature chapter. So, I hope that you have learnt something new and let us go and solve some problem in the next lecture next tutorial.

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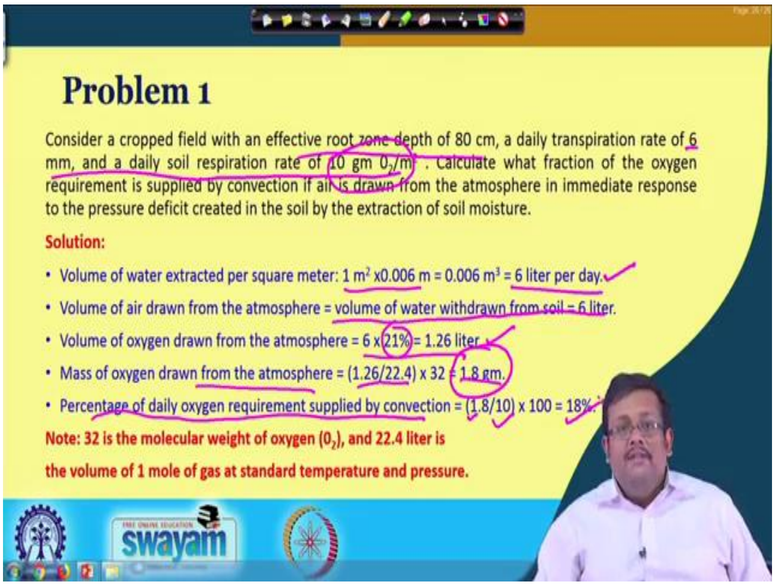

So, will be solving 3 problems; obviously, let us, you know, relating to soil aeration and soil temperature. So, let us start with problem 1. So let the problem says consider a crop field with an effective root zone depth of 80 centimeter, a daily. So, the effective root zone here is 80 centimeter, a daily transpiration rate of 6 millimeter and a daily soil respiration rate of 10 gram oxygen per square meter. So calculate, what fraction of the oxygen requirement is supplied by convection if air is drawn from the atmosphere in immediate response to the pressure deficit created in the soil by the extraction of soil moisture.

So, let us first calculate the volume of water that is being extracted per square meter. So, the volume of soil water that is being extracted per square meter by the crops through transpiration process is 1 square meter multiplied by 0.006 meter. So because, we are converting 6 millimeter to meter; so, we are getting around 6 liter per day. Second, you can see volume of air drawn from the atmosphere will be similar to the volume of water withdrawn from the soil that is 6 litre. Because, whatever water are we have in the plants drawing from the air, drawing from the soil, I am sorry, this water will get replenished by air from the atmosphere. The similar volume will be maintained.

So here, so a volume of air drawn from the atmosphere will be similar volume to the volume of water that is been withdrawn from the soil. So, volume of oxygen drawn from the atmosphere will be 6 multiplied by 21 percent that is 1.26 liter because, we know in the atmosphere, there are 21 percent of oxygen and also mass. So, the mass of oxygen drawn from the atmosphere, if you convert it to the gram from liter will get around 1.8 gram and that comes from 1.26 over 2 into 2.4 multiplied by 32. So, how it comes because, you know that 32 gram is the molecular weight of oxygen, 32 is the molecular weight of oxygen and 22.4 liter is the volume of 1 mole of gas at standard temperature and pressure.

So basically, we are converting this liter of oxygen to the gram. So once, we calculate this is 1.8 gram, the final question is we have to calculate, what fraction of the oxygen requirement is supplied by convective air by convection, if air is drawn from the atmosphere in immediate response? So, the percentage of daily oxygen requirement supplied by convection is 1.8, which you have already got and 10 is the total is a daily soil respiration rate got from here percent. So, that will come around 18 percent. So, I will hope that you have understood this problem this solution.

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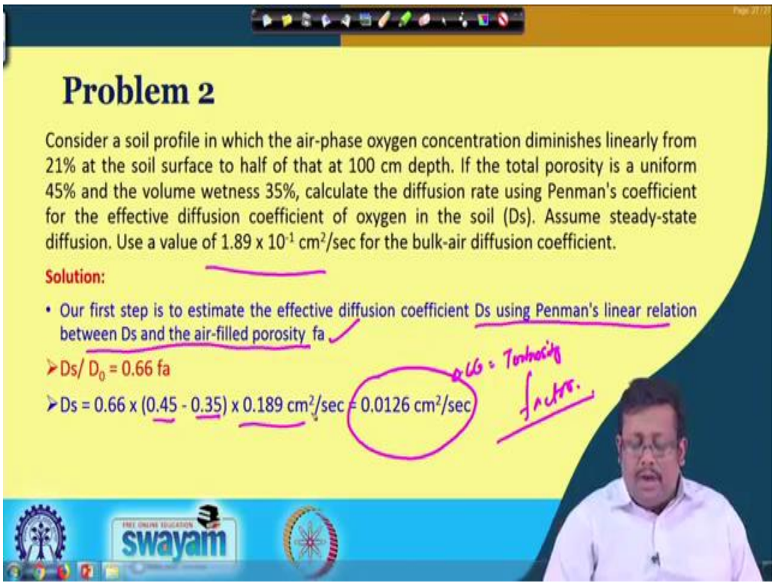

So, let us go ahead and see what is our next problem. Now, this also, you know, deals with soil aeration. So, this problem says that consider a soil profile in which the air phase oxygen concentration diminishes linearly from 21 percent at the soil surface to half of that at 100 centimeter depth. So, if the total porosity is a uniform 45 percent and the volume wetness is 35 percent, calculate the diffusion rate using Penman's coefficient for the effective diffusion coefficient of oxygen in the soil Ds.

Assume steady state diffusion and use value of 1.89 into 10 to the power minus 1 square meter per second, sorry, square centimeter per second for the bulk air diffusion coefficient. Again, you have to consider that there is a soil profile and there is a steady state flow and it linearly this oxygen concentration, you know, depletes from 21 percent at the soil surface to it is half at 100 centimeter depth. If you know they have given the total porosity of 45 percent and also they have given volume wetness 38 percent. So, we have to calculate the diffusion rate using Penman's coefficient.

Now in the last lecture, we have already discussed about the fick's law of diffusion as well as their Penman's modification. So, we will be using that Penman's modification and fick's law for solving this problem. So, our first step is to estimate the effective diffusion coefficient Ds using Penman's linear relation between Ds and the air filled porosity fa. So, if you remember the Penman's Penman equation shows Ds over D 0 equal to 0.66 fa, where 0.66 is the tortuosity factor. Now we know that this fa or air filled porosity can be calculated by subtracting the volume wetness from the total porosity.

Now, we know the total porosity is 0.05 and the volume wetness is 0.035 and basically the bulk diffusion air diffusion coefficient value is 0.189 square centimeter per second, which we got from here. So, ultimately we are getting 0.0126 square centimeter per second, this is Ds. So, once we calculate, Ds let us see what is our next step.

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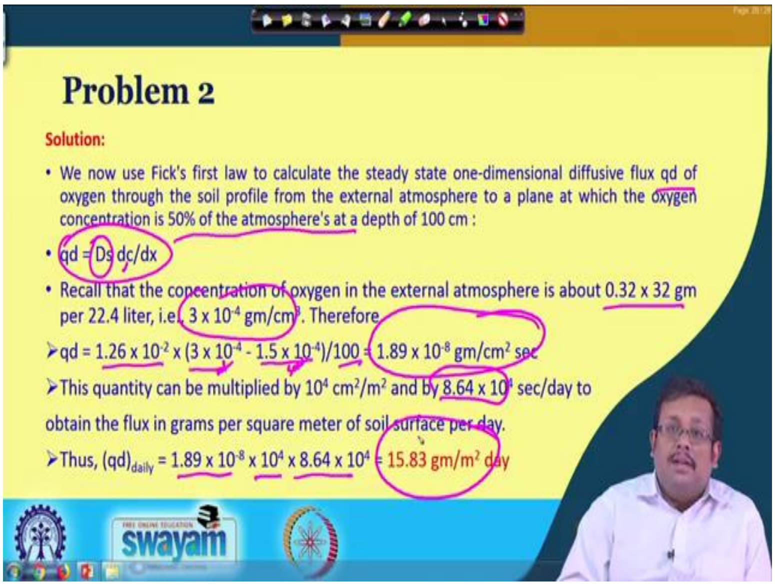

So, we now use the fick's law to calculate the steady state one dimensional diffusive flux qd of oxygen through the soil profile from the atmosphere to the plane at which the oxygen concentration is 50 percent and the depth is 100 centimeter. So, let us use the Fick's first law. So, the Fick's first law is qd equal to Ds multiplied by dc by dx. Now recall that the concentration of oxygen in the external atmosphere is about 0.32 multiplied by 32 gram per 22.4 liter. So, that comes around 3 into 10 to the power minus 4 gram per cubic centimeter. So, therefore, by substituting this number into this equation, we get value of qd that is 1.26.

So, we have already calculated this in the, you know, this Ds value we have already calculated this. So, the initial you know initial concentration of the external air is this and the final concentration will be 50 percent as we can see the oxygen concentration is about 50 percent of the atmosphere. So, the final concentration is 1.5 multiplied by 10 to the power minus 4, because you know the dc is the changes in your concentration.

So, we are getting in the changes of concentration from the atmosphere to the soil at 100 centimeter depth. So, here dx is 100. So, ultimately we are getting 1.89 multiplied by 10 to the power minus 8 gram per square centimeter into second. So, this quantity can be multiplied by 10 to the 4 square centimeter by meter square and by 8.64 10 to the power 4 second per day, to obtain the flux in gram per square meter of soil surface per day because, you know that in one day, there will be this amount of taken. So, 8.64 multiplied by 10 to the power minus 4 seconds.

So, you just need to convert this 1.89 into 10 to the power minus 8 gram per square centimeter second to, you know, flux in gram per square meter of soil surface per day. So, for getting that we have to multiply this 1.89 into 10 to the power minus 8 with 10 to the power 4 into 8.64 multiplied by 10 to the power 4. So, we are getting it a total of final value of 15.83 gram per square meter per day. So, this is our final solution.

So, basically in this solution, we are using first the Penman's equation to calculate the Ds and using the Ds we will calculate the diffusion flux qd using the Fick's law. And remember that, here we have to calculate the, you know, diffusion gradient also and this concentration gradient. And this concentration gradient can be calculated by subtracting the initial concentration of oxygen and the final concentration of oxygen. And, we know that final concentration is just half of the initial concentration and the distance is given it is 100 centimeter.

So once you get that, we have to just convert into gram per meter square using suitable multiplication factor.

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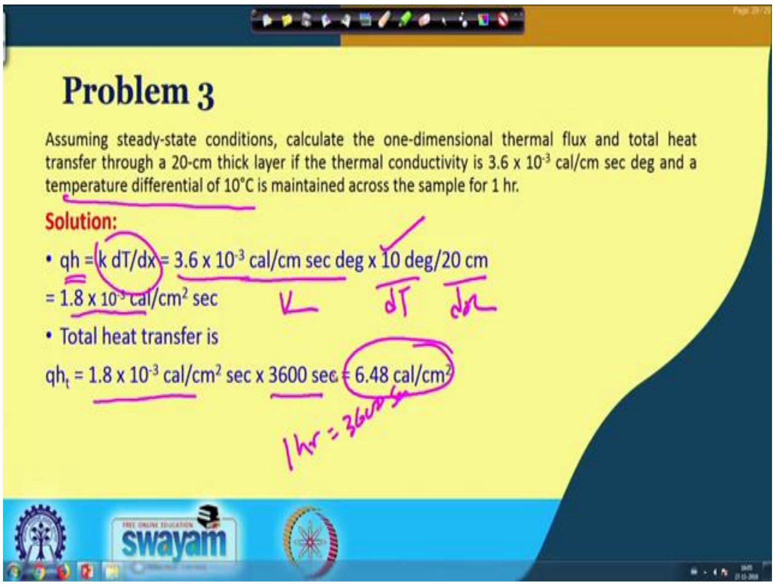

So, I hope that you have understood this solution. So, let us go ahead and see our third problem. So, in this problem it says that assuming steady state condition, calculate one-dimensional thermal flux and total heat transfer through a 20 centimeter thick layer. If the thermal conductivity is 3.6 into 10 to the power minus 3 calorie per centimeter second degree and a temperature differential of 10 degree centigrade maintained across the sample for 1 hour.

So here, first and you know we will be using Fourier's law for solving this problem and as you can see we are we are basically calculating qh here and this qh can be calculated by using this formula, where k is the thermal conductivity and dT over dx is the temperature gradient. And you can see that, you know, the thermal conductivity value is already given that is 3.6 multiplied by 10 to the power minus 3 calorie per centimeter second degree. And so, we have to and here the temperature differential is already given that is 10 degree centigrade. So, it is basically Dt, this is k and this is dx.

So, dx you already know that is 20 centimeter thick layer. So, ultimately we are getting 1.8 multiplied by 10 to the power minus 3 calorie per square centimeter second. So, we have to calculate it for 1 hour or 3600 second because, you know 1 hour equal to 3600 second. So, what we are what we got it is qh, we know that total heat transfer is basically the multiplication of qh with the total number of seconds in 1 hour. So, ultimately, we are getting 6.48 calorie per square centimeter. So, guys these are couple of, you know, problems and their solutions, I thought that I should discuss with you to give, you know, to help you understand different soil physical process specially, soil temperature and soil aeration.

And these will be helpful for you to in the near future for solving several related questions; obviously, I cannot cover all the, you know, different types of problems, because of time constraint. However, I would, you know, I would expect that you will go ahead and consult different text and reference books for solving. And for consulting different types of problem related to the soil physics, soil physical parameters like soil layers, soil temperature, and soil water and soil porosity and so on and so forth.

So, by, you know, by this we are wrapping of the soil physical processes and from the lecture which will start, which will start next week we will be starting the soil chemical process. So, if you have any questions, please feel free to email and feel free to ask me any questions. And I will be more than happy to explain any queries you may have.

Thank you very much.