Environmental Geotechnics
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Lecture – 15
Particle Energy Filed Theory

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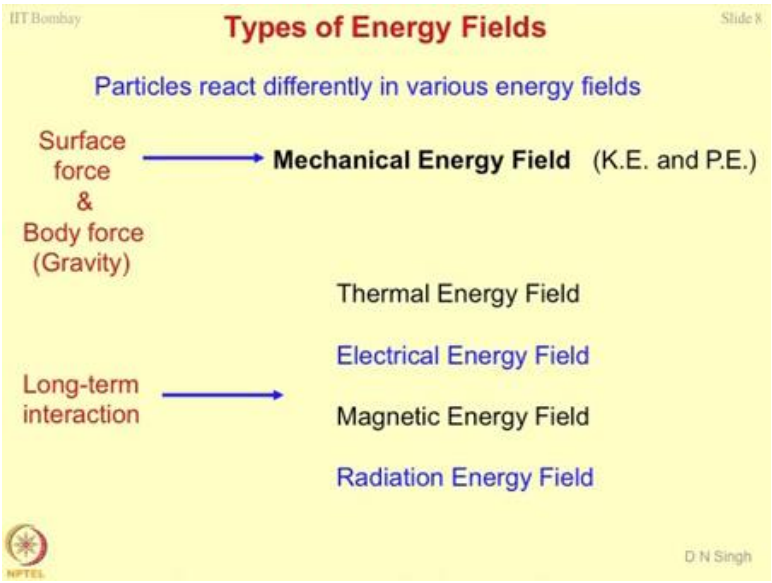

Now, the question is if you want to study the long-term interaction, what should be done? Because this reading is going to be short term in certain use in some time. So, if you are interested in long term interaction you have to talk about different energy fields. And they energy fields could be thermal energy filed, electrical energy filed, magnetic energy field, and radiation energy field; this is part clear? No? Don't agree? Express yourself.

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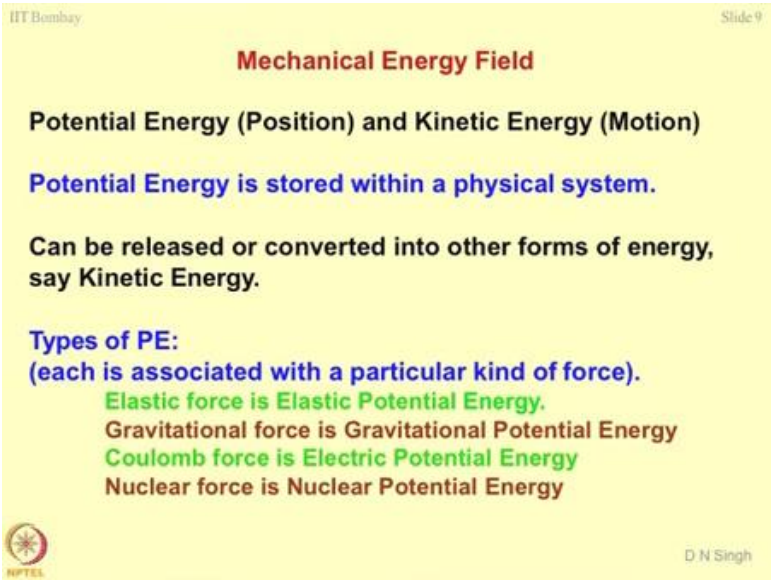

So, let us start with the mechanical energy filed. So, as you said that mechanical energy consists of two things that is the position, potential energy, and kinetic energy which is the motion. So, any potential energy will be stored in a physical system, is this ok and this be released or converted in other forms say kinetic energy. And something which we are doing right now is when we you wrote the soil mass if it is saturated water comes out and particles compress. So, potential energy has not converted in to two components.

So, if you say PE on the left-hand side is equal to kinetic energy plus PE 2, where PE is of the different grains and their reorientation and the spacing between the two phases. And kinetic energy is the amount of water which comes out in the form of some velocity component and the movement of the particles; types of potential energy.

So, each unit associated with a particular kind of force, elastic force is nothing but elastic potential energy, how would you compute energy associated with a phenomenon when you plot low deformation craft; can you compute the energy or the work done system or by the system? You integrate the graph on the x axis; is it not? So, work done will be nothing but force multiplied by displacement dx. So, f(dx) integration of this will give you the energy which is stored in a system, it is nothing but a elastic force as long as you are working in a elastic region. Gravitational force which is nothing but the gravitational energy, a location of the point or the position of the point with respect to each other.

Coulomb force is nothing but electrical potential energy, the energy stored between the two charges and of course, the nuclear force which is nothing but the nuclear potential energy. So, present a geomechanics and the people what they trying to do is, they are trying to tap these concepts of energy in redefining the concepts associated with all mechanisms which take place in soil mass. I given a examples of two, because right now only two things come to your mind that is the completion and consolidation, theories which can be rectified very easily. If you do this stress in a very controlled environment forget about the sound and light energies other things can be controlled you can measure the temperatures and velocities then what not.

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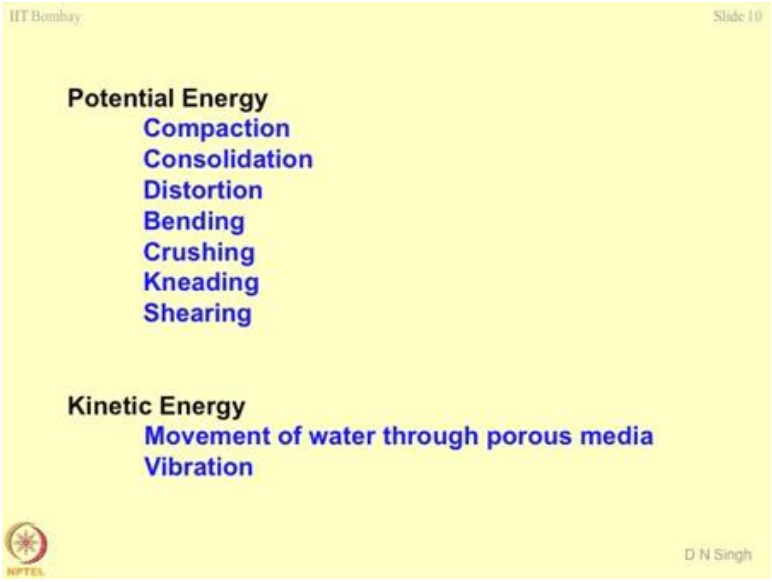

So, basically if you try to focus on what are the components of the potential energy, the first one is compaction process which his govern by the potential energy, what happens densification. So, initial sample which was of certain volume gets reduced sample size gets reduced. Consolidation is this correct, rearrangement of the grains, rearrangement of some new structure of the soil mass. Distortion of the grains I have talked about either because of bending or crushing or because of rolling.

So, this is bending, crushing, kneading is a sort of a compaction where again the potential energy goes in sets into the grains and grains get reoriented. Shearing: shearing is also a sort of a potential energy of course, if you will get a phenomenon which is the dynamic phenomena. When you are shearing two materials, so there is a moment clear,

but then the rearrangement in the grains because of shearing process is nothing but because of the PE getting store into the system. How about the kinetic energy? Movement of water through porous media either through consolidation or because of seepage access it pore pressure generation vibrations. So, in vibrate the system is nothing but a process which is related to kinetic energy.

So, as you can notice that present a scenario is people are trying to put things together, you know no clear-cut models is there right now. But definitely these are the foundation instruments for developing new models based on which the new classical models will be proposed in the days to come. So, blasting operation; how would you define this process? It is a chemical energy which is stored in the blast alright and gets converted into a mechanical energy.

And this mechanical energy results in densification of the soil and movement of shearing compaction gives in the medium, go one stay ahead the shear gives in compaction ways they have creating a different state of the material and densifying them. So, this is the concept which you used in tamping of sandy layers or modification of sandy layers by using vibro-flotation or by heavy compaction. So, shock ways have to pass through the porous media, so that becomes densified. Is this part clear? So, thus enough examples which convince us that yes this components should be studied in details.

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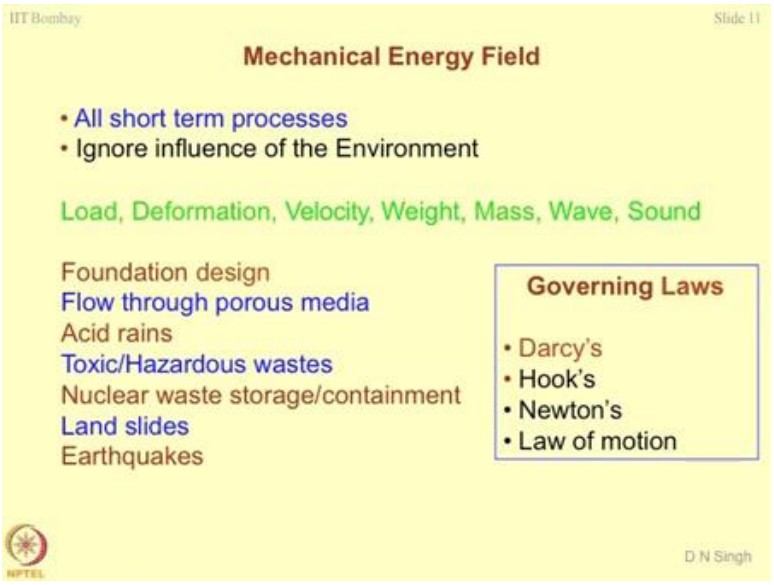

Now, let us talk about the mechanical energy field, basically these all short-term processes. When we say short term, short term with respect to the life of the structure which is going to be is it not. And then will be influence in the environment, particularly decay, alteration of the material in the due course of time, no mechanical loading can simulate this. In centrifuge what you are doing? In centrifuge you are utilizing the mechanical energy in the form of accelerated gravity. So, this is also a form of mechanical loading on the system and that is the reason you cannot simulate any bio chemical process which may occur otherwise in nature in the centrifuge, there is a limitation is it not.

The load deformation, velocity, weight, mass, wave, sound all these phenomena they are associated with mechanical energy field alright. But this point is very important when we model our system with the help of using mechanical energy theory concepts, we are not talking about the influence in the long run. Where do you use these concepts of load, deformation, velocity, weight, mass, wave, sound, foundation design, load deformation characteristics, bearing capacity, bearing pressures, flow through porous media, velocity comes by the picture through a control mass or volume, acid rains.

The influence of acid rains on the foundations and structures creation of voids and so on; toxic hazardous waste, nuclear waste storage and containment, again you are talking about the migration of the contaminants from contaminated side to uncontaminated sides. Landslides, it is a good example of how potential energy and kinetic energy can interchange itself several times.

So, landslide takes place because of excessive potential energy when the soil mass of the rock mass falls down it attends kinetic energy again it defragments. Always defragmented materials they will again start moving, rolling down, sliding down and again they will achieve some stable position and so on, and of course, earthquakes where the waves, and sounds, and the mass, and the velocity comes into the picture.

So, this is what the scenario right now we are able to tackle all these problems associated in geomechanical engineering profession with the help of simple mechanical engineering mechanical energy field theory is it not. They are exposed to loading processes and we have more interested to finding out deformation. The second question if you want to model these things what are the laws which are associated with this. So, you use Darcy’s

low, Hook's low, Newton's low and Low of motion particularly those of you who might be working in landslides they believe in a lot Newton's low of motion and low of motion basically.

Contaminant transport, seepage through porous media and all Darcy's low and load deformation characteristics will talk about Hook's low. So, the basic low of mechanics are these four which we are utilizing in characterizing the porous media or the geomaterials based on mechanical energy concept is this alright.

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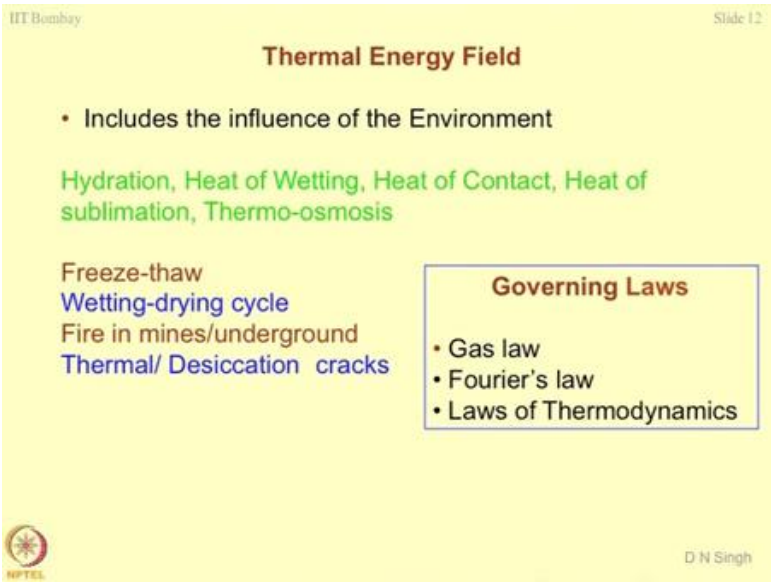

The second important energy field which is giving attention of the everybody's particularly researchers is the thermal energy field, and fortunately this energy field includes the effect of environment. Any interaction process will cause heat to generate, a good example is you add soil and water together there must be some heat of hydration of soil is it not thermal cracking and so on.

So, hydration is the word which is associated with this type of process, we call it as heat of hydration, the amount of heat which is liberated because of addition of water to soil mass or a geomaterial. We talk about heat of wetting; have you heard of this heat of wetting? Heat of contact, and heat of sublimation, thermo osmosis anyway these are the applications. Actually, heat of wetting and heat of contact are the terms which I am trying to point and I am trying to develop some models based on these two terms. Any guess what heat of wetting would be?

Student: For example, if some sand (Refer Time: 12:40) add, water, some heat will be generated but it is not the form of (Refer Time: 12:45) actually heat is generated it is.

That is hydration; that is right, so there is some difference between hydration and heat of wetting and heat of contact. See truly speaking this should have been put in a reverse order, the pause material comes in contact with something whatever amount of heat gets generated, later on the metal process starts which is surficial phenomenon and ultimately everything enters and penetrates due to the metrics of the material when the hydration starts. So, most of the time you will notice though we call it has hydration process, if you want to look an interaction of geomaterial with environment. The first thing is the material comes in contact with something and what is that happening at that moment should be captured.

And the second thing is what amount of energies required to build the system completely? And of course, when comes your hydration process. So, similarly with a concept on which one of my Ph. D scholars will work which is knows as that is geomaterial contaminant interaction. So, the first question which comes to my mind is how to define this interaction, and I get motivated while coining these terms you know by our colleagues in construction materials is always define heat of hydration of cement.

So, if you want to find out the activity of a material please note these words and correct me if you do not agree, then the way we define a activity in geomechanics is not a very correct way. Because if you want to define the activity of a mineral the best way would be to give it enough chance to interact with water contaminant and find out how much amount of energy is getting liberated out of it, so that will be the perfect interaction.

So, that way if you just want to you know freeze at the point of interaction what is happening to the system these terms are of great use that is heat of wetting, heat of contact. We will talk about heat of sublimation in the subsequent slides, thermo osmosis is the phenomena where we in which you apply some heating osmotic pressures increase water oozes out and the system is stabilizes.

Some of the practical real-life problems would be freeze thaw process, if you want to model freezing and thawing of the geomaterials wetting drying cycles. I think this is the topic which is I have plotted also for my M. Tech students and I do not know if I am correct, I think I have floated this topic wetting and drying cycle. The whole idea of

studying this type of cycle says that what really happens to the system in case they come and contribute with water and then the environmental conditions become such that they have to expel water from them.

So, it is a sort of annealing process which a metal goes through when the casting is done. So, this will show you the vulnerability of the material towards environmental degradation. And of course, fires in mines and the underground environment is the famous example of how these studies are becoming so important particularly methane catches fire when you do mining. And thermal and desiccation cracks which are formed because of excessive heating of the soil mass. So, the question is what are the laws which you are going to use for in doing these types of studies alright.

So, v equal to k into y is nothing but a mechanical law Darcy's law where you are using two mechanical energies equating them with each other. Now here, when you talk about thermal energy field the governing laws would be gas law.

$PV = nRT$

Fourier's law of heating and cooling and laws of thermodynamics and you must have studied this Carnot cycles, Carnot's engines. So, I think this concept can be utilized in finding out the thermal equilibrium between the soils and the water and the soil and the contaminants and so on. I hope you will agree that this is required to be studied by people in the long run is it not.

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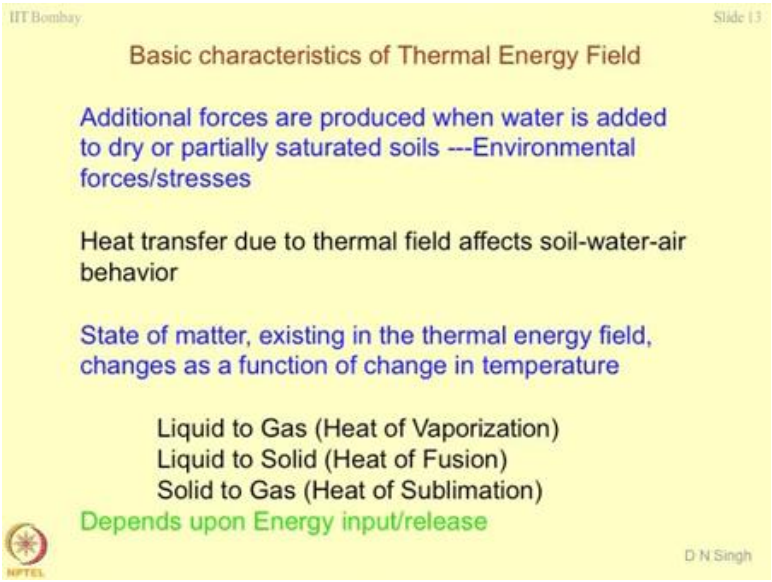

What are the basic characteristics of thermal energy fields, so this is very interesting I am sure you might have experienced also? There is some additional force which get developed because of you know thermal energy field exploration to the particles or the soil mass. So, additional flows are produced when water is added to dry or partially saturated soils and instead of seeing when you boiled milk, there is a skim formation and that is skim is the very dynamic process. So, the entire membrane keeps on showing lot of tension developing into the system, the same thing is happening in the form of surface tension on the soils also when you do shrinkage limit as cracking and all.

So, this basically indicates that because of the thermal flux the soil mass becomes very dynamic system and that dynamic system has to be studied to quantify what are the forces particularly in terms of thermal stresses which are getting generated in to the soil mass. So, heat transform due to thermal field which may affect soil, water, air behavior, because a common sense is there will be a dilation or volumetric expansion in all the three phases of the soil mass because of thermal field exposition.

I will be talking about these basics when I will touch upon the thermal properties and thermal characterization of the geo materials in subsequent lectures. So, state of matter which is existing in the thermal energy field will be changing due to the temperatures which are employed on this. The first phase is that liquid may get transmitted into or

transformed into the gaseous stage because of heating, so it is nothing but the heat of vaporization.

So, when you can find out the heat of vaporization of a material when it interacts with water or when it interacts with some contaminants, I can quantify this interaction you agree with this. So that means, heat of vaporization will be a good quantification of interaction between geomaterials and environment, the second is liquid to solid transformation. What is this known as? Heat of fusion.

So, people who are in atomic industry they are using this concept quite a lot, they amalgamate the entire waste under in-situ conditions it is a fusion process which is going on alright. And third one is solid to gases and solid to gases is known as heat of sublimation. So, there could be a situation where the entire waste can be sublimed into a gaseous form clear and these gases can be used for some other a specific industrial application.

So, basically this soil when depend upon the type of energy input or the release which is coming out of the system. So, when you say energy input and the release it becomes a reversible process, if I put the heat into the system it melts, if I take out the heat from the system it freezes; clear. So, that means, when I say liquid to gaseous and gas to liquid system it is just whether you are taking energy from the system when you are inputting the energy into the system. Composed layer if you compress it much more what happens? It liquefies; clear. So, liquefaction basically gives you low temperatures, so you can do air conditioning by this process.

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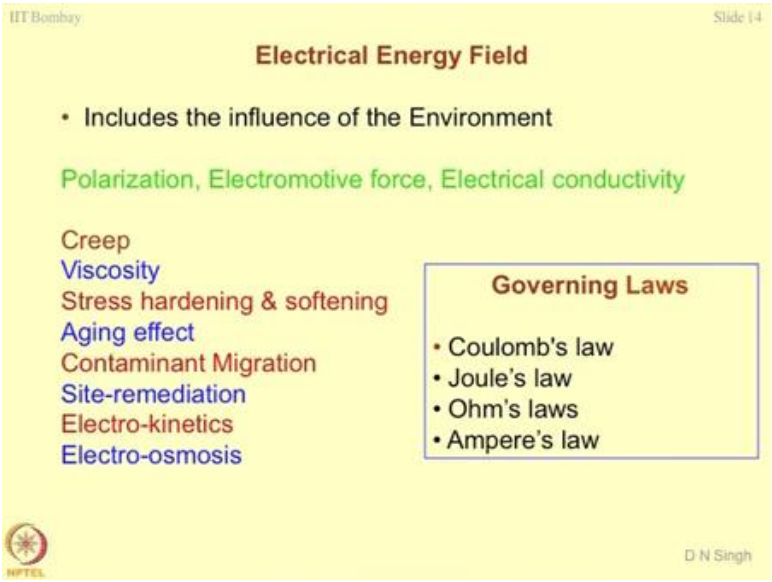

So, we can quickly cover electrical magnetic field which includes the influence of the environment as such means of the minerals which you have in the soil, they are magnetic minerals and hence they will create electric field. So, when you talk about polarization electromotive force, electrical conductivity this type of energy field become quite important.

So, particularly those who are studying creep, viscosity, stress hardening and softening, aging effect of sands, contaminant migration you might have seen we are using this concept site remediation particularly electro kinetics and electro osmotic process. Where you can use electrical magnetic field to decontaminate the soil mass by applying different type of electrodes and you can create a situation where all the contaminants may get collected into some zones. What are the laws we will be using for this type of modeling? The Coulomb's law, Joule's law, Ohm's law and Ampere's law. So, with the help of these laws you can deal with electrical magnetic fields and it is implication in geotechnical engineering.

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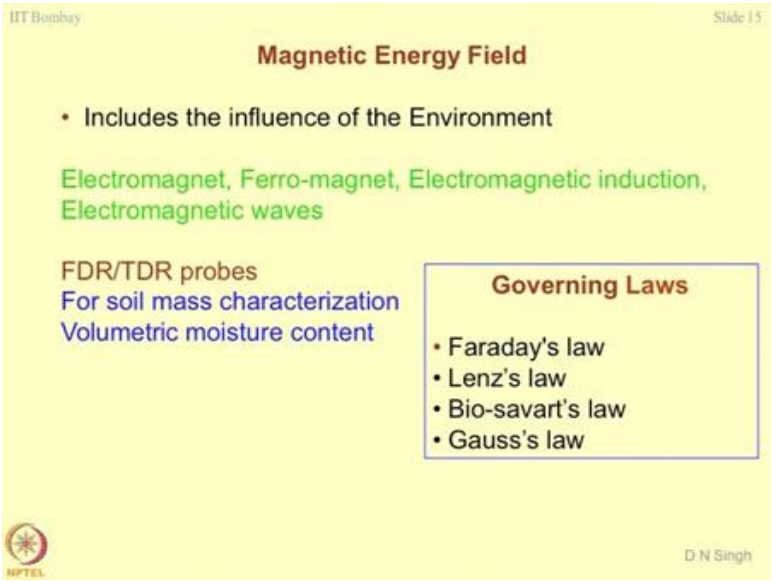

Then comes a magnetic energy field, of course, this is on the reducing order of the intensity of the effect. So, the most important effect is mechanical engineering followed by the thermal energy field, followed by electrical energy field, followed by magnetic energy field where again it will include the influence of the environment particularly if your minerals are magnetic in nature.

So, we talk about electro magnet, electromagnetic effects, thermo magnetic effects, induction, electromagnetic waves which pass through the soil mass. Based on these concepts we are using time domain reflectometry, and frequency domain in reflectometry probes. And the basic idea is using these probes is that you will not be characterize the soil mass for determining its volumetric moisture content. What are the laws which you will be using for governing this type of situations? Faraday's law, Lenz's law, Bio Savart's law, Gauss's law alright.

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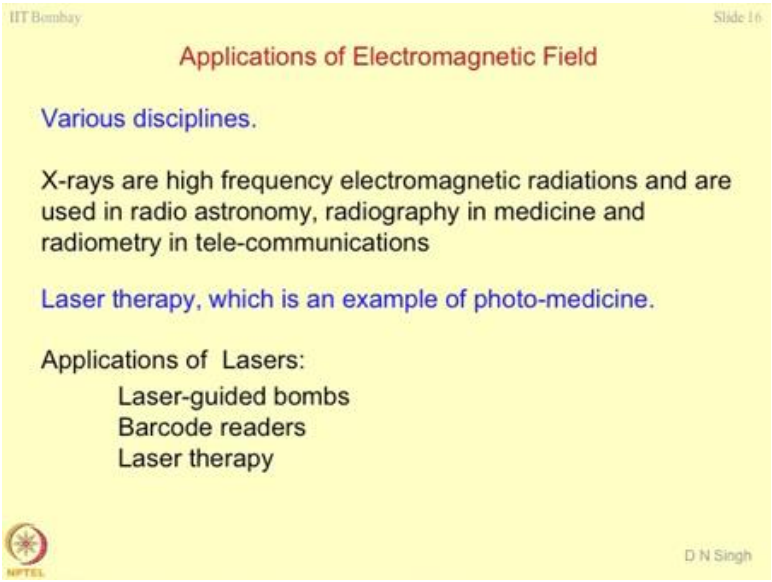

And what are the applications of electromagnetic field and various disciplines are X-rays which are nothing but electromagnetic ways are different high radiations. You use them in radio astronomy, radiography, medicine, telecommunication laser therapy is very useful which is an example of photo medicine. And application of laser beams is basically guided bombs, barcode readers, and laser therapy.

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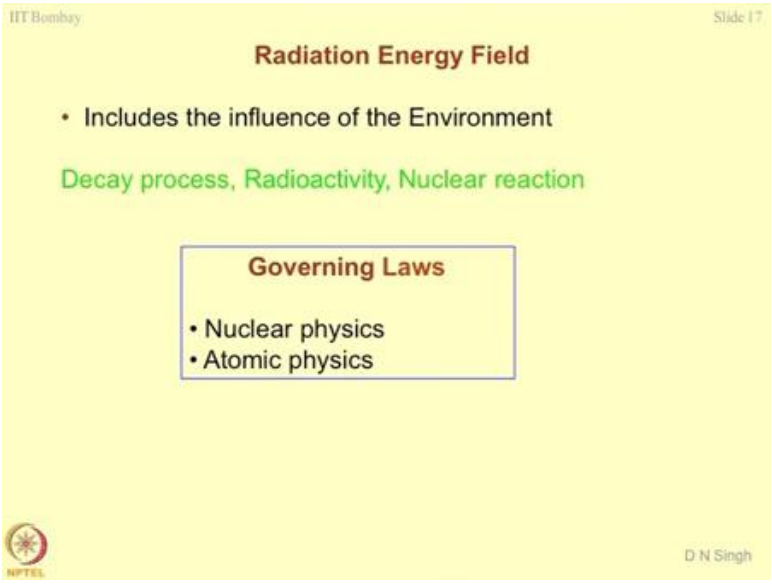

Well, radiation energy field does not much of influence and though it also includes the influence of environment basically it talks about decay, radioactivity and nuclear

reaction. This field is less exposed and explored till now and the governing laws should come from the nuclear physics and atomic physics, so ultimately having studied all these what is that we are trying to do.

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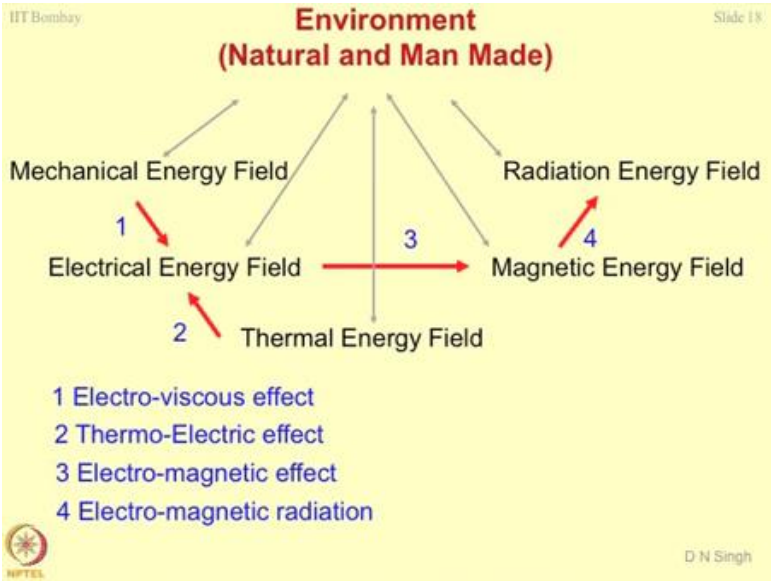

This is what actually we are trying end up, I hope you will appreciate that we talked about the environment which is natural and manmade where we have mechanical energy fields, electrical, thermal, magnetic, and radiation. Ultimately what we want to know? We want to study how these energy fields can be used in the best possible way to understand the response of geomaterials.

So, suppose you consider mechanical energy electrical energy, so there is nothing but a coupling phenomenon which is known as electro viscous effects. So, those of you are working in clay mineralogy, they use electro viscous effects to find out the double layer diffuse layer concepts and so on. If you put these two together in electrical energy field in thermal energy field it becomes electro thermo electric effects.

So, you can use one cause and one effect to see how thermal energy, electrical energy are getting influence with each other. Electrical energy, magnetic energy field is nothing but electromagnetic process based which are being used quite a lot in geotechnical engineering and geology these days. And magnetic energy field and radiation energy field will form electromagnetic radiations in which people are quite interested these days particularly in designing the atomic shelters during the war. This is where I will stop

today, I have given you lot of ideas about where the geo mechanics should head to in days to come and what is the role of people like us in developing the subject in more realistic manner.