Computational Electromagentics and Applications
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Lecture No 36
Algebraic Topological Method (ATM-I)

So far we have covered finite difference finite element finite volume methods and also some aspects of the have been covered we have been taught in schools and also in our under graduation and most of people also go through post graduation and research looking at electromagnetic purely from the field theory point of view there is nothing wrong in it but there is something different that we can do about it can we model electromagnetic problems using different set of tools there are different set of tools what they are and how one can understand the significance and also the practical use of such tools or any applications in engineering so that is the main theme half hour discussion today so we are going to go and look into problem specifications in electromagnetics but we are going to use a different set of tools. So what are these tools.

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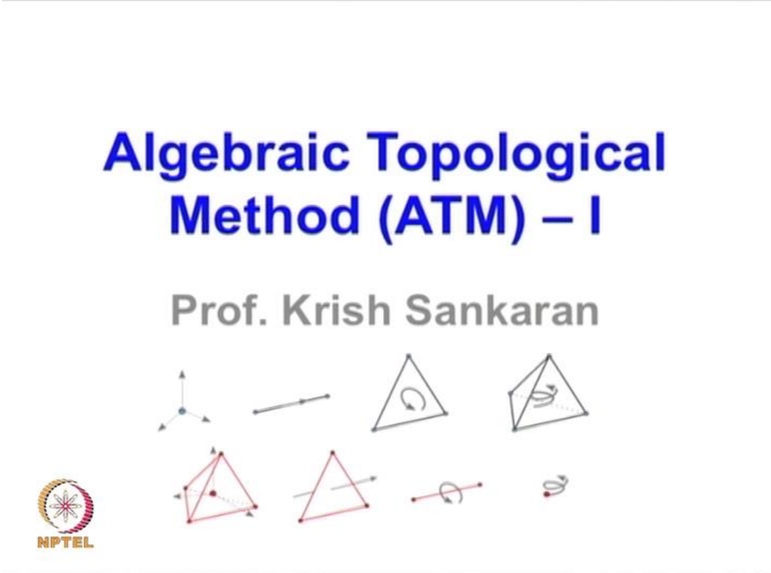

I call them algebraic topological method because it comes from a domain research called algebraic topology which is quite known to theoretical physicist and mathematician a large extent the domain of algebraic topology is unknown to engineers and practicing. Let’s say applied physicist community the reason is simple they have been using a set of languages which is quite difficult for engineers to follow and secondly its formulation is so heavy and complex that most of the engineers find it quite foreign. In some aspect they are even quite put down by the idea of looking into it seeing the practical value of it so in this chapter what I am going to do it I am going to make it as simple as possible using simple words simple words in the sense simple concepts and simple ideas that are known two engineers and based on that I am going to build the idea so the entire tools that is called the algebraic topological method.

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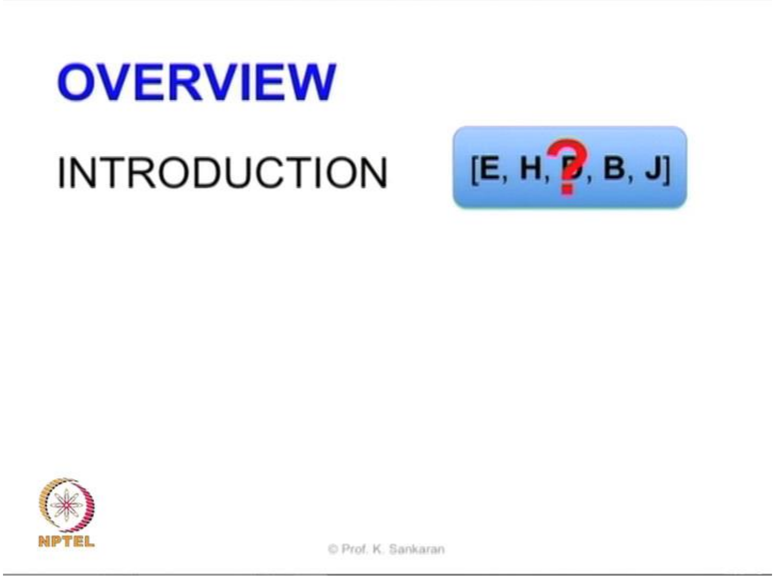

so what you are going to look into it is the question of what is the definition of field and why do we need it and basically questioning also the need for using fields like electric field magnetic field density field and so on and so forth so basically we are going to read analyse are fundamentally ask the question what is the need of going into the field theory or using the vectorial notations and vectorial calculus.

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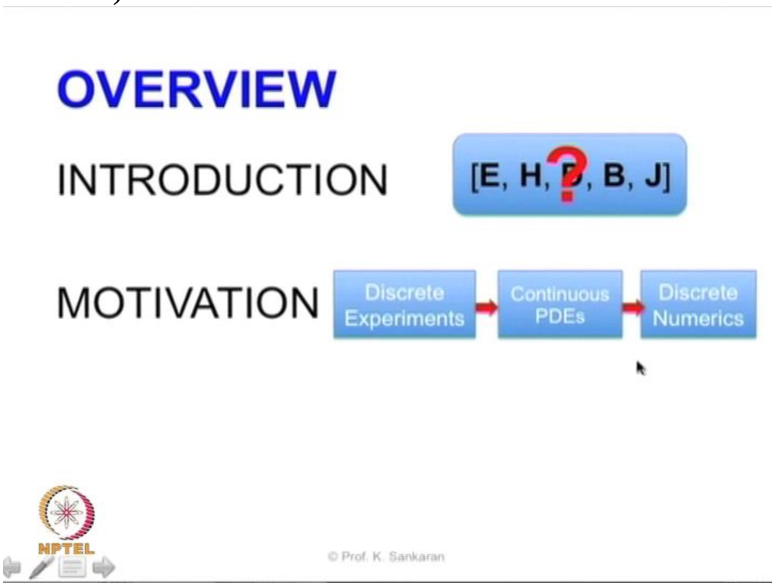

The second thing is we are going to set the basis for our algebraic topology kal method in other words the motivation are going into the algebraic topology kal method as you might know most of our experiments have discrete set of measurements and from the discrete set we going to continuous field continuous domain where we use partial differential equation to model those physics and then when we do numerical methods computational electromagnetics to be specific we tried to go back again to the discrete domain so the basic question is what is the need for this continuous PDEs.

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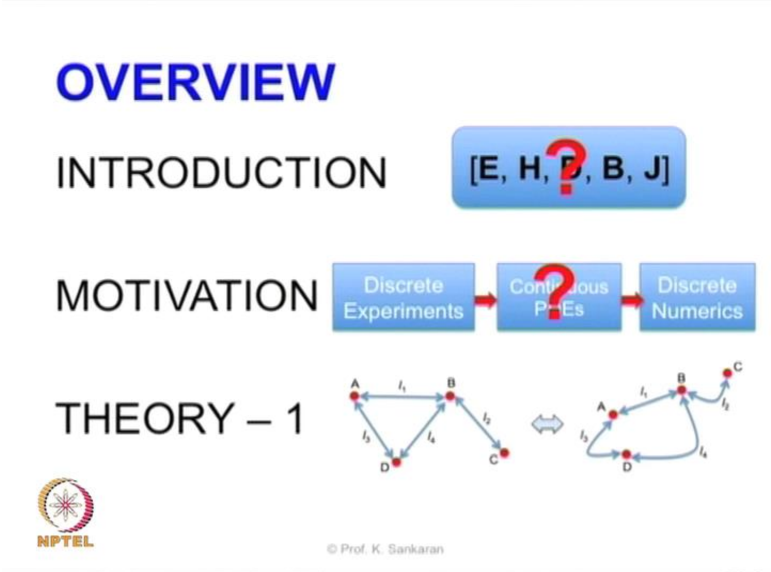

And finally in this first set of module we are going to look into the basic theory behind algebraic topology in specific we will look into some of the key definitions that we will be using in modelling electromagnetic problems with that being said let's start with the introduction

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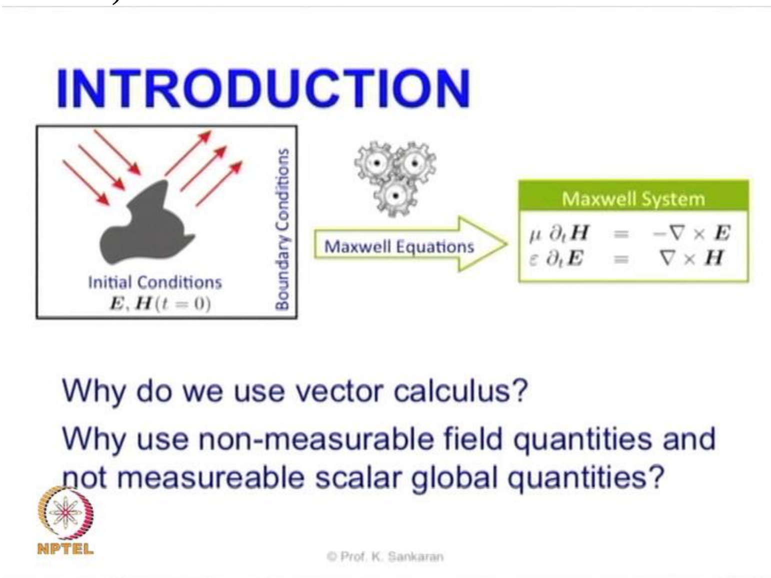

So you might know that any electromagnetic problem let's say we have a set of fields given we call them as initial conditions at time equal to zero and we have certain boundary conditions also given and based on that we try to solve our usual Maxwell equation. So the question here is we are basically using E and h vectors and again E and H they are vectors so always we are going into vectors and secondly we are using the vectorial Calculus and partial differential equation to model the Maxwell equation fundamentally the question is what is the need for or why do you always use vector calculus in other words what is the need for vector calculus this question arises from the fact that most of our measurements in fact in the case of electromagnetics Oliver measurements are scalar quantities whether it is current voltage fluxes whether it is magnetic flux or electric flux they are all even potential for the matter of fact they are all scalar quantities and we can't even measure electric field magnetic field directly we can deduce them mathematically.

So if that being the case why do we start with factorial notation and vectorial calculus and the second question that we try to ask his as he said most of our measurements are based on scalar quantities why do we normally go for vectorial quantities the second question is very much related to the fact that we can only reduce them but not measure them with that being said this is the basic questions you have to try to understand before we going to modelling the entire electromagnetic equation using scalar quantities the real reason is we have been asked or we have been thought to use vector calculus because the domain of electromagnetics is dominated by mathematician's in the early stage of its development example Maxwell himself who is a mathematician by training and they have well defined and also elaborately developed the theory of differential equations and the vector calculus basically can be applied or used along with PDA a differential equations in a much more natural way and you can do a lot of those magical manipulations like you know tending to infinity attending 20 and how you map differentiability what are the requirements of the differentiability so on and so forth although you might know that in reality this might not the case for example parameters there might be discontinuous field.

So in these kind of situations the artificial Limb postman tour all the artificial constraints on differentiability continuous differentiability they are only mathematically needed because you can only use differential equation or vector calculus under those conditions. So that being case there is no real physical reason behind calculus for differential equation the reasoning is poly mathematical because those mathematical tools has been already developed it's easy for us to take them and use them but nobody have really asked the question is it fundamentally the need I mean that being said in the last 5060 years there is a group of researchers from network theory and also secured theory they have started using they have been using algebraic topology one way or the other but they have been quite an arrow set of researchers. So the entire Idea didn't really get Momentum across electromagnetics community in general

So that is one of the main introduction that I would like to give and with that introduction we will look into the motivation that we have to built for going into this particular set of problems. So let’s go into the motivation.

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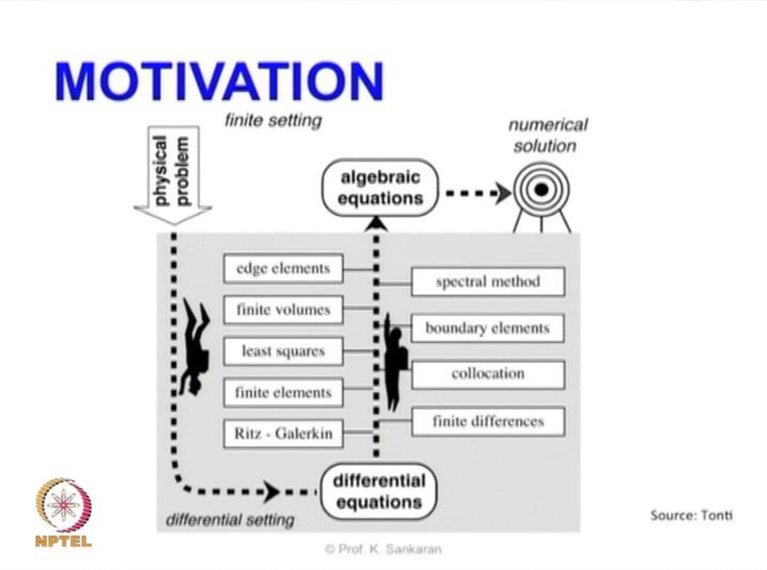

So let’s go into the motivation the motivation is we have a physical problem and this physical problem is defined or basically available from experimental measurements or you know experimental facts once we have this physical problem we are trying to model this physical measurable into differential equations which is again in the differential settings this is in a continuous space once we are here we get back from differential equation to difference equation which is basically the algebraic equation using one of those methods that we have already studied either finite difference method or co-location boundary elements spectral method as element finite volume so on and so forth.

So its like if you see this as an ocean you are jumping deep into it and then going back again to a surface this is fundamentally a flawed assumption this assumption can be question by changing the view of setting the problem at the first place.

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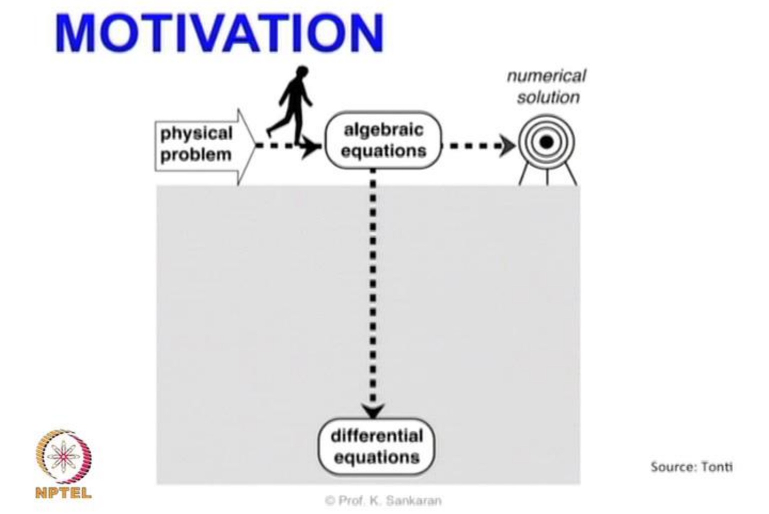

So what you are going to do now is we have a physical problem which is based on discrete set of measurements from here we are going directly going to the algebraic equation is also in the discrete set of equations and then directly get numerical solutions so what does that mean what we mean here is

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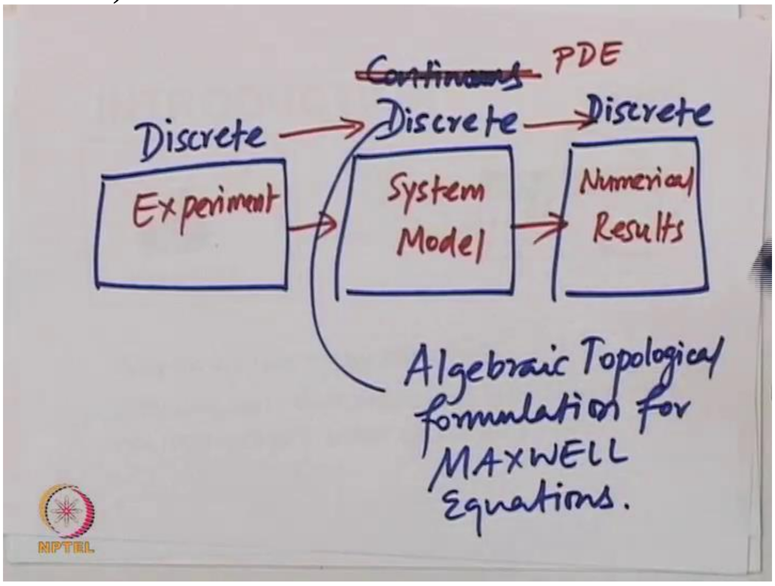

So we have 3 set of planes one is experiment we have here a system model and then we have numerical results so the earlier approaches given discrete this could be continuous or discrete this is always discreet so what you are doing now is we are not going to take the PDE root which is here we take a discrete route and is discrete route what we will get here is basically the algebraic topological formulation for Maxwell equation so what we need is finally to get the algebraic equation that we can numerically solve or computationally solve using a computer. So if this is done we are able to do the same thing what one can do in the case of finite volume or finite difference or finite element methods so with that as a basis for the motivation and roll we are going to go and look into the nitty-gritty the fundamental theoretical framework so we will look into some of the concepts that are needed for a us 2 model these problems using discrete set of equations and also using only scalar quantities so we are going to learn some or learn in fact I should use the word relearn some of the definitions of field quantities using our new set of tools so with this motivation we will go into the next module thank you Good Bye!