Computational Techniques

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Module No. # 01
Lecture No. # 01
Introduction

Hello, my name is Dr Niket Kaisare from department of chemical engineering at IIT Madras and I am going to deliver essentially 40 lectures series on computational techniques. This topic is also known as numerical methods. In the first module basically, I will give the overall introduction to this particular topic.

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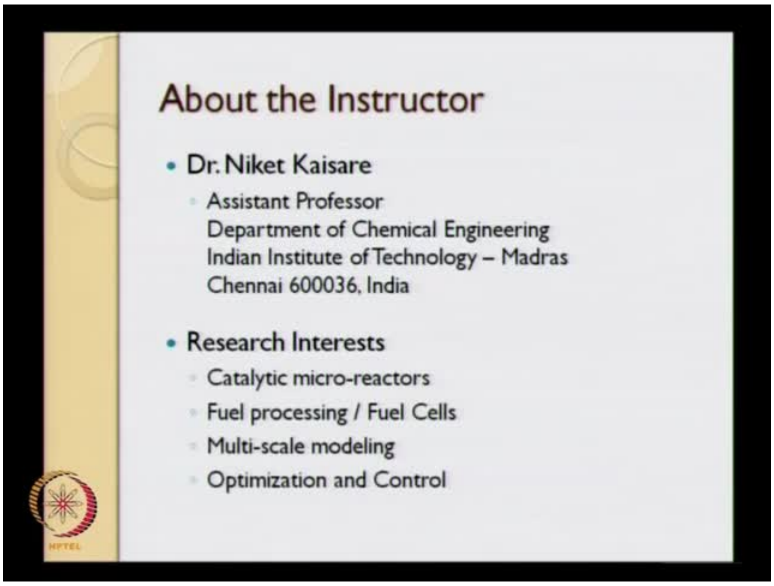

So, first let me just give you some details about myself. My name is Dr. Niket Kaisare as I said; I am from chemical engineering and my research interest essentially involves looking at catalytic micro-reactors, fuel processing/fuel cell system, multi-scale optimizations, multi-scale modeling and process control. So, essentially what I do for my research is look at models for various small scale systems and basically I use computers in order to get the results numerically from these systems.

So, one of the most important aspects of my research is using these numerical methods within a computer framework in order to understand, how the actual systems behave in the real life. So that is the kind of research interest I have and that is really the background, why I am doing this computational techniques course. This computational technique or numerical methods or whatever you would want to call it essentially they are ways to do the computation, which are otherwise tedious; we can use the computers in order to do simplify the job for us and their popularity essentially has come out because of the popularity of computers and cheap computing.

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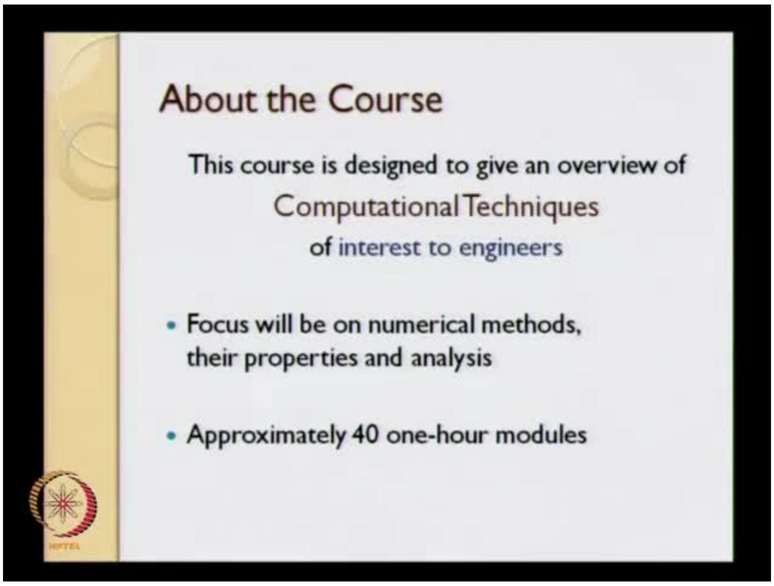

So, about this course; again, this course is designed to give an overview of computational techniques of interest to engineers; so, that is really the key word over here. Numerical methods or computational techniques have been used in various fields not just in engineering. For example, forecasting of the weather patterns that requires solving very large scale differential equations and it requires really fast computing and really the numerical methods or computational techniques are at heart of these different models. Likewise, let say us stock predictions, lot of these trading companies they decide what stocks to buy, how to make the investments, and so on based on prediction of how the markets are going to behave. So, the numerical techniques are used over there as well.

Another example, where numerical techniques are used; for example, let us say an industry wants to decide, how much raw material to purchase, how much product to manufacture, and so on and they will essentially create what is known as a supply change management problem. And at the heart of those problems again, really when you go down to the lower most level of it again, you will have these numerical techniques. We need these numerical techniques to efficiently solve these models in order to understand, how the system behave in order to optimize, how the system behave in order to control at the heart of these control techniques also go these modeling methods and these numerical methods which we will then solve in order to make decisions on what to do.

So, the focus of these particular lecture series will be on the numerical methods, their properties and analysis; the focus will not really be on the applications of these numerical techniques; the focus really will be on using this numerical techniques, understanding these numerical techniques and trying to see what properties they have, how they behave.

So, we will essentially take simple examples in order to understand the systems; we are not necessarily going to take chemical engineering examples, but these examples are going to motivate what these numerical techniques are or this computational techniques are, what are their properties, when can be apply them and how can we apply them?

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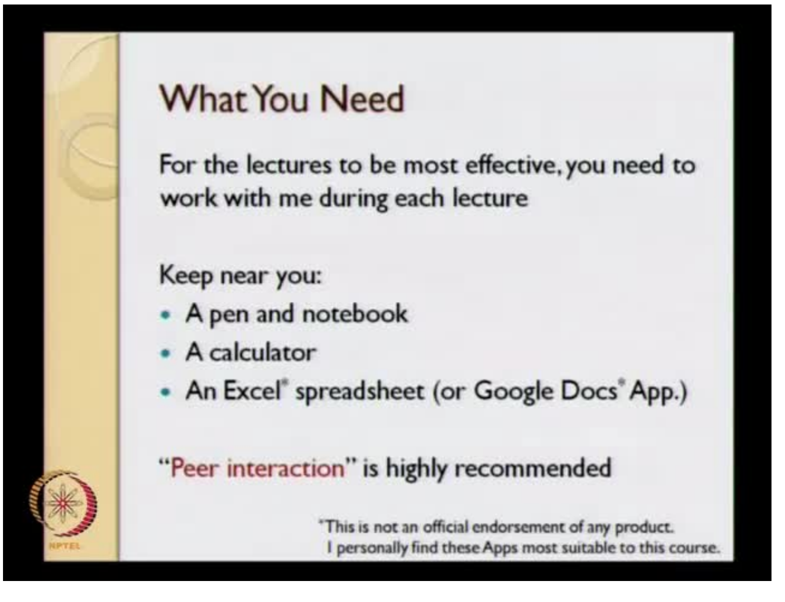

This course will be divided into approximately 40 one-hour lectures and that is the overall number of lectures I plan to cover and essentially what you need to get the best out of these lectures is essentially to work with me during the lectures.

So, what I will try to do during each lecture is you know, I have certain example problems, where perhaps, if you are watching this on YouTube or something like that, you can just click on the pause button and try to solve this particular problem along with me and then see once the problem is solved, you can compare the results that I have gotten with the results that you have got.

If that is the way you proceed, it will be very beneficial these overall lecture series; these lectures are essentially meant for second and third year undergraduates students BE, BTech students in their second and third year. So, I do not assume any sort of background; the background that I assume is essentially 10th and 11th grade mathematics. You should be familiar with and you should be able to use a calculator and spreadsheet, such as Excel and if you do not have an Excel that is not a problem; you can also use the Google docs application; there is a spreadsheet in Google docs that is available.

So, we will really require a pen, and note book, and a calculator to do those hand calculations and an Excel spreadsheet and Google docs in order to solve some of these relatively simpler problems. But still something that cannot be solved using a calculator; you will need this spreadsheet in order to solve that and my final point is what I have found is the learning is enhanced if people are not doing it on their own, but along with a couple of friends. So, if you have a couple of friends, you have the same goals in understanding numerical techniques, and so on; you can always work with them and try to understand some of these things together.

So, these are general suggestions for students, who are essentially in their second or third year. If you have already gone through a course in computational techniques or numerical methods or whatever they might call, you can just go right ahead and view these lectures.

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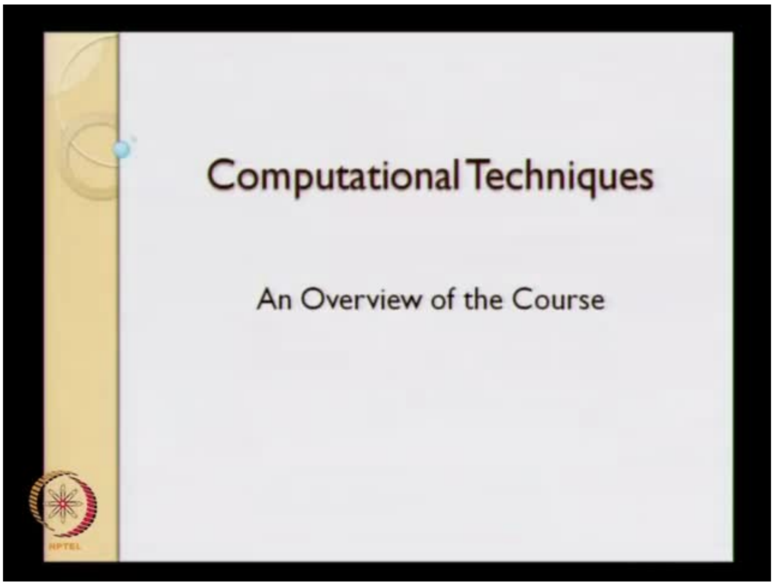

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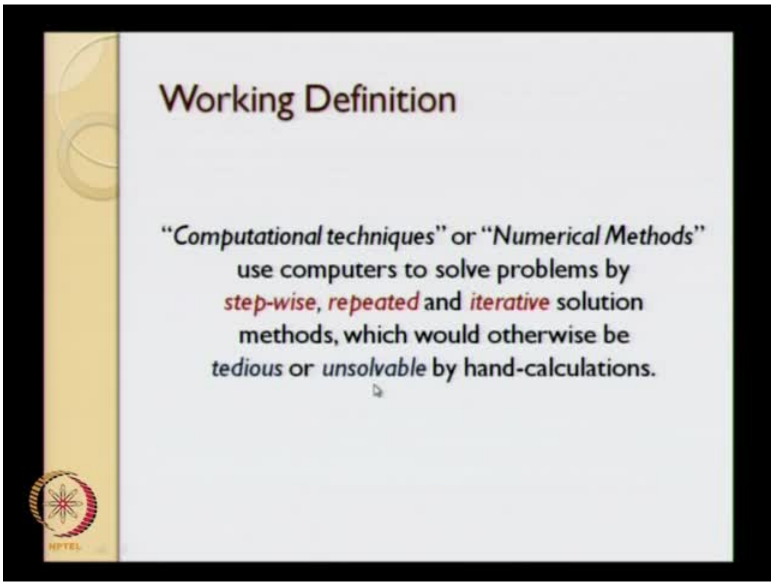

So, now, let me give you an overview of the course; what we are going to cover in this course and how we are going to go about it and so on. Before I do that, I will give a working definition of what we mean by computational techniques.

Again, the word computational techniques, numerical methods, numerical techniques or computational methods are really used interchangeably by people. So, at the heart of these computational techniques are essentially computers that we are going to use to solve problems. These are the kind of problems, which its fairly difficult or perhaps, impossible to solve it analytically; you have to take a pen and paper, and try to algebraically or geometrically try to solve these type of problems its perhaps, difficult or impossible to do it.

So, we are going to use the computers to solve these problems by step wise, repeated and iterative solution methods; so the solution methods are essentially going to be repeated. So, what that really means is that if you have a small problem, you will use the solution methods, the algorithm steps you will use one or two steps in order to solve a small problem; when you get to a larger problem, you will have to repeat those two or three steps over and over again, until you reach a particular predefined criteria, which tells you that yes, now, I have got the solution of this particular problem.

Again, what I mean by that, I will come to that in this lecture; I will take a very small example and I will come to that aspect. And it is a step wise procedure, that means what you want to reduce the overall system to is a system of it is an algorithm of various different steps that you need to carry out one after the other and that is what makes it very amenable to putting it in a computer and using those computers to solve the problems. And these are methods, which would otherwise be either tedious or unsolvable by hand calculations.

And just to give you an example, if we are going to talk about say the models for solving the overall climate models essentially to see, how the global warming is going to affect the overall system. In that particular case, these models have millions of equations; you know, you can perhaps, solve one or two or three equations with hand, but you have a million coupled highly non-linear equations; it is going to be very difficult to solve or not difficult. In fact, in pretty much impossible to solve those equations by hand and what you will then need to do is use those computers to do these calculations, which are otherwise tedious or unsolvable by humans.

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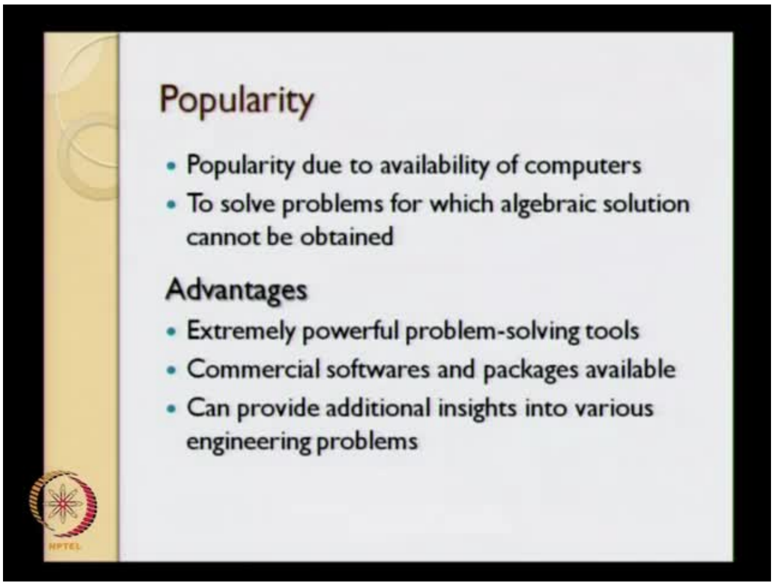

So, again, I had mentioned right in the begging beginning, the numerical techniques or computational techniques became popular because of availability of cheap computing. So, over about the last 25 years or so essentially computers have become very inexpensive and pretty much, every home has a computer these days and essentially that is what has led to the popularity of these computation techniques.

They are useful to solve problems for which algebraic solution cannot be obtained. For example, if you have a complicated set of equation and you want to find the roots of that particular equation, it is sometimes it is easy to use pen and paper to solve them; sometimes it is not all that easy to use pen and paper; in that particular case, you will use these numerical techniques in order to solve them.

The several advantages of these numerical techniques are that, first they are extremely powerful problem solving tools; just the example I took a couple of minutes back the climate models. These climate models would be impossible to solve, if we did not have extremely powerful problem solving tools and extremely powerful computers, where we can solve them.

So, both of these conditions are perhaps, necessary conditions for us to solve these complicated types of problems. The second advantage is that the commercial software's and packages are now a days readily available, which are suitable for certain type of applications; they may need not be general purpose. And the final advantage of these numerical techniques is that they can provide additional insights into various engineering problems. For example, how you can provide insights is, you solve this particular problem using some of these numerical methods and you tweak these problems in order to understand what are the physical reasoning behind, how these particular equipment or that particular reactor behaves.

So, what really the numerical methods allow you to do is they allow you to look at your experimental system in a more closer way and try to understand why the system is behaving in a particular way and try to analyze all those results in a better manner.

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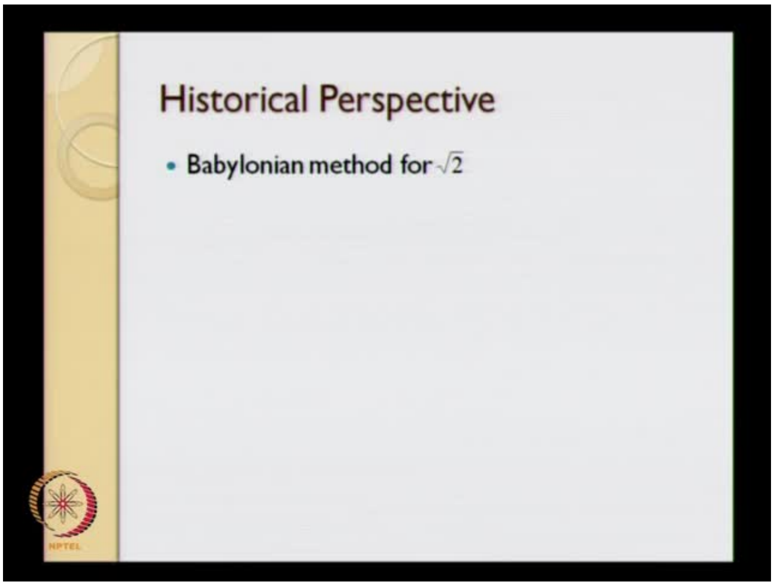

So that is what really the aim of using a numerical technique is going to be; that is not something that this particular course is going to focus on; we are going to focus on understanding these numerical techniques itself. Now, I will just give you a historical perspective of behind these numerical techniques. So, although the popularity of the numerical techniques can be essentially be attributed to computing and computers, but the use of the philosophy behind numerical techniques comes almost 2000 years before even the first computer came into existence.

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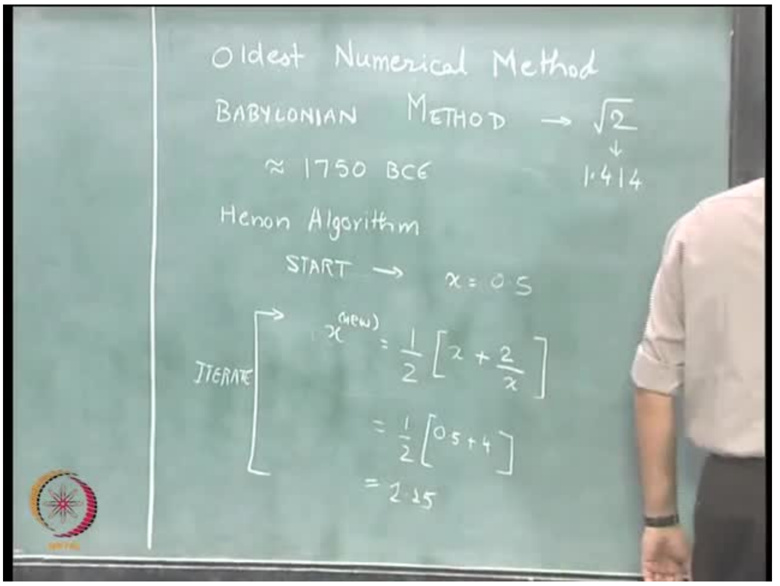

And perhaps or arguably the oldest numerical method is perhaps, the Babylonian method to find square root of 2, Now a days finding square root of 2 is fairly simple; what you do is you take a calculator and just punch a couple of keys and you will get this square root of 2. If you go back, this is about approximately 1750 BC; if you go back essentially 2000 years rather 3700 years back that was a time when these guys developed an approximate method for finding the square root of 2, and the method that we can also called as the Henon algorithm is goes like this.

Let us say, we will start with some approximation of… we will call this particular variable as x. We will start with certain approximation say x equal to 0.5; we do not know the actual value of square root of 2, but we know that the square root of 2; one of these square roots is going to be positive. So, we will start; let us say with an approximate value of x equal to 0.5. So, the method that we will use is x new, that is, the new guess of our x value is going to be an average of x and 2 divided by x.

So, for example, if we start with x equal to 0.5, what we will get is, for x equal to 0.5 half of 0.5 plus 4 2 divided 0.5 is 4; so our new guess is going to be 2.25. Now, remember, the solution of square root of 2 is approximately 1.414. If you look at this particular value or if you look at this particular value both these values are pretty far away from the actual value of 2 up to 3 digits after the decimal; we can say is 1.414 and neither of these values are close enough to the actual value.

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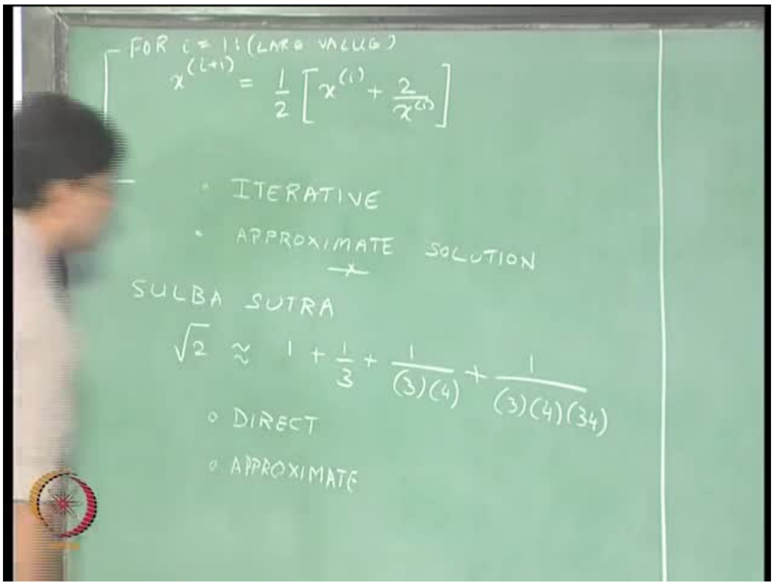

So, what do we do? We take this x new value and repeat this particular procedure over and over again. So, we iterate; this is what we call by iterating over this particular equation and we do that repeatedly, until we get the actual solution. So, now, what happens is, what we will rewrite this equation as x i plus 1 equal to half of x i plus 2 divided by x i.

We are kind of, trying to write it in an algorithmic form and then we will repeat this for i equal to 1 to some large value n and this overall process is what is known as an iterative method, and it captures the essence of all the numerical techniques that have come after or beyond this particular point. This particular method is 1, it is iterative; the second thing is that, this method gives you an approximate solution. The solution that we are going to get for square root of 2 is not going to be an exact solution, but it is going to be an approximate solution.

Now, we can specify up to what level we want to go, when we want to solve this particular problem and based on those specifications we will get this particular approximate solution at certain point we will say, well we are going to be happy with this approximate solution because we do not care about the say the 10th digit after the decimal point.

So, we are essentially going to say, we are going to be happy if we get the solution accurate to the 10th decimal place. I will take this example again, in a couple of minutes, but let us proceed with the overall historical perspective about square root of 2, what the Henon algorithm is it is an iterative algorithm and it gives you an approximate solution.

In India, we had this Sulba Sutra it came independently and approximately 1000 years after the Babylonian method and according to this Sulba Sutra, square root of 2 is approximately equal to 1 plus 1 by 3 plus 1 by 3 multiplied by 4 plus 1 by 3 multiplied by 4 multiplied by 34.

So, this was this Sulba Sutra it came approximately in 600 BC and this is the approximate value of square root of 2 that the Sulba Sutra gives you. Now, this particular method is what is known as a direct method; why it is direct is, because there is no iteration; you are not going over this particular equation again and again, you are taking one equation plugging in those values you will get the final solution and that is why it is a direct method, but again the solution is not a true solution, but it is only an approximate solution.

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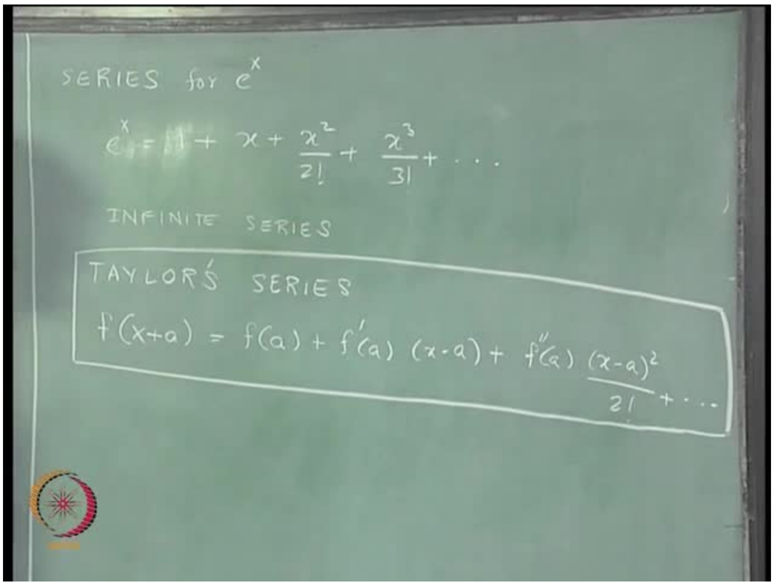

So, these are the couple of methods that have been proposed for finding this square root of 2, which are kind of familiar to the numerical techniques that we look at these days. This is basically a series and we are essentially aware of say, infinite series such as the series for finding e to the power x and e to the power x is 1 plus x plus x square by 2 factorial plus x cube by 3 factorial, and so on, and it is an infinite series. And we can essentially use this particular series; we can essentially keep adding additional terms in this particular series and we will get the result to be closer and closer to e to the power x.

So, when we chop off this infinite series at a certain point, what we will get is, we will get an approximate solution. So, the Sulba Sutra is not an infinite series, it is a finite series and that is why the result that you get is an approximate, but it is still a direct result, but the methods that are going to use infinite series, which we will look at during this particular course. We will end up getting an approximate solution, but we will have to iterate on this infinite series or each time add an additional term in this infinite series and decide, whether we are happy with the quality of the solution or whether we need to proceed further and further with additional terms.

And the most popular infinite series in this particular course is going to be the Taylor's series. I will just write down the Taylor series is f of x plus a, where x is going to be a variable and a is some particular value that we are chosen is equal to f of a plus f dash of a multiplied by x minus a plus f double dash of a multiplied by x minus a square divided by 2 factorial, and so on, and that is also an infinite series, where f of x plus a is found out as a some of these various terms, which involves the functional value evaluated at point a and the first differential, second differential and so on and so forth evaluated again at point a. The Taylor's series is going to be our work (( )) during this course; we are going to use it extensively in order to understand these numerical techniques, what they are they are they are going to be and we will come across this Taylor's series pretty much again and again in every module in this particular course.

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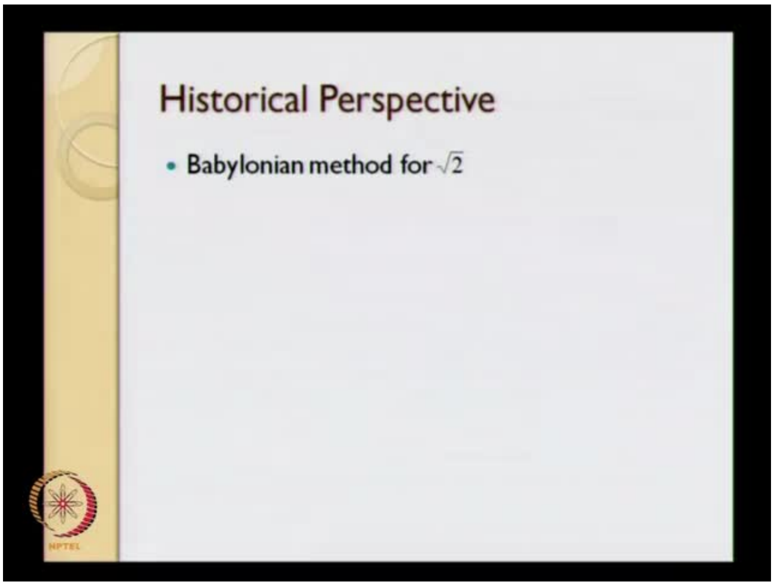

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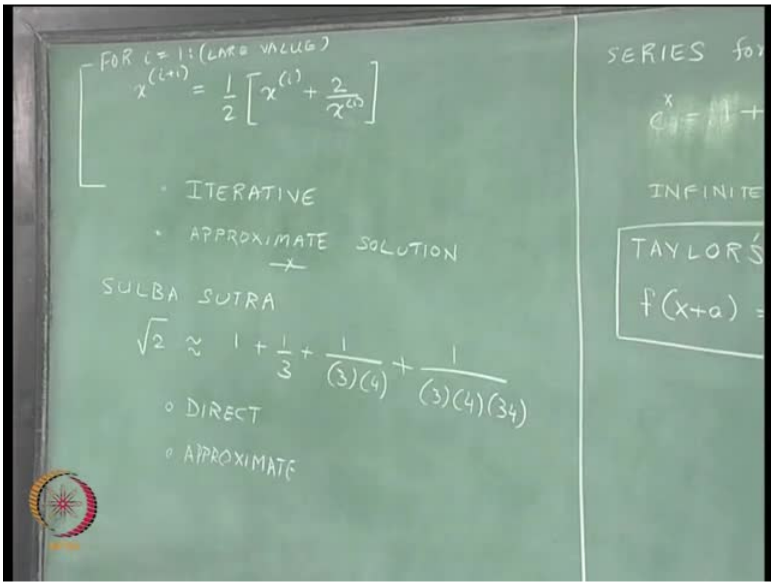

So, again, with respect to historical perspective just to summarize what we get from the history about square root of 2 is that the numerical methods are going to give us approximate solution to the real problem. And second is they are going to be either iterative methods or direct methods direct; methods means that is at certain point of time we are going to stop with the solution and we will get perhaps, the true solution or an approximate solution. Iterative method means we are going to repeat that particular problem, repeat that particular procedure over and over again in this particular case. The procedure was very simple, very straight forward; just take an average of x and 2 divided by x it is and that is how this particular method worked.

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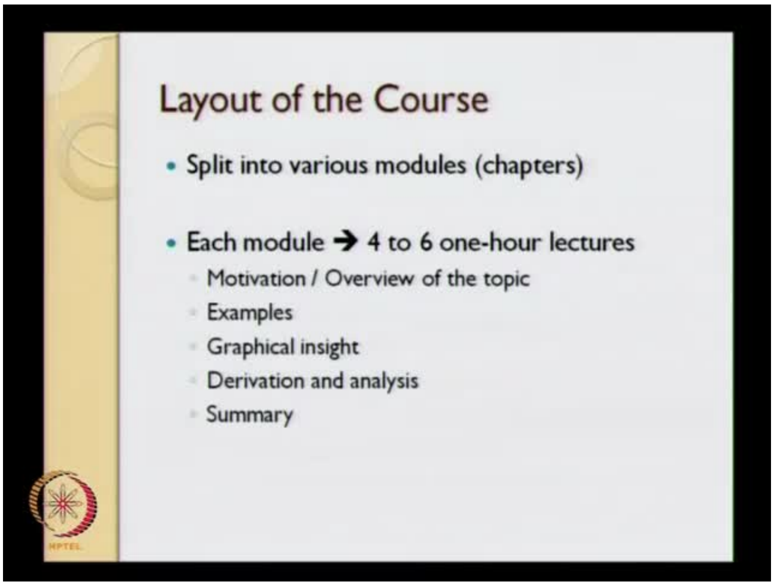

The layout of the course is that, course will split into various modules; each module you can think of as a chapter in a textbook and it will covered in about 4 to 6 one-hour lectures. Each lecture, we will go over the various aspects, such as the motivation and overview of the topic, then we will take a couple of examples; we will get a graphical insight; we will derive the overall equation, analyze them; try to understand, how this particular method works and finally what I will do pretty much in the last half an hour of each module is, in the last lecture of each module for about half an hour, I will spend to summarize what we have covered essentially in that particular module. And what I will do is, let I will just go over, how each of these items with can be covered for the Henon algorithm that we just looked at for finding square root of 2.

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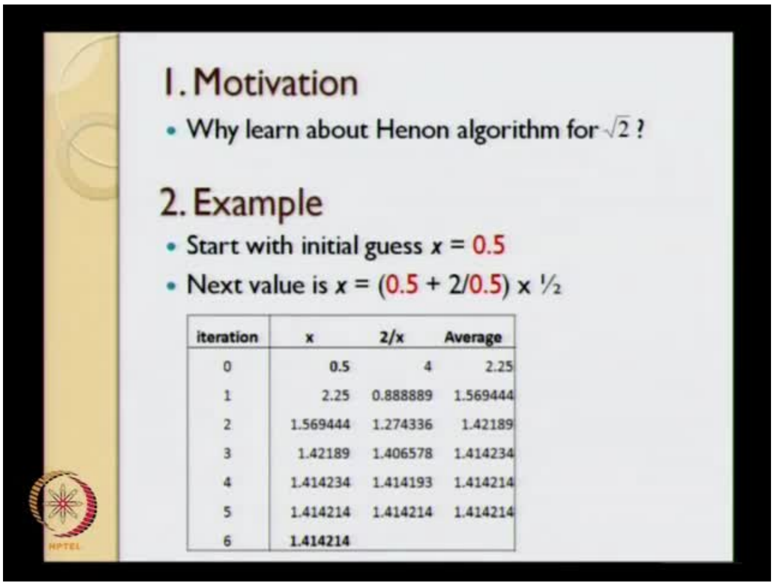

So, the motivation is essentially why learn about the Henon algorithm itself and the reason for talking about Henon algorithm are essentially two fold; one is because well history is interesting and we are trying to put things in perspective of essentially what people before us thought about, how to solve this particular problem. The second reason for this is that it really is one of the first or perhaps, the first numerical method and using this particular simple example, poses us very nicely in order to talk about these numerical methods itself. Then we took that example, we started with the initial guess of 0.5 and again, we calculated the next value x equal to 0.5 plus 2 divided by 0.5 the average of that multiplied by half and the next value.

So, what I have done is I have used an Excel sheet over here and this is just a result from the Excel sheet. The first column is the iteration - number of iteration, 0th iteration essentially signifies that was the initial guess that we started off with; the initial guess that we started of with was x a over here, I am writing 2 by x and the average of these two numbers I am writing in the 4th column. The numerical method tells us essentially x is going to be the average of x and 2 divided by x; so that is new value of x. So, you have taken this particular value and put it over here; we started with 0.5 the average of 0.5 and 2 by 0.5 is 2.25; we took that 2.25 as the next guess.

So, the next guess after that is going to be 2.25 and 2 divided by 2.25; we take the average of these two numbers and the average of these two numbers happens to be 1.569.

So, this average is going to be the value of x at the second iteration and we continue this over and over again until a certain point. In this particular case, I have done the Excel simulations up to iteration number 6, what we see over here is the first value was of x, the first initial guess of x was 0.5, the second initial guess was 2.25 both these values are quite for away from the actual solution 1.414214.

The third value comes fairly close; we reach 1.569, the 4th value is even closer 1.422 1.414, 1.414, 1.414. In this particular example, I was interested in getting the result up to 6 digits after a decimal point and that is why when the 6th digit after the decimal point did not change; I said, I am going to be satisfied with my solution and I take the value of x that I obtained in the 6th iteration as my solution.

So, this particular example has all the features essentially of the numerical techniques that we talked about. It is an iterative procedure; it is the same simple equation that we apply over and over again in order to get the solution. We start with an initial guess and slowly converge to the desired solution and we define a stopping criterion, where we are going to say that the solution that we now have we are satisfied with.

So, this is the way we would do the findings of square root of 2; if you were to use a Henon algorithm and formalize it under the computational technique frame work that we are going to use in this particular course.

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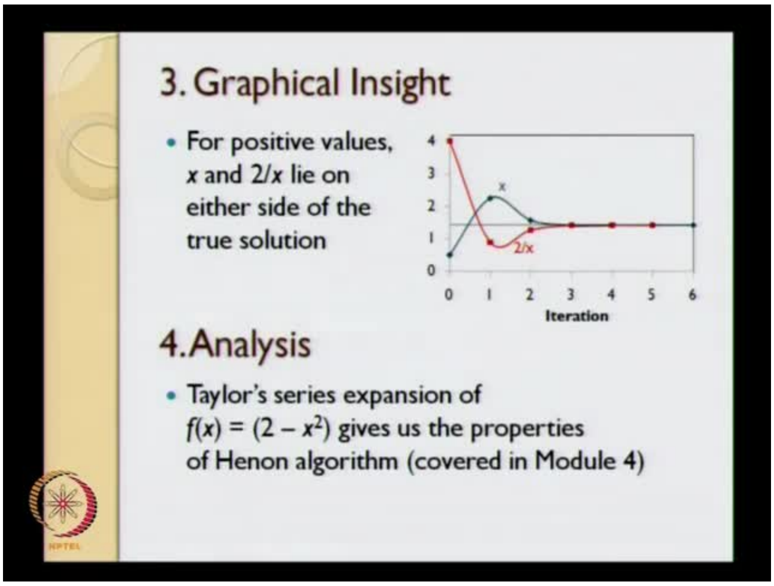

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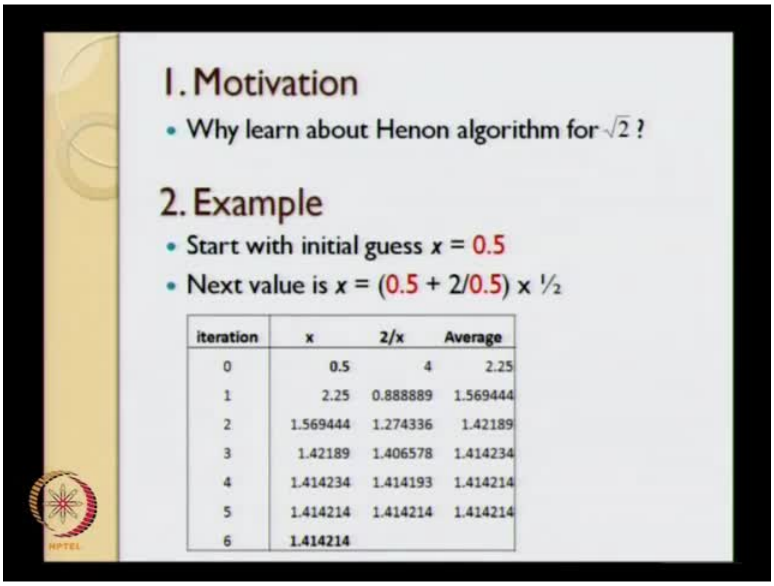

Now, let us look at the graphical insight; what I show over here in the blue curve over here is essentially, how the value of x behaves. So, if I go back to the previous slide, this value of x I am plotting as the blue curve and this value 2 divided by x, I am plotting as the red curve over here. So this is the blue curve, this is the red curve defining x and 2 divided by x. The x axis is the iteration number; 0th iteration is the initial guess, first iteration, second iteration and so on.

This particular x value, the x value at iteration number i, is thus the average of this red value and this blue value in the previous iteration, and this black line or thin black horizontal line that you see over here is the true solution of square root of 2. you What you find is an interesting thing and again this is where the history becomes very interesting is, if you want to see, why perhaps, if we want to go back and think about why the Babylonian people thought about this particular algorithm is essentially if you look at x and 2 divided by x they lie over here; they are lying on either side of this particular line.

So, if x is less than square root of 2, 1 by 2 by x is going to be greater than square root of 2 over here; from this value of x, the value, next value of x has gone to 2.25. So, the value of x now is greater than square root of 2, but value of 2 by x you will see is less than square root of 2 and you will see this pattern repeating throughout the over the overall values.

No matter, what positive value of x you choose; the value of 2 divided by x is also 1, it is also going to be positive, and second it is going to lie on the other side of the line square root of 2. So, essentially what we are doing over here is, we are hoping that if we take the average of x and 2 divided by x; we will go closer and closer to square root of 2 and the reason is that the average of x and 2 divided by x always lies between the values x and 2 divided x and these two values will eventually converge to the desired solution.

So that gives us the graphical insight behind this Henon algorithm and possibly trying to think about, how or why the Babylonian people perhaps, thought of this particular algorithm in order to solve this particular problem.

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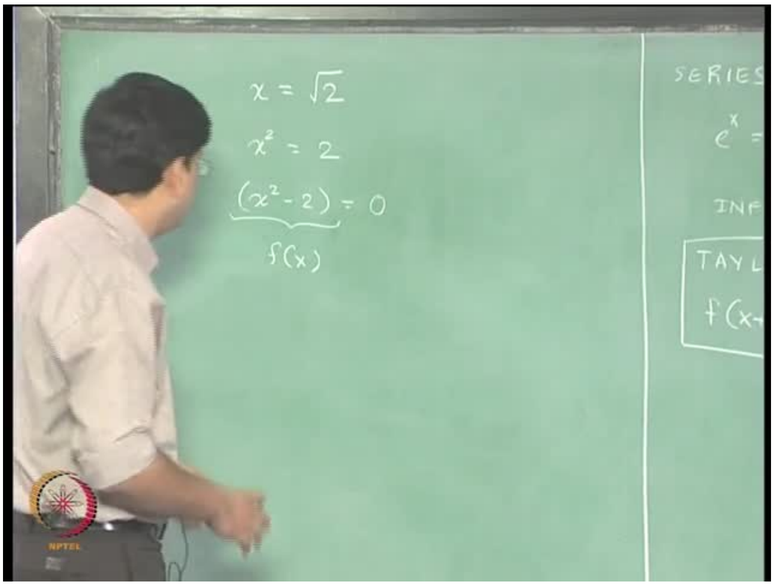

Next, what we would do? And again, I am not really going to do it in this particular module, but we will defer it to the 4th module is we will do a Taylor series expansion and try to find out, how this particular Henon algorithm can be derived in a regress manner. And I will just give you an overview of what we are going to do is essentially we want to find the solution x equal to square root of 2.

We will square both sides and then we will able to write x square equal to 2 and that equation, we can write that out as x square minus 2 equal to 0; if we call this particular guy as our f of x; this problem has now, reduced to finding out where the particular line f of x is going to cross the x axis.

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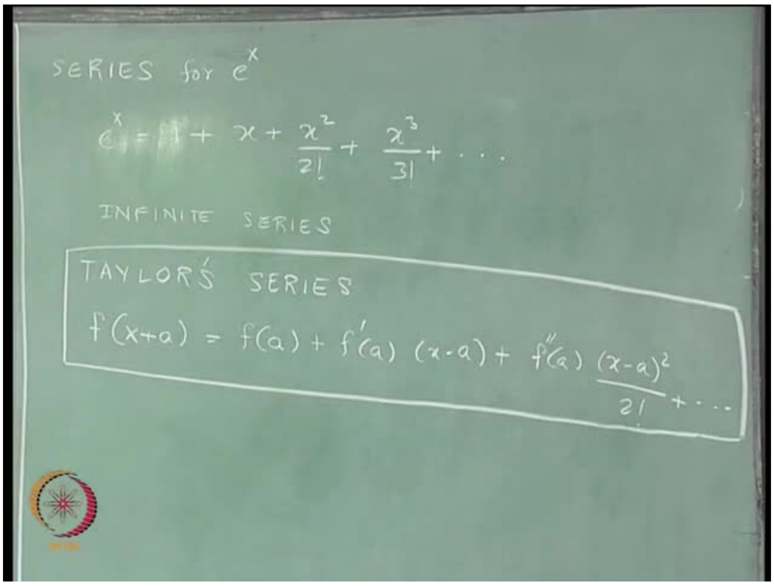

So that is the problem that we have reduced to and then we will use this Taylor's series expansion that I spoke about over here. So, we will use this particular Taylors series expansion around any point a, and then we will try to find out, how this particular Henon's algorithm is going to behave from a numerical prospect.

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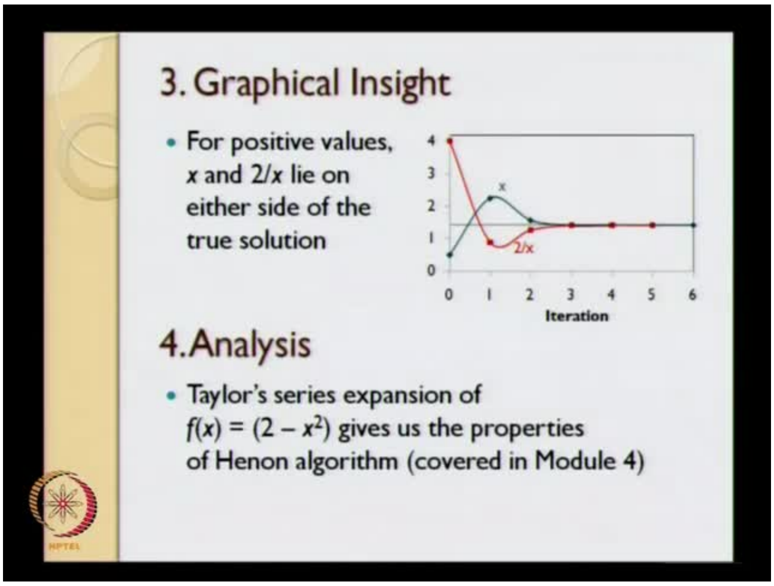

We will do that in the 4th module, but the overall point is that each module that we are going to take is going to have… essentially we are going to cover an analysis; lot of it is going to be based on relatively simple problems trying to analyze the particular method and try to see what those that particular method what are those properties of that method, and so on and so forth; and that is what we are going to do in this particular course and finally at the end of the each module I am going to summarize what the module says.

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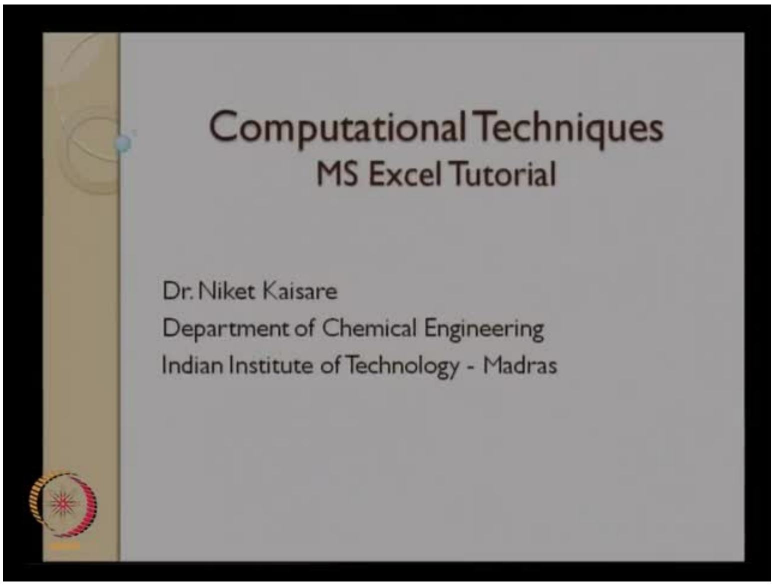

So, what I am going to do next is take up a tutorial of Microsoft Excel to show, how you can use Microsoft Excel in rest of this particular course; I will just go over quick presentation that I have made on using Microsoft Excel.

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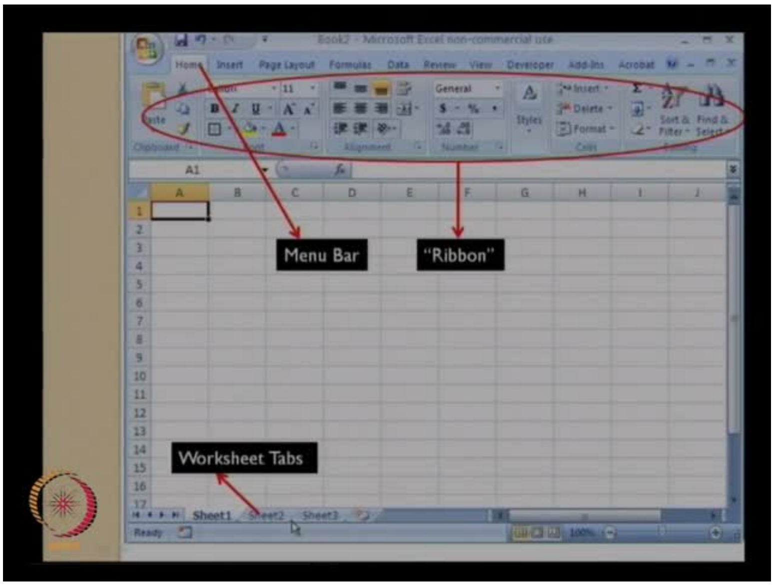

So, when you open Microsoft Excel, this is the kind of the overall window that will open in front of you; this is the Microsoft Excel window it is called the worksheet. At the bottom, you will have the list of all the sheets that are available; at the top this is the menu bar and this is what is known as the ribbon as I have shown in the next particular slide.

So, this is the menu bar as you can see the various menu options - the home menu option tell you various things about cutting and pasting the this particular guy tells you, allows you to change the fonts over here; you have various formatting for the numbers so on and so forth. The other menu that will be useful for us is the formulas menu, and the final menu that will be useful for us is the insert menu, when we are going to insert any figure in this Microsoft Excel.

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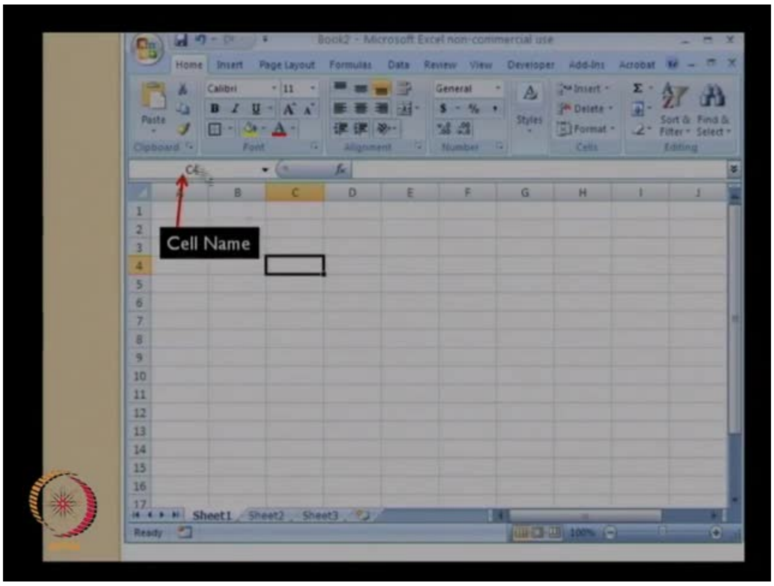

This particular sub menu is called a ribbon in the Microsoft Excel and this is a fairly self-explanatory stuff when you actually open up a particular menu bar; this gives you the various options under that menu bar. And finally, as I told earlier, at the bottom you have the various tabs for the work sheet over here; what is showing is there are three different worksheets; the worksheet that is currently active is what is called sheet number 1.

The next thing that I want to point out to you is that the worksheet contains nothing but a range of rows and columns; so the columns are named as A B C D E F and so on and the rows are numbered 1 2 3 4 5 6 and so on.

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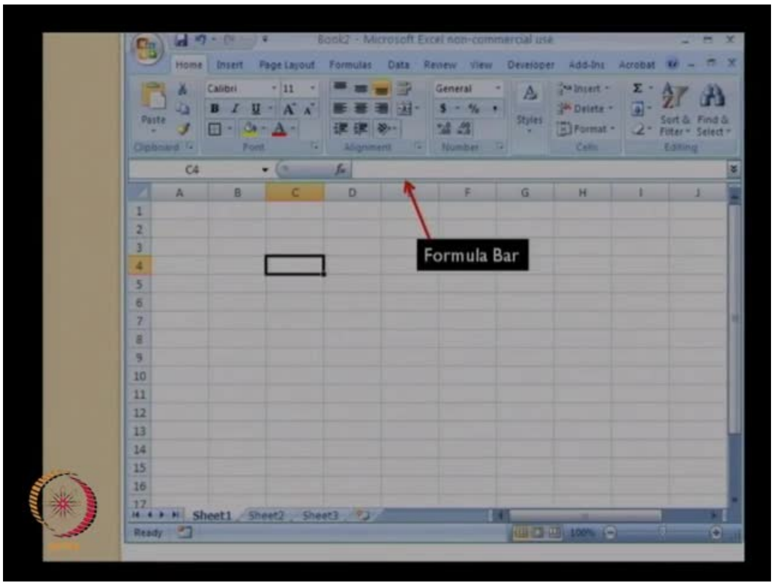

This particular guy over here is the current cell; this current cell is represented as C, the column C and row 4. The location or the name of the cell is located over here; so this tells you the current active cell, this particular guy over here and as you start entering anything into the cell, you will also be able to see it in this formula bar; any numerical formula and so on, you will be entering in the cell and you will able to see this in this particular formula bar.

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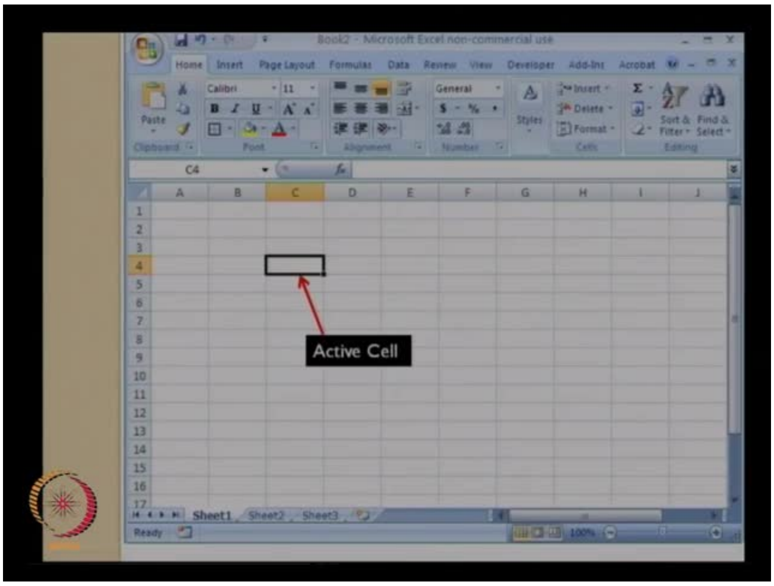

What we are going to do is take a look at, how we enter numbers; how we enter statements and words letters and so on as well as, how we do computations in Microsoft Excel and this particular cell, this cell C 4 is called the active cell.

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So, if you have Microsoft Excel that is installed on your machine, you will probably have a shortcut on your desktop; you can double click that shortcut and you can go to Microsoft Excel. If you do not have Microsoft Excel, the other options that are available to you include the open office; so open office has a worksheet, which is very similar to

Microsoft Excel, and the third option that is available to you is using the Google documents. In Google documents, you have the work sheet or the spreadsheet documents; the spreadsheet documents works very similar to the way Microsoft Excel does at least for the examples that I have looked at. But the whole idea over here is to promote this learning of this computational techniques using this Microsoft Excel or using any kind of a worksheet equivalent to Microsoft Excel.

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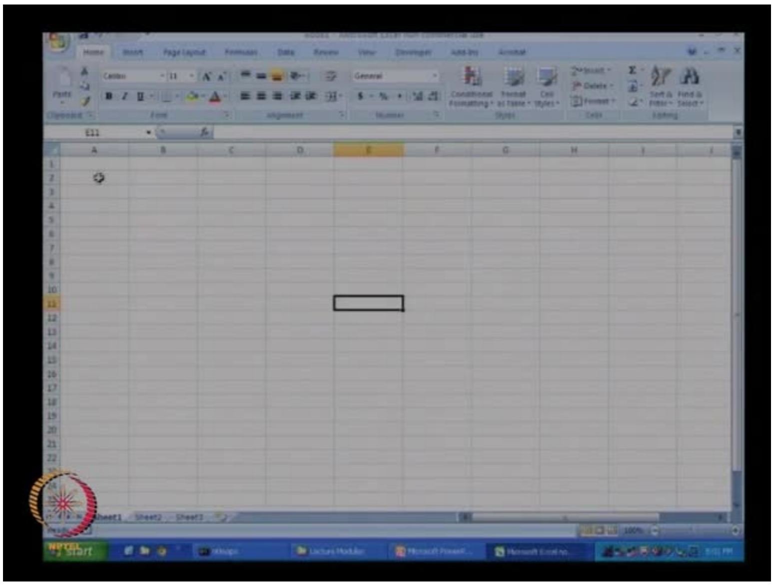

So, let me double click this and it will open a worksheet in Microsoft Excel; so this is the worksheet, which looks very similar to what we have seen earlier. Now, one of the things we can do is, we want to select the entire rows and columns; we can press, click and press at the top, and the entire row and column will be selected; if we want, we can increase the width of each row or width of each column and let me just go ahead and increase the width of each column to 100 pixels; the width now, it shows as 100 pixels and you will see that the overall width of this particular worksheet has increased.

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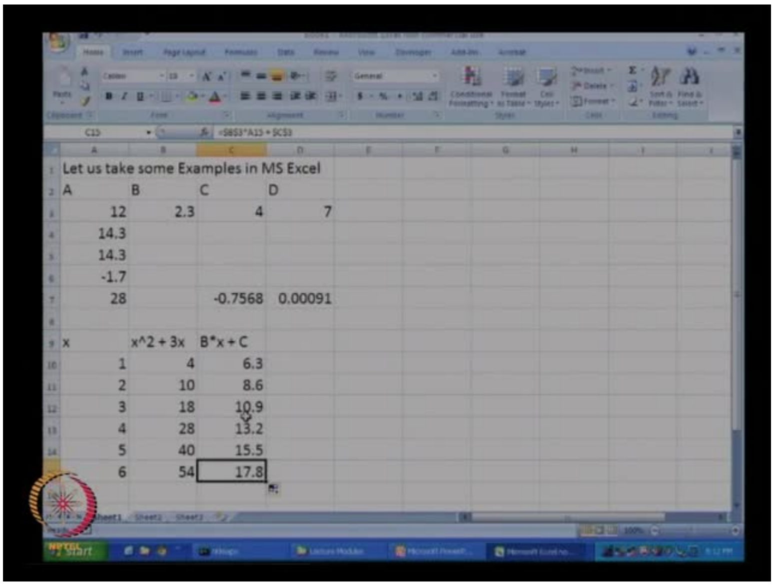

Next thing that I am going to actually do is just select a few rows and columns and just increase the font size from 11 to a larger font size; let us say we will make this font size as 18, so that anything we write will be visible to us. Now, I will start typing in the current row A1; A1 is the current row. Let us take some examples in MS Excel and I press enter and this is what I get in this particular cell; if you look at the formula bar whatever we have written over here, appears in the formula bar and this is the overall thing that appears in that particular cell.

As you will find that the amount of material that we have put in this cell exceeds the width of this cell; so what we will do is, we will go over to multiple cells and we will just merge the cells; the cells can be merged by using this merge and center button that we have over here or right write clicking on this and clicking on format cells, and format cells go to alignment and click on merge cells and this will merge all the cells.

So, what we have now is that cell A1; now, encompasses four columns and is encompassing one single row. So, let us now, take four numbers; let us call those numbers as A B C and D; let us arbitrarily take number 12 2.3 4 and 7. Let us say we want to add the two numbers A and B; in that case, what we are going to do is, we are going to use the formula; to start entering the formula, I first need to type equal sign; once I type equal sign, it is now ready to take up the formula. What I can do is, I can take this my mouse and move to the cell that I want to and this is going to be the value of the variable A plus B, and I can press enter and I have added those two numbers.

Alternatively, what I can do is I can write equal to and look at the number of this particular cell, this cell is A3; so equal to A3 plus, I want to add that to the cell B3.So, when I write A3 plus B3 immediately what you see is that A3 is colored with blue color and that particular cell is highlighted over here; B3 gets colored with green color and that particular cell gets highlighted over here and when I press enter, I will get the number 14.3.

Let us say now, we want to take the difference B minus C; so we want to take this 2.3 minus 4, what I can do is I can press equal to, I can click on this; I can press minus; I can click on this and I will get the difference between the two and that is minus 1.7.

A third way of doing this and let us say, we want to get the value of C multiplied by D, what we can do is press equal to and then take the cursor keys; cursor keys are the arrow keys, up arrow, left arrow, right arrow and so on. I will first click on the right arrow and right arrow as you can see leads to this particular cell and the number of that cell immediately comes in our formula bar as well as in our cell.

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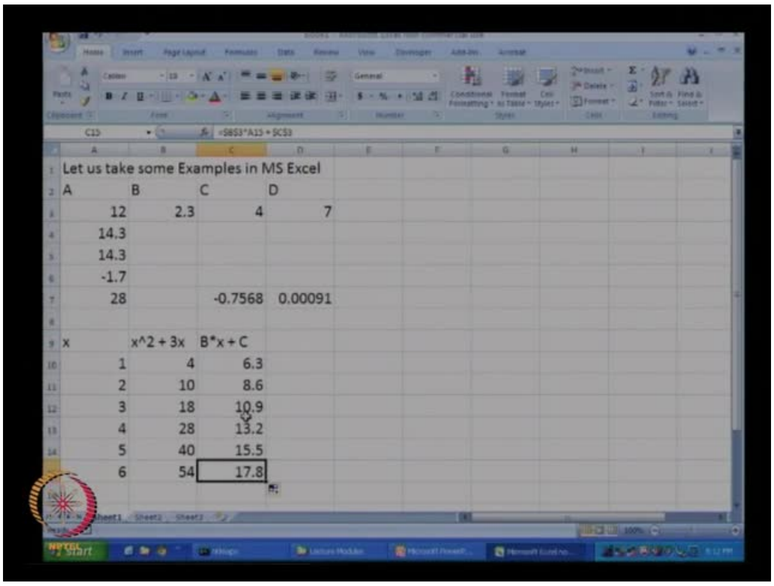

I will click the right cursor key once again and B7 will change to C7, because we will go to this particular column and this particular cell; so I press the right cursor key once and now, what I will do is, I will press the up cursor key 4 times 1 2 3 and 4 and we have gone to C3.

As you can see, every time I press the cursor keys, as this particular guy moves you will see that this particular number also changes and we have this number 4 highlighted; for multiplication, we will use star and 4 multiplied by this; this we can take by moving on the cursor key or clicking using the mouse, either ways is equivalent to each other and we press enter and we get that number. Not only this we can also have trigonometric functions, exponential functions so on and so forth. To get trigonometric function, let us say we want sine of 4; so we will type equal to and we will start typing the formula, as you start the typing the formula, the formula that are available to you will be highlighted in this drop down menu; we can choose this particular formula sine and that is by double clicking that sine gets available over here and I can then go and click over here, close the bracket and press enter and I will get this as sine of 4.

Likewise, let us say I want to take e to the power 7; all I need to do is equal to exponential exp and the number 7 and press enter. Now, if I wanted to get e to the power minus 7, what I can do is I can go on to this particular formula; go to this formula bar and click at the appropriate location; when I click at that appropriate location, I will be allowed to edit this particular formula and instead of, e to the power 7 I wanted e to the power minus 7; I will just put the negative sign over there and press enter and I get e to the power minus 7.

Now, let us look at the case where we have certain numbers x and we want to find say x square plus 3 x and let us say I start with value of x equal to 1; again, what will do is equal to I will use the left cursor key to highlight this x to the power 2 plus 3 multiplied by x; again, to get x i will press the left cursor key and I will press enter; so this is going to be 1 squared plus 3 multiplied by 1 and that value equal to 4.

Now, let us say I want to repeat that same formula for x equal to 2; I will just press this x equal to 2; I will go on to this particular number, highlight it and just drag it below; I drag it from the right edge and I will drag it below and as you can see, the formula gets automatically updated. So, I have two square, which is 4 plus 3 multiplied by 2 that is 6, which is 6 plus 4 is 10 and I get the number over here as 10.

So, what has happened? When I drag now, take a look at this formula bar what has happened? When I have dragged, initially I had this as A10 multiplied by 3 A10, when I dragged it below A10 automatically became A11 and this also became A11.

Now, let us say we wanted to do it not just for 1 and 2, but we wanted to do it for 1 2 3 4 5 6. So, what I can do is I can highlight both these numbers 1 and 2, take my cursor at the right bottom and just drag it below; when I drag it below as you can see in this small square that appears below just next to my cursor I see a number 6, that means I have drag enough to get up to number 6. Excel has automatically filled in all these numbers; now, what you can do is take this and again drag it below and you will get this formula that is repeated at each time.

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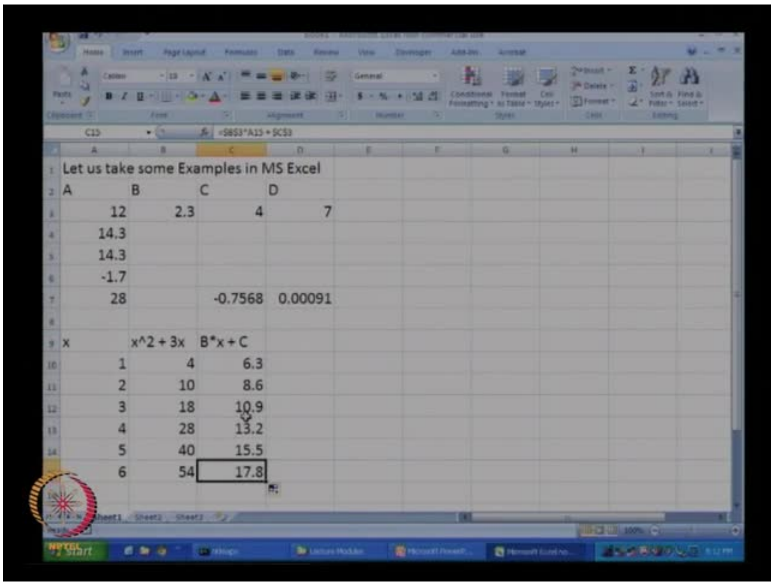

Let us say that we want to calculate B multiplied by x, where B is this value over here plus C; let us say we want to calculate that value. In that case what we will do is I will press equal to, I will take my mouse and click on the value of B multiply it by x plus again, I will take my mouse and then click on the value over here and press enter. So, this is going to be 2.3 multiplied by 1 plus 4, which gives you 6.3. Now, lets us say I want to repeat this for x equal to 2 also; we let us see what happens if we drag and drop it over here.

If we drag and drop there is some problem and why is that problem? That problem happens, if… Now, we can see what happens; I am just clicking the button F2, F2 is edit; so if I click F2, I will see what happened. So, when I dragged from here below, the formula got updated; you see what has happened is, x instead of this being operated on this particular value has now gone to the value below, but what has also happened is these two also have been dragged below. So, this is what happens; it is consistent with the overall Excel behavior; if we drag it once more again, these two columns also get dragged below.

If we want to prevent that, the way to do that is I will clear this, what I had just done. The way to do that is use the dollar signs. If you use the dollar signs, the numbers when you drag do not change; if I use dollar B dollar 3 and dollar C dollar 3 nothing happens over here, but when I drag it what is going to happen is dollar B dollar 3 and dollar C and dollar 3 will not change to B4 and C4. I will just drag it over here and we will just click on F2 and we will see B has remained where it is, C3 three has remained where it is, what has changed is from A10 we have changed to A11.

So, dollar makes Excel keep the cell numbers as when we had entered in the formula, and then what we will do is click at this particular edge and drag it below; so that these numbers get repeated for the entire column. So, this is what we get when we do this for this straight forward exercise.

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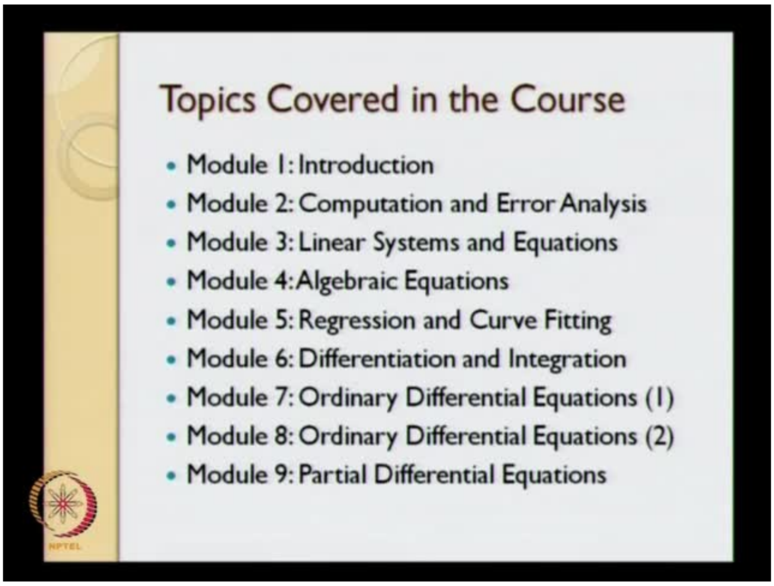

This is the list of topics that we will be covering in this course; the first module is this particular module, it is just the introduction of the numerical technique.

In the second module, we will look at computation, then numerical representation in the binary system, error analysis; as I said, the numerical methods are all going to be essentially approximate methods for solving these problems and because they are approximate methods there are going to be errors associated with approximation of that solution and what those errors are and how those errors propagate in these numerical techniques we will cover; we will give an brief over view of that in module 2. In module 3, we are going to look at linear systems of equations; essentially we want to solve; we know the problem of finding the intersection of two straight lines or three straight lines and so on forth that is what will be covered in in module 3.

Module 4 is going to cover a solution of algebraic equations; you just got very brief overview of what we are possibly going to cover in module 4. An example of a non-linear equation is x square minus 2 equal to 0. In this particular case, we want to find out the solution of that particular, where that particular curve x square minus 2 intersects the x axis.

In module 5, we will look at regression also called curve fitting and interpolation. So, if we have say 10 data points of x and y what the best straight line that can pass through these 10 data points? Again, it is something that you have perhaps, encountered in your high school or first year classes; we are going to take a look at regression and curve fitting in a more formal setting.

Module 6 is going to cover differentiation and integration using numerical methods to do differentiation and integration for really complicated problems. Modules 7 and 8 are going to cover ordinary differential equations and how to solve numerically solve these ordinary differential equations. Module 9 is going to cover partial differential equations; it is only going to give an overview of how to solve the partial differential equations. That is where I end the first module on introducing this particular topic. Next lecture onwards we will cover computation and error analysis for this system. Thank you.