**Optimization in Chemical Engineering**
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**Lecture – 57**
**Software Tools for Optimization (Contd.)**

Welcome to lecture 57. So, this is the last week, week 12 and in this week we are talking about Software Tools for Optimization. We have talked about MATLAB in some length you are now familiar with various MATLAB functions available in the MATLAB optimization toolbox. And, we have seen they are used to solve various optimization problems. In our previous lecture, in this week we have seen that Microsoft Excel solver can be used as an optimizer.

It is a built in optimizer in the excel spread sheet. So, in today's lecture we will take certain examples of constrained optimization and unconstrained optimization and solve using Microsoft Excel solver tool.

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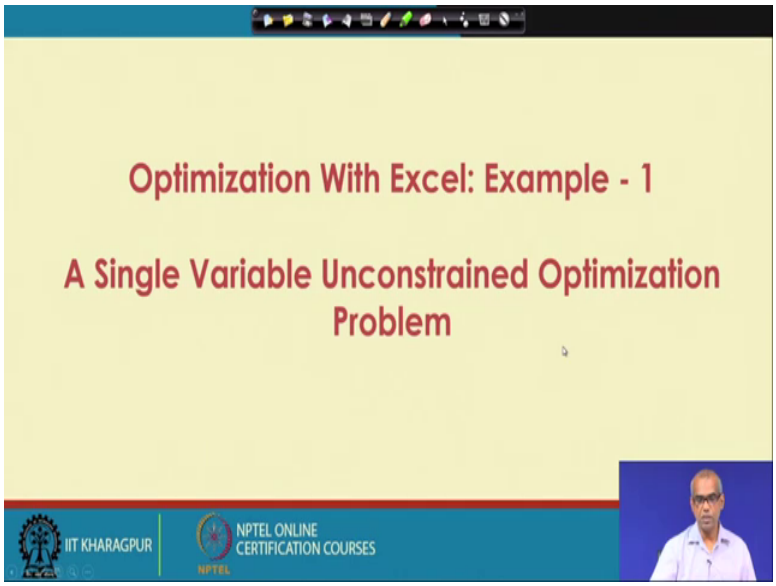


So, as a first example we will take a single variable unconstrained optimization problem, this is the problem we have introduced in our previous lecture.

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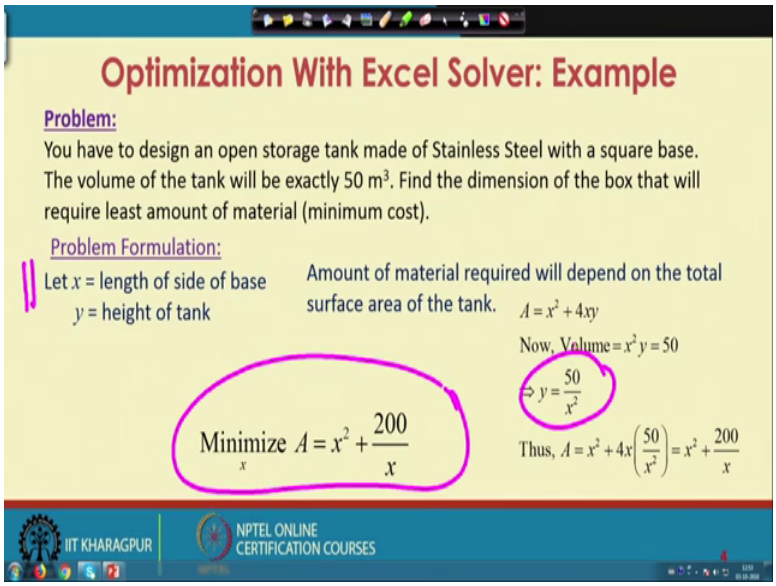


That you have to design an open storage tank made of stainless steel with a square base the volume of the tank will be exactly 50 meter cube.

We have to find the dimension of the tank that will require least amount of material, note that least amount of material corresponds to minimum cost of construction. See we consider x as length of side of base and y as height of tank, the total surface area of the tank can be computed as x square plus 4 xy, where x square is a surface area for the base and 4 xy at the surface area for 4 sidewalls.

The volume is given as exactly 50 meter cube. So, x square y is 50 and that allows us to express y in terms of x. So, y equal to 50 by x square, by putting this into expression of A I get an expression of A as a function of x alone and a equal to x square plus 200 by x is that relationship.

So, this is my objective function I have to minimize A equal to x square plus 200 by x. So, the unconstrained optimization problem formulation is minimize x square plus 200 by x by finding out x. So, for what value of x, x square plus 200 by x will be minimum that will be the length of the base, length of the side of the base which is a square. And height then can be obtained from y equal to 50 by x square relationship.

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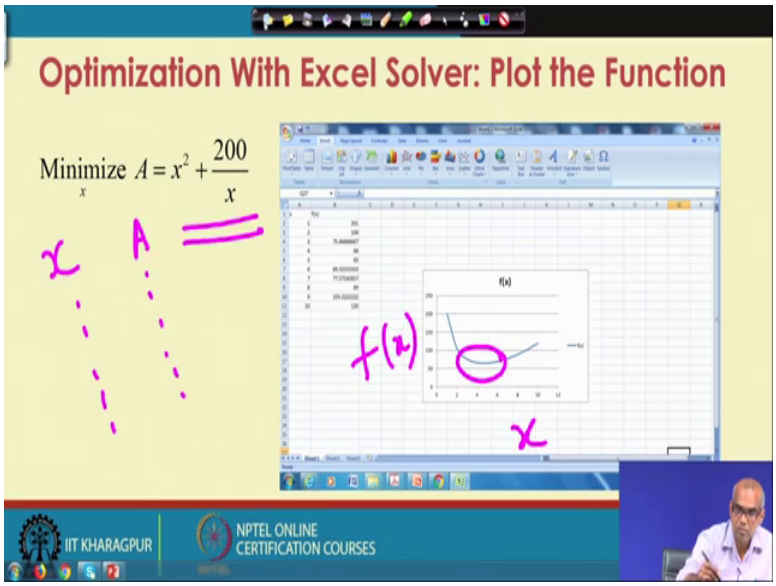


So, it is always a good idea for particularly single variable unconstrained optimization problem to plot the function and get an idea about the location of the minimum. So, using excel you can plot x versus area for various values of x compute area, using this formula and plot f x versus x. You can see that a minimum lies somewhere in the region say 3 to 5 or even between around 4.

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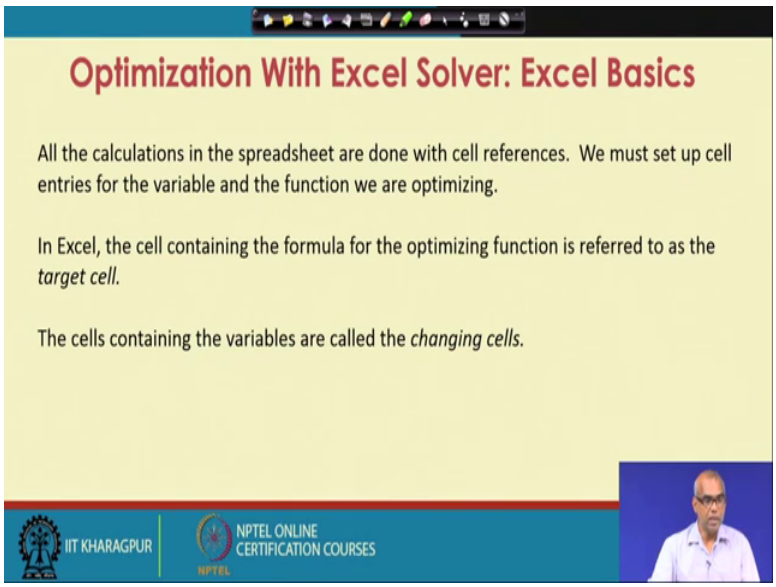


As you have discussed in our previous lecture all the calculations in the spreadsheet are done with cell references, we must set up cell entries for the variable and the function we

are optimizing. In excel the cell containing the formula for the optimizing function is referred to as the target cell. The cells containing the variables are called the changing cells. So, there are 2 types of cells target cell and changing cells. The target cells contain objective function and the changing cell contains the variables.

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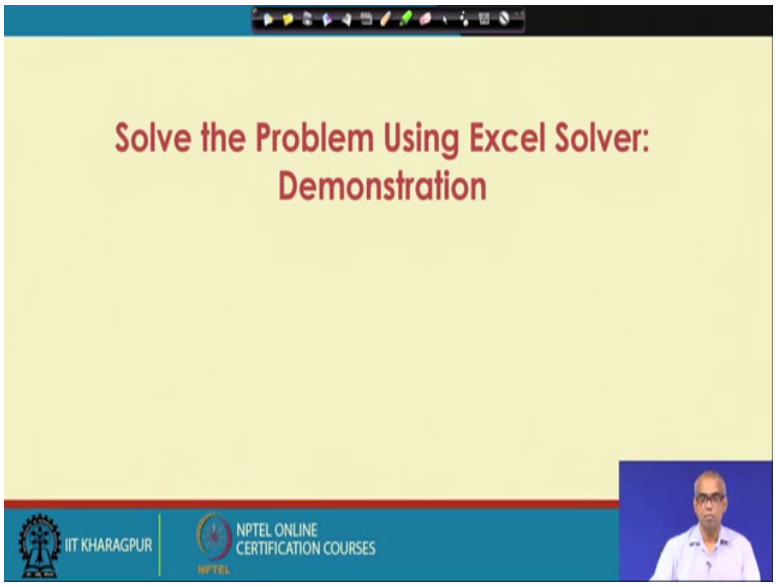


So, now, let us demonstrate the use of the solver to solve the unconstrained optimization problem minimize A equal to 200 plus x square plus 200 by x. So, let me launch Excel 2000. So, Excel 2013 is present in this computer.

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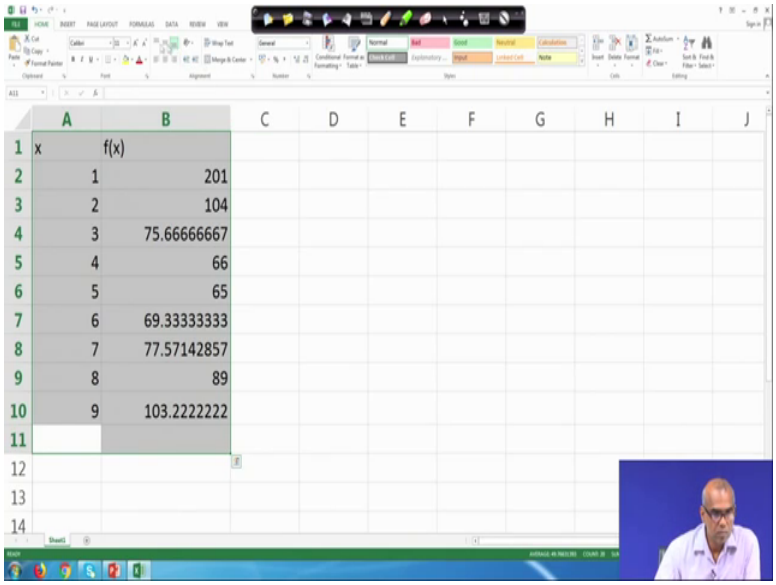

So, let me first zoom it ok. So, as you said that there is always a good idea to plot the function single variable unconstrained function. So, let me plot x versus area. So, let me plot for x equal to say 1 to 9, let us say plot for 1 to 9 and x square plus 200 by x. So, it will be A 2 square plus 200 by A 2.

So, you can expand the width of the B cell as required. So, now, so, you just compute f x which is x square plus 200 by x for all values of x. Now you can plot this right.

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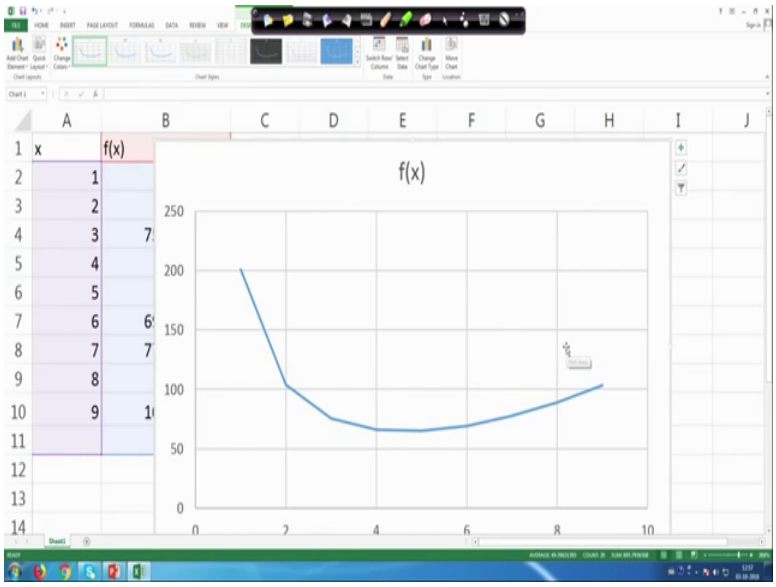


So, you can see that the solution or the minimum will lie somewhere around 4.

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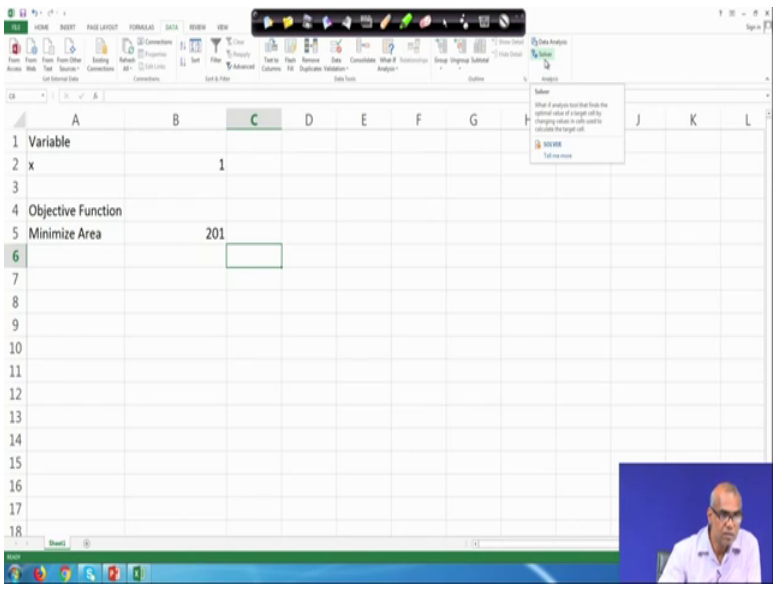

So, now let us solve the unconstrained optimization problem. So, let us keep a label called variable, I have 1 Variable x. So, I put x here in column B let me give and some arbitrary value of x, which will be used as initial guess by the solver.

So, let me skip 1 row and then write Objective Function. So, my Objective Function is minimized area. So, in the same row and under column B, let us write the formula for the area that is x square plus 200 by x. So, x square will mean B 2 square plus 200 by x.

So, now we have defined the problems in excel sheet. Now, you are ready to solve the problem using solver. So, as we discussed in our previous lecture, that the solver is available under data tab. So, click on the data. So, solver is available here. So, if solver is not available there, then you have to click on the file, then you click on the options, click on the add ins and you have to select the excel add ins, click on the go to check the solver add in box click ok.

So, then you will see that the solver appears under data tab. So, I already have loaded here if it is not loaded on your PC you can load the solver just as we demonstrated. So, now, click on the solver. So, you get the dialogue box for input of solver parameters your objective function is set objective. So, here click on the cell and then click on B 5 which contains the objective which contains objective function.

So, you see under set objective B 5 has appeared. Next you have 2 and you have options like max min value of so, you are solving a minimization problem. So, let us click on min by changing variables cells. So, we are changing x here. So, click on this by changing variable cell and then click on B 2, which contains the variable, we do not have any constraint here.

If we have constant, you can select add and then can add constants and the constants will appear here. Now, you can check make unconstrained variables non negative; that means the dimensions cannot be negative. So, I should check it. So, it has been checked. Now, look at this drop down menu you have 3 options GRG non-linear, simplex LP and evolutionary. GRG non-linear is an optimizer which uses Generalized Reduced Gradient algorithm.

Simplex LP is for solution of linear programming problems. Evolutionary method can also solve say non-linear optimization problem, you have options button you can click on

the options and you get this window. So, we have options for all methods GRG non-linear and evolutionary. Forward scheme is being used for the derivative computation let all these things we will have to default setting. So, now you are ready to solve the problem hit the solve button.

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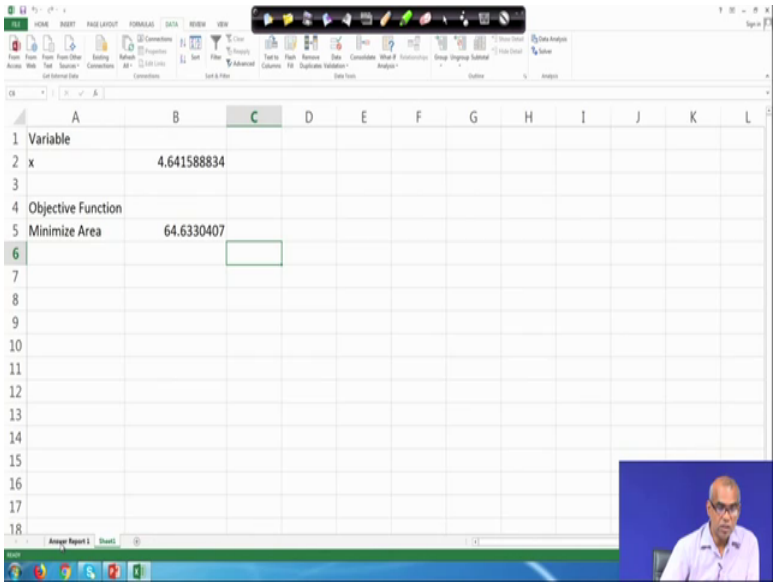


The solver results is shown in this dialogue box it is written here solver found a solution. All constants and optimality conditions are satisfied. Click the radio button keep solver solution also select answer under reports click on ok button. Now, you look at under column B, it contains the optimal solution for the problem.

So, x equal to 6.4 is the optimal length of the side of the base and the minimum area is 64.63. Once you have x y can be found out as y equal to 50 by x square. So, this is how you can easily solve using Excel solver any unconstrained optimization problem. Now, you will see that answer report is available click on the answer report.

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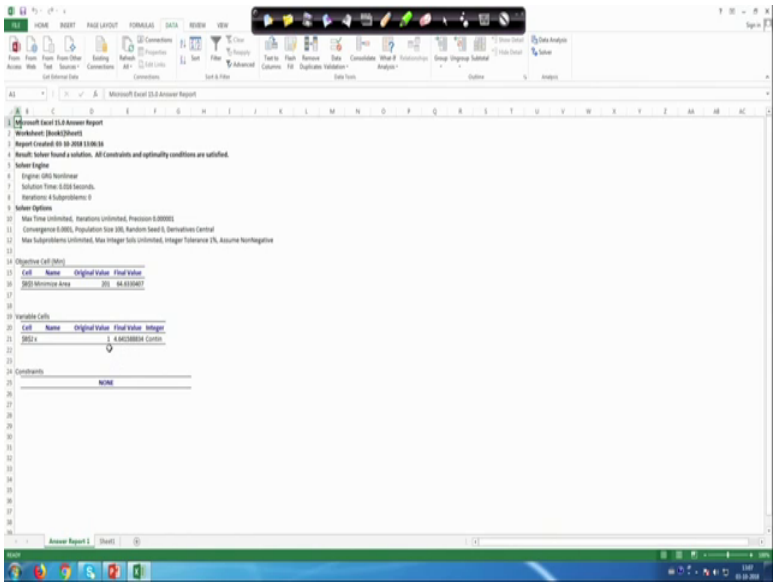
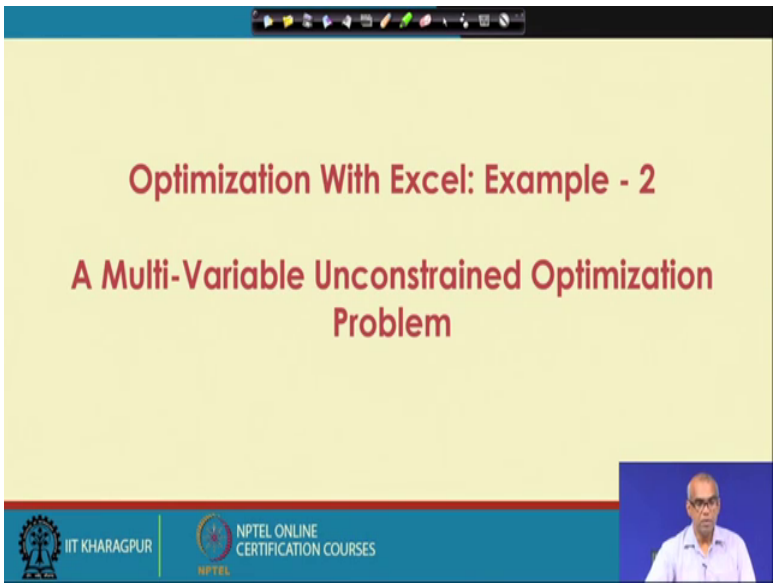


And, this contains information about the solution. We started with x equal to 1 as initial guess and then converts to the final solution 4.64. Corresponding to initial value initial guess value of x equal to 1, the area value was 200 and 1 that is obvious x square plus 200 by x. So, 1 plus 200 equal to 201 and the final value is 64.6.

The solver was GRG non-linear solution time 0.0 1 6 seconds, 4 iterations were required. So, there are various informations about the solution, solution procedure under answer reports. So, this is how you can use excel solver for solution of unconstrained optimization problem. So, this was the solution.(Refer Slide Time: 19:03)



Now, the next problem is multi variable unconstrained optimization problem.

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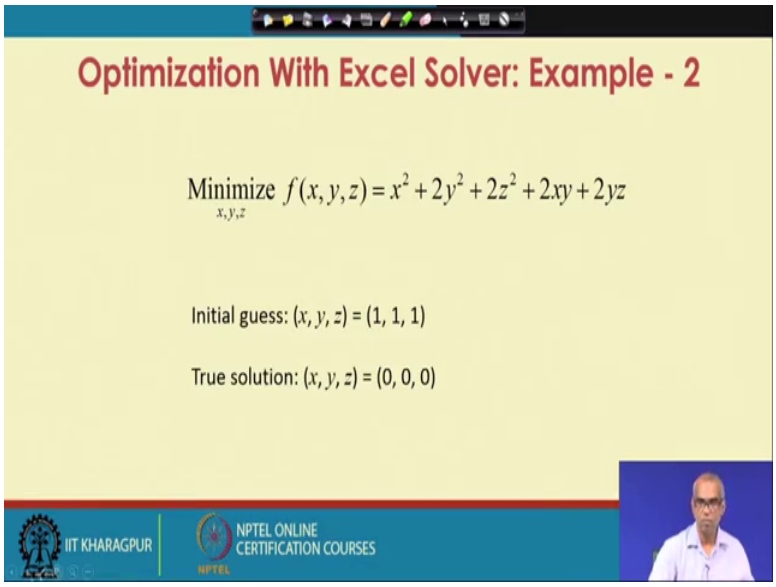


See have a problem where you wish to minimize x square plus 2 y square plus 2 z square plus 2 xy plus 2 yz. The initial guess is 1 1 1. The true solution for this problem is 0 0 0. So, let us go and solve this problem. So, the problem is x square plus 2 y square plus 2 z square plus 2 xy plus 2 yz we have to minimize this. For that you have to find out xy and z.

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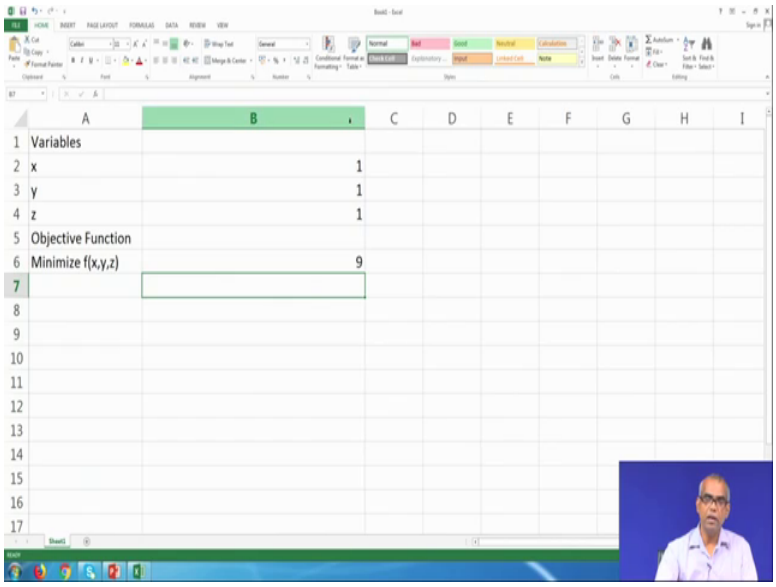

So, let me again launch excel and I will again zoom it. So, I write variables give the label you can put now x y z as 3 variables. And, then you give objective function. Let me expand it an objective function is minimize f which is a function of x y and z.

So, let me get guess values 1 1 1. So, we have to now write the objective function. So, the objective function is x square means B 2 square plus 2 y square; that means, B 3 2 into B 3 square plus 2 z square; that means, 2 B 4 square plus 2 xy 2 into B 2 into B 3 plus 2 yz. That means 2 B 3 into B 4.

So, now, press enter. We have now set up the problem in excel we are ready to solve click on data tab, click on the solver. So, set objective click on the set objective cell click on B 6 which contains objective function. We are minimizing click on minimization by changing variable cells we are now changing x y and z.

So, we have to set B 2 B 3 and B 4. So, to do that click on this by changing variable cells, you can click on this red button, and then drag the cells which contains x y and z click on the red button. And, you see B 2 to B 4 appears. Check make unconstrained variables non negative select GRG non-linear there is no constraint. If, there is constraint we have to click on add and then you will be able to add constraints now hit the solve button.

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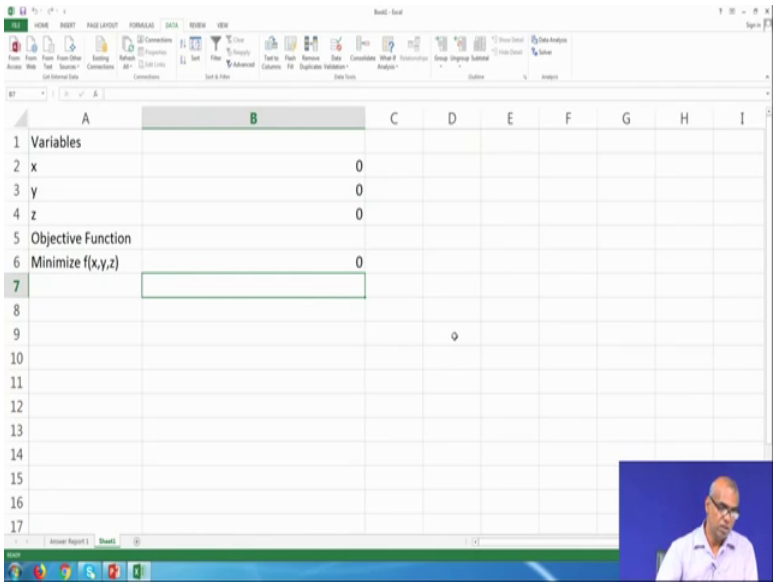

So, the solver found a solution all constraints and optimality conditions are satisfied. Click on the radio button keep solver solution also click on answer under reports. Now, click ok. So, this is the solution you get. As, we discussed initially the true solution is x equal to 0 y equals to 0 z equal to 0 we obtain the same solution. The objective function value is also 0, click on the answer report.

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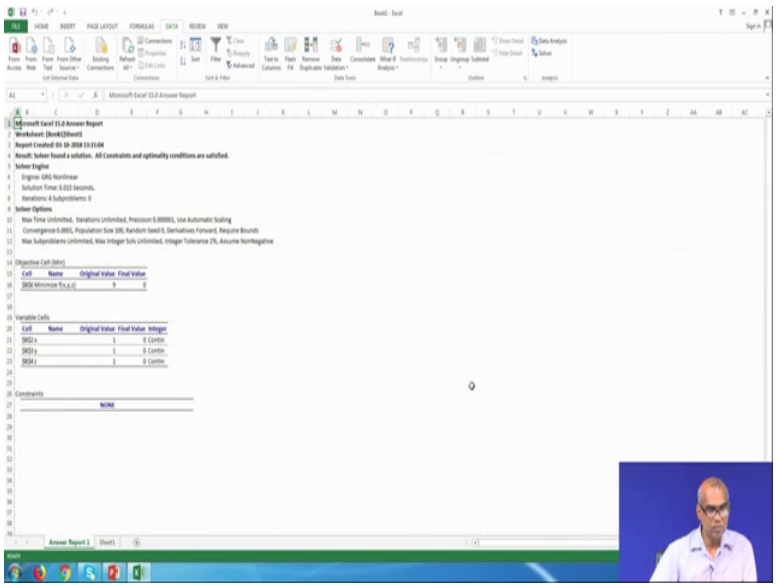

You get more information about the solution procedure, how much time it took 4 iterations were required original function value was 9 and original initial guess was x, x equal to 1 y equal to 1 z equal to 1. And finally, we converge to true solution x equal to 0 y equal to 0 and z equal to 0 corresponding minimum function value is also 0.

So, this is how you can solve a multi variable unconstrained optimization problem using Excel solver. So, now, again let us go back to our slides.

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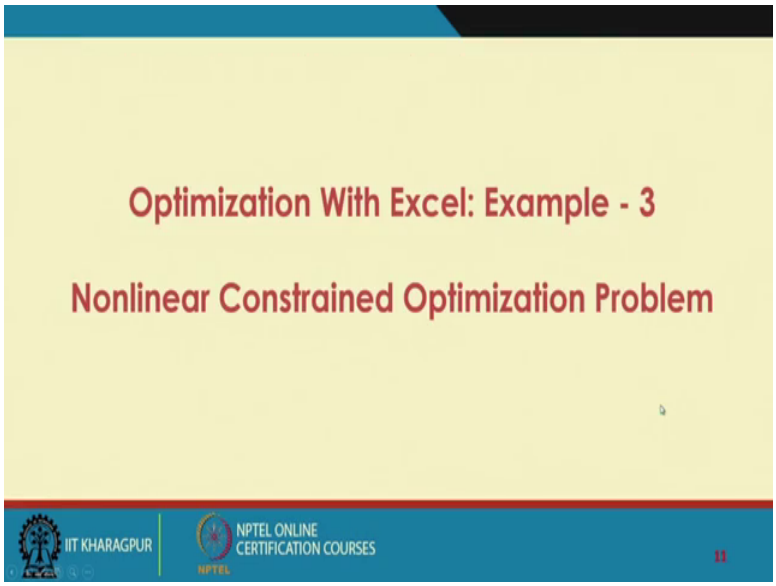


Now, let us consider a non-linear constrained optimization problem.

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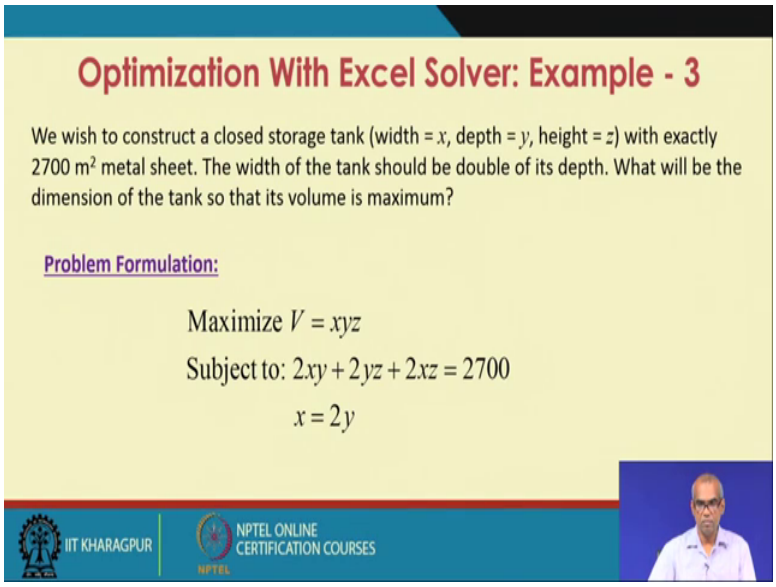


We wish to construct a closed storage tank width is x, depth is y, and height equal to z with exactly 2700 meter square metal sheet.

So, this time we wish to construct a closed storage tank. The width equal to x depth equal to y and height equal to z with exactly 2700 meter square of metal sheet. The width of the tank should be double of it is depth; that means, x equal to 2 y, what will be the

dimension of the tank so, that it is volume is maximum. So, when 2 problem formulation will be maximized V equal to x into y into z.

That is the volume subject to total surface area should be 2700 meter square. So, 2 xy plus 2 yz plus 2 zx equal to 2700. And, another constraint is x equal to 2 y. So, this is the problem now we want to solve, V equal to x y z subject to 2 x y plus 2 y z plus 2 z x equal to 2700 another constraint x equal to 2 y.

So, we have 2 constraints. So, now, let us see how will we solve using Microsoft Excel? Again let us launch let me expand and then let me zoom so, that you can see clearly.

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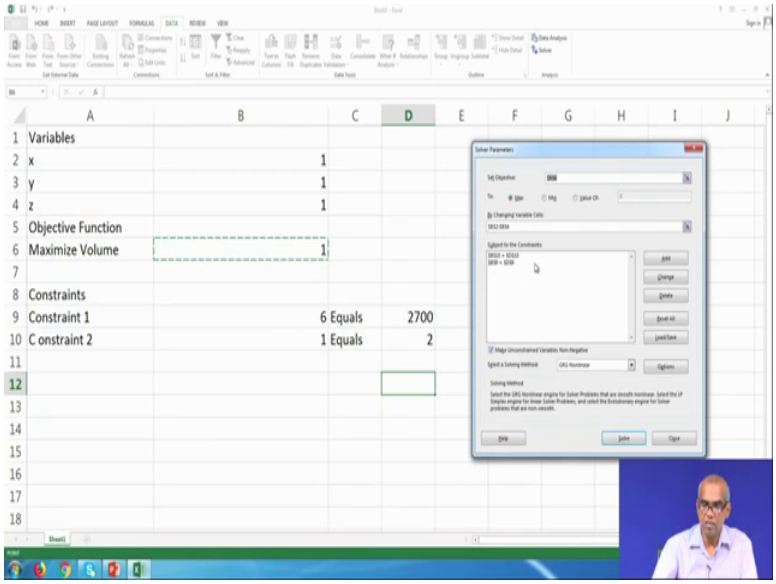


So, I write variables I have 3 variables now x y and z. Then, we give their initial value 1 1 and 1, then we write objective function which is maximize volume.

Let me write the formula for that is x into y into z; that means, B 2 into B 3 into B 4 B 2 into B 3 into B 4. Now, let me put let me skip 1 cell and write Constraint. So, let me write Constraint 1 or let me first write Constraints and then below it I write Constraint 1 and here I write Constraint 2.

So, what is my Constraint? The first constraint is 2 x y plus 2 x z plus 2 z x equal to 2700. So, let me write the formula for that 2 into x y; that means, B 2 into B 3 plus 2 y z 2 into E 3 into B 4 plus 2 z x; that means, 2 into B 4 into B 2. So, this Equals to Equals

2700. Constraint 2 says x Equal to 2 y. So, x is B 2 equal to B 2 Equals 2 y so, 2 so, equal to 2 into B 3.

So, we are now done with the problem setting, we are now ready to solve hit tab click on the solver set objective, objective is available under B 6 click on B 6 we are maximizing the volume. So, click on max, button by changing cells x y and z, click the red button under by changing variable cells, click the red button and then drag x y z.

So, B 2 to B 4 appears, now we have constraint here. So, click on add button. So, here you give the cell reference that contains constraint one this. From here drop down menu you take equal to and then on the other side constraint one right hand side of the constraint 1, which is 2700 which is under D 9.

So, click that. So, now, click on add. Now, do the same thing for the second constraint, click on the cell reference click on d 10 that contains Constraint 2 under dropdown menu, click on the equality sign and then click on the d 10 which contains the right hand side constraint of the Constraint 2.

So, you add. So, both I have added now cancelled to come out. So, now, this is what it looks like. You are ready to solve make unconstrained variables nonnegative chosen GRG non-linear, 2 constraints appears here. So, click on solve.

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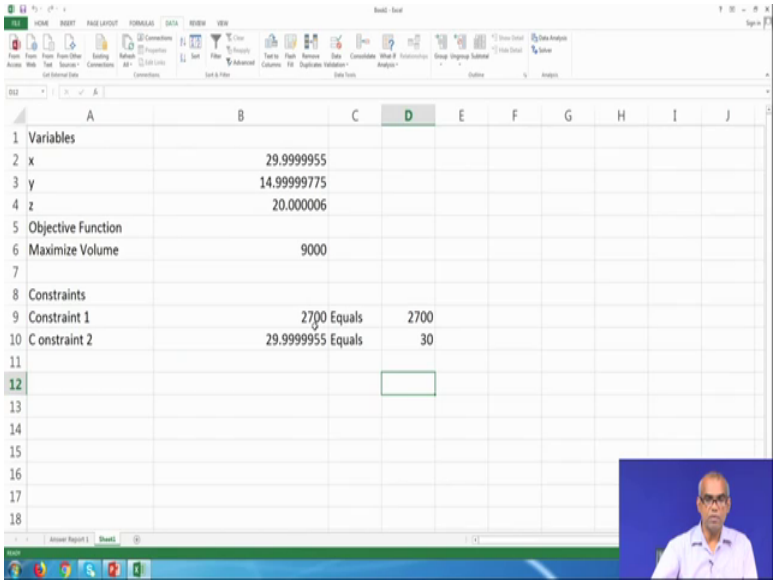

So, solver found a solution all constraints and optimality conditions are satisfied, keep the solver option also click on answer under reports click on ok. So, this is a solution 29.99 this is 30, 14.99 is 15.

So, 30 x equal to 30 y equal to 15 and z equal to 20, that should be the optimal dimensions giving the maximum volume of 9000 meter cube. Look at here the constraints are satisfied 2700 equal to 2700 29.99 9; that means, 30 equals 30.

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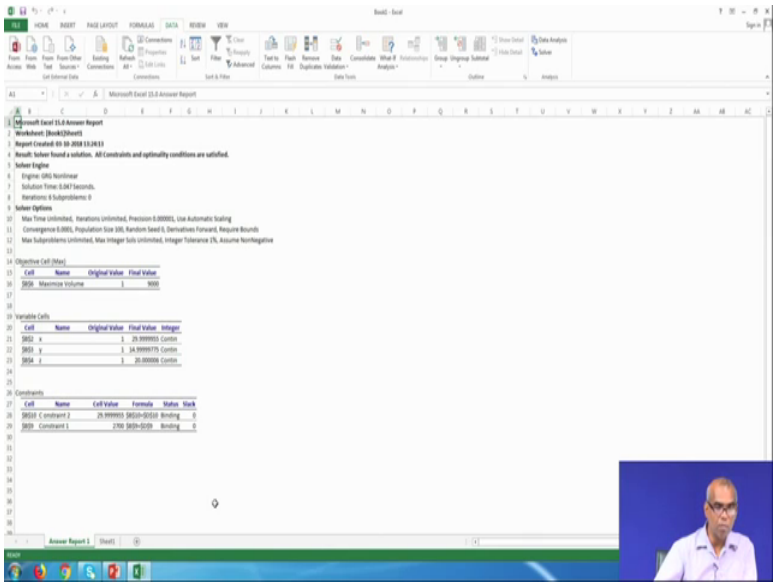

So, we have been able to successfully to solve the problem click on the answer reports to know more about the solution procedure, 6 iterations were required initial guess values was x equal to y y equal to 1 z equal to 1 and it converts to the final optimal solution x equal to 30, y equal to 15 and z equal to 20, leading to the optimal or the maximum value for the volume as 9000 meter cube. So, this is how you can solve constrained non-linear optimization problem. So, with this we will stop our lecture 57 here.