



IIT KHARAGPUR



NPTEL ONLINE
CERTIFICATION COURSES

OPTIMIZATION IN CHEMICAL ENGINEERING

Software Tools for Optimization

WEEK – 12: LECTURE – 56)

Dr. Debasis Sarkar

**Department of Chemical Engineering
Indian Institute of Technology Kharagpur**

Software Tools for Optimization

Week 12:

- MATLAB, EXCEL Solver for Optimization

Software Tools for Optimization

Some of the popular software tools for optimization are:

1. MATLAB Optimization Toolbox (www.mathworks.com)
2. MS Excel Solver (Microsoft)
3. LINGO (www.lindo.com)
4. MINITAB (www.minitab.com)
5. GAMS (www.gams.com)
6. CPLEX (www.ilog.com)
7. AMPL (www.ampl.com)

Optimization With Excel Solver

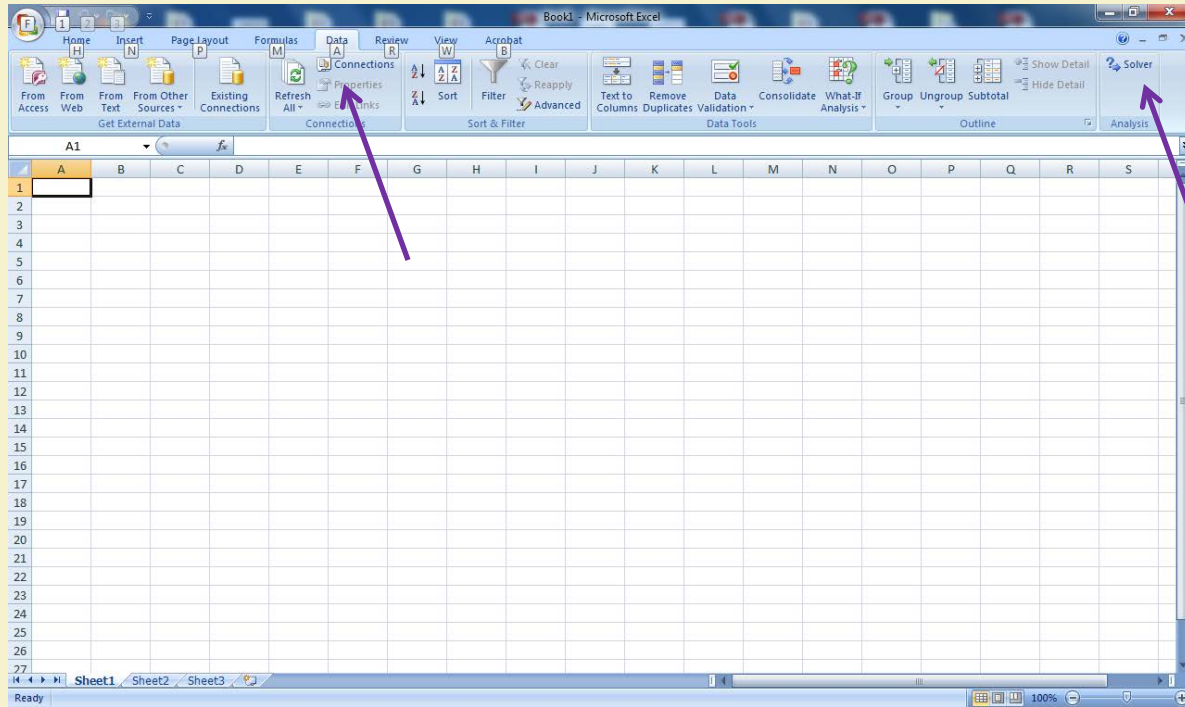
The Microsoft Excel has a built-in optimizer called SOLVER. This has capability to solve linear nonlinear programming problems. One can place integer or binary restrictions on decision variables. SOLVER can be used to solve problems with up to 200 decision variables.

The SOLVER Add-in is a Microsoft Office Excel add-in program. The optimizer SOLVER can be found in the ANALYSIS group on the DATA tab in Excel. If you do not find the SOLVER under DATA tab, you first need to load it in Excel.

Optimization With Excel Solver: How to Load it?

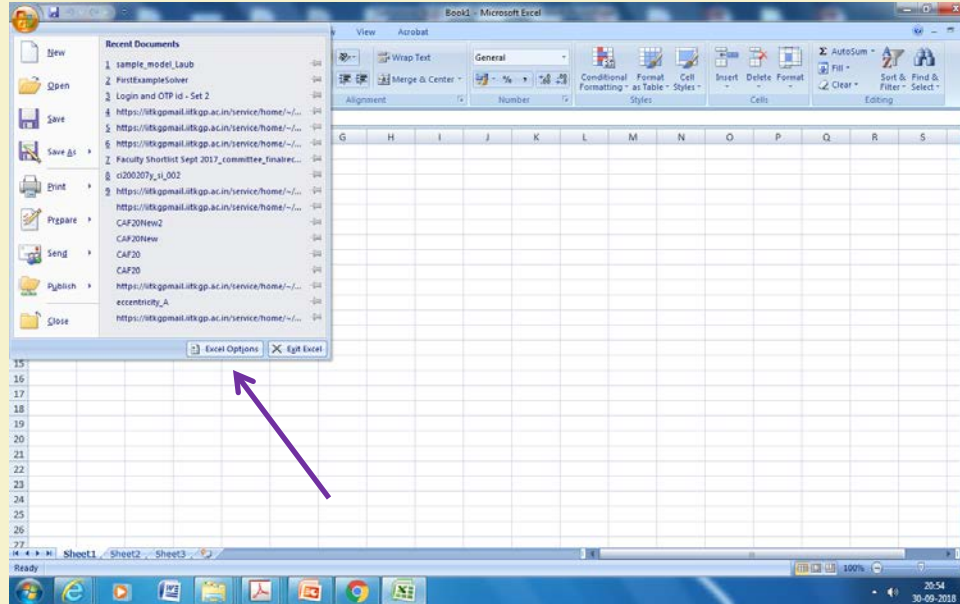
1. Click the Microsoft Office Button , and then click Excel Options.
2. Click Add-Ins, and then in the Manage box, select Excel Add-ins and click Go.
3. In the Add-Ins available box, select the Solver Add-in check box, and then click OK.
4. If Solver Add-in is not listed in the Add-Ins available box, click Browse to locate the add-in.
5. If you get prompted that Solver is not currently installed, click Yes to install it.
6. After you load Solver, the Solver command is available in Analysis group on the DATA tab.

Optimization With Excel Solver: How to Load it?



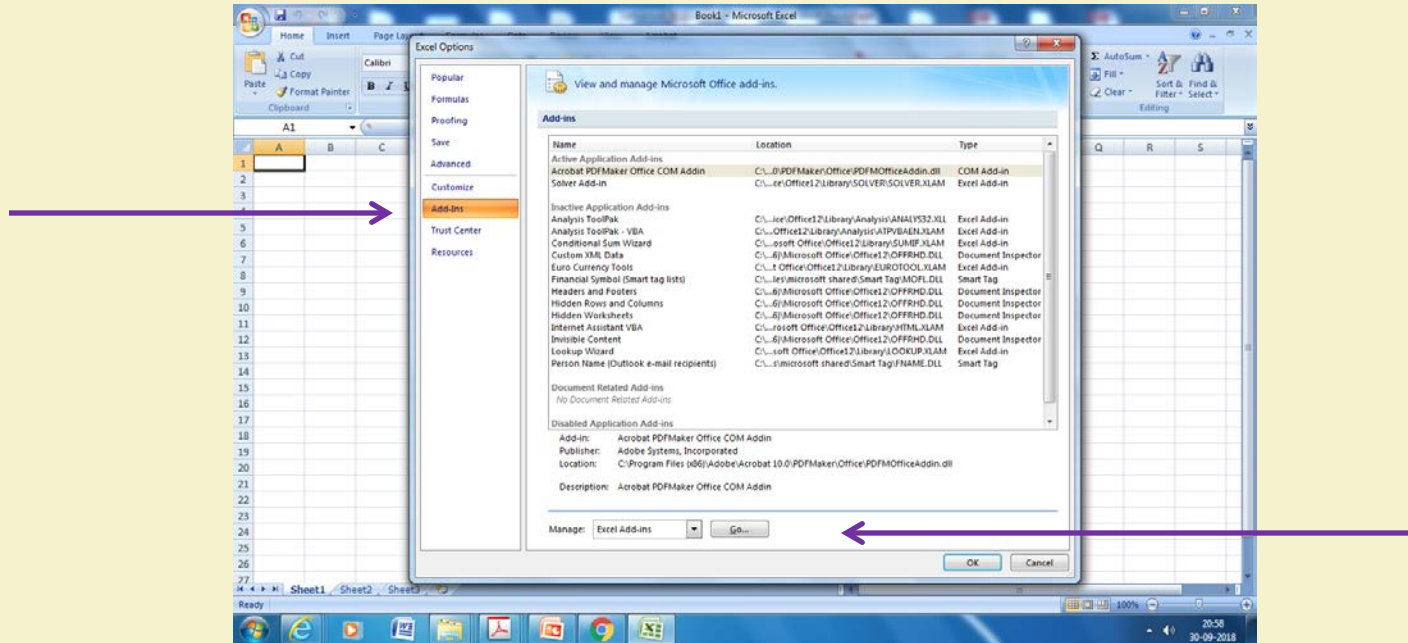
Optimization With Excel Solver: How to Load it?

1. Click the Microsoft Office Button , and then click Excel Options.



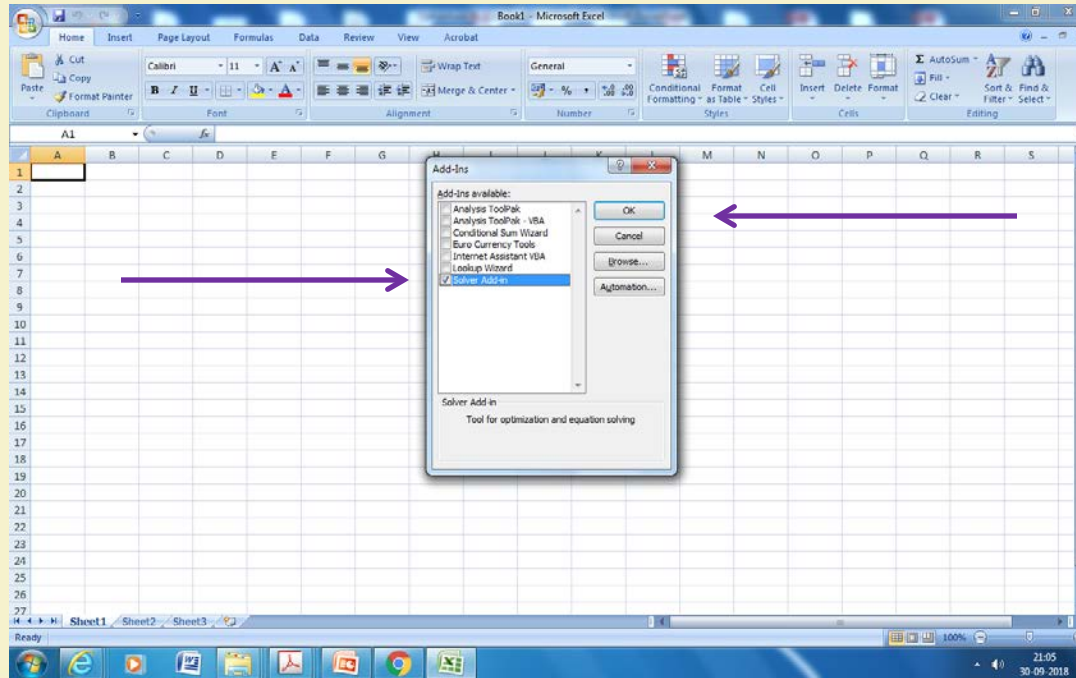
Optimization With Excel Solver: How to Load it?

2. Click Add-Ins, and then in the Manage box, select Excel Add-ins and click Go.



Optimization With Excel Solver: How to Load it?

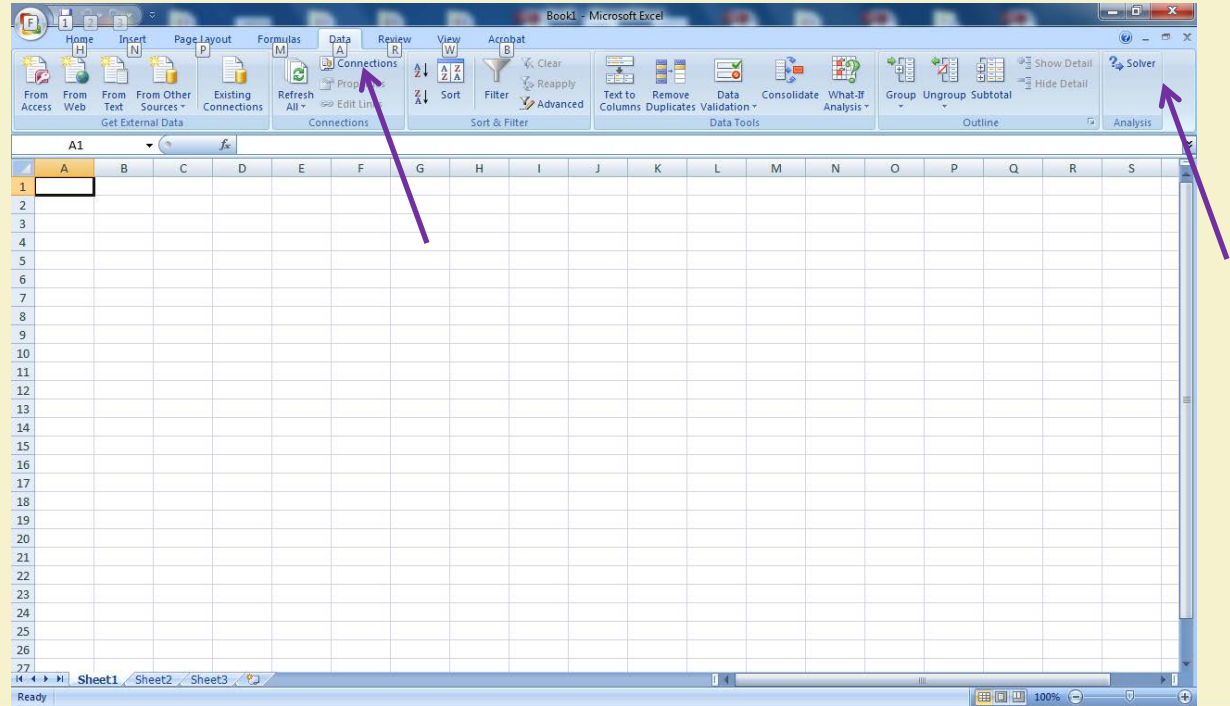
3. In the Add-Ins available box, select the Solver Add-in check box, and then click OK.



Optimization With Excel Solver: How to Load it?

Now you will find SOLVER under DATA tab.

You are now ready to solve an optimization problem with Excel SOLVER.



Optimization With Excel: Example

A Single Variable Unconstrained Optimization Problem

Optimization With Excel Solver: Example

Problem:

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 m^3 . Find the dimension of the tank that will require least amount of material (minimum cost).

Problem Formulation:

Let x = length of side of base
 y = height of tank

Amount of material required will depend on the total surface area of the tank.

$$A = x^2 + 4xy$$

$$\text{Now, Volume} = x^2 y = 50$$

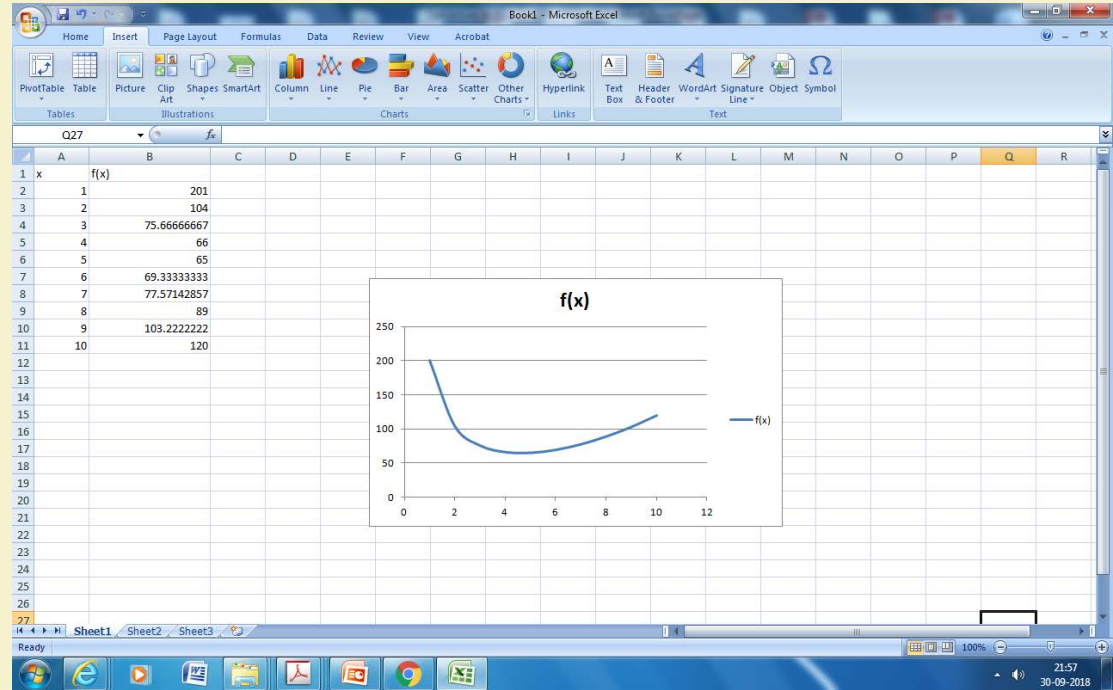
$$\Rightarrow y = \frac{50}{x^2}$$

$$\text{Minimize}_x A = x^2 + \frac{200}{x}$$

$$\text{Thus, } A = x^2 + 4x \left(\frac{50}{x^2} \right) = x^2 + \frac{200}{x}$$

Optimization With Excel Solver: Plot the Function

$$\text{Minimize}_x A = x^2 + \frac{200}{x}$$



Optimization With Excel Solver: Excel Basics

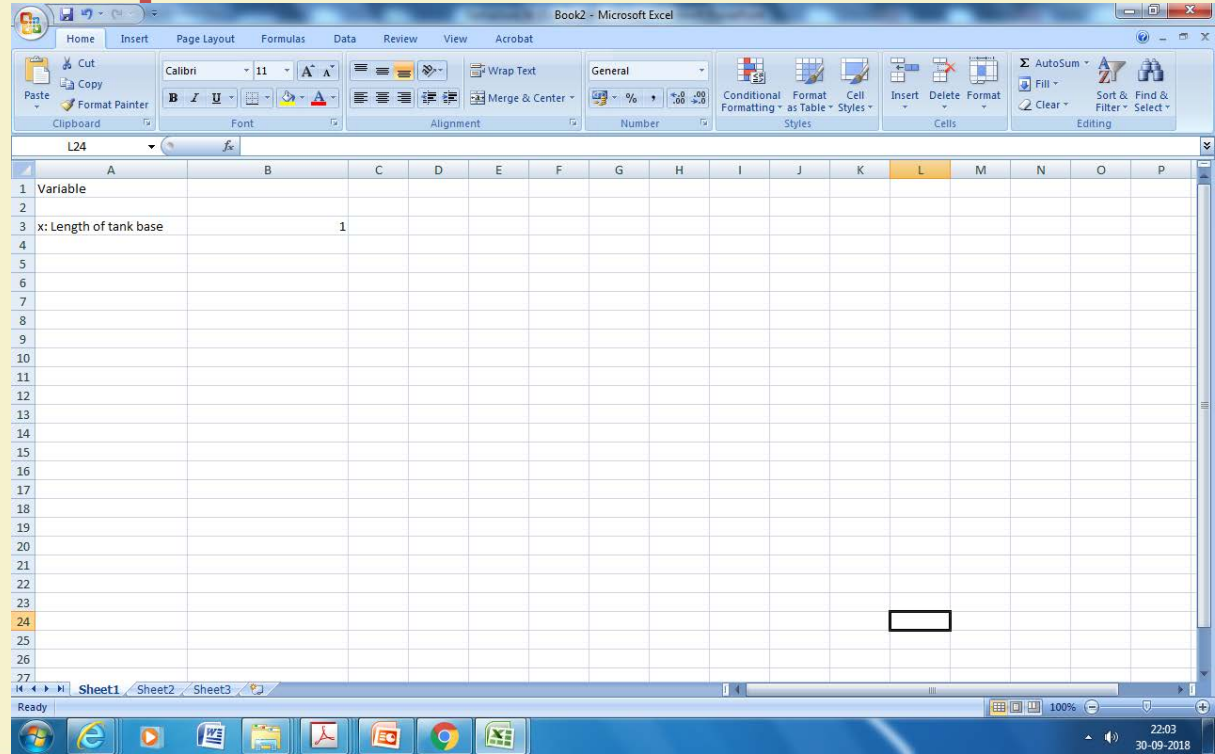
All the calculations in the spreadsheet are done with cell references. We must set up cell entries for the variable and the function we are optimizing.

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*.

Steps to Set up the Problem in Excel

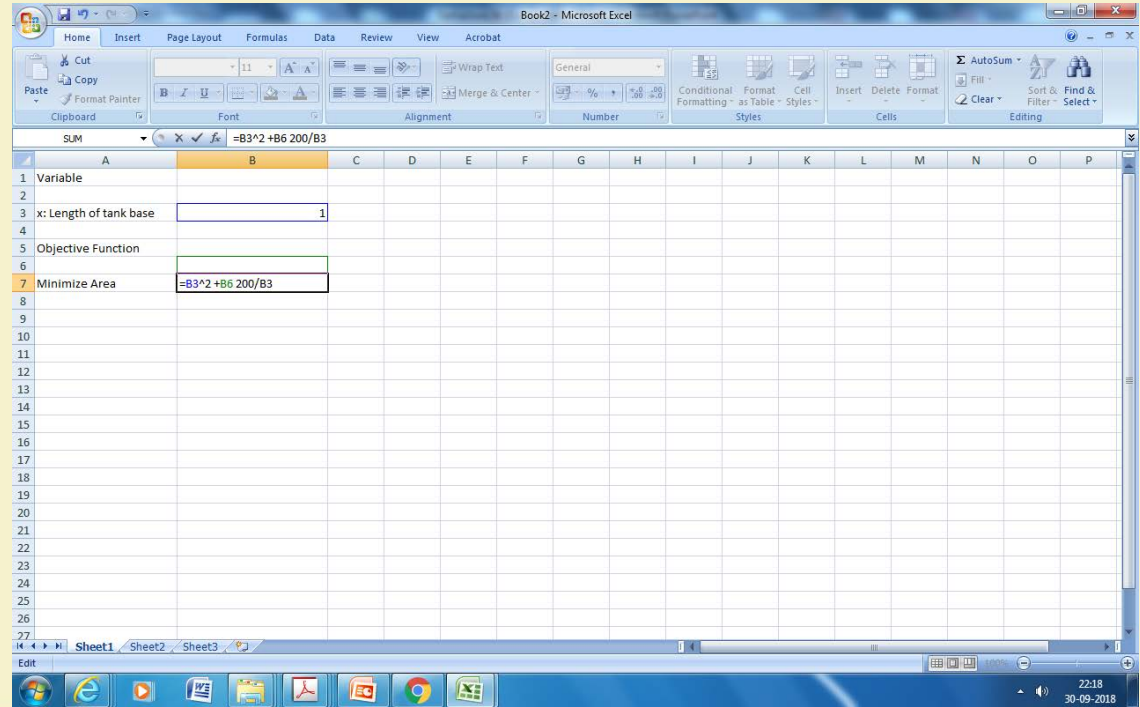
In a blank spreadsheet, first type a heading called “Variable” in cell A1, followed by the variable description in A3 and its value in cell B3. The variable x is initially assigned a value of 1. This is initial guess.



Steps to Set up the Problem in Excel

Enter the information for the area function as follows:

- Type a heading called “Objective Function” in cell A5.
- Type a description of the objective in cell A7.
- Enter the objective function formula in B7. The formula is $= B3^2 + 200/B3$



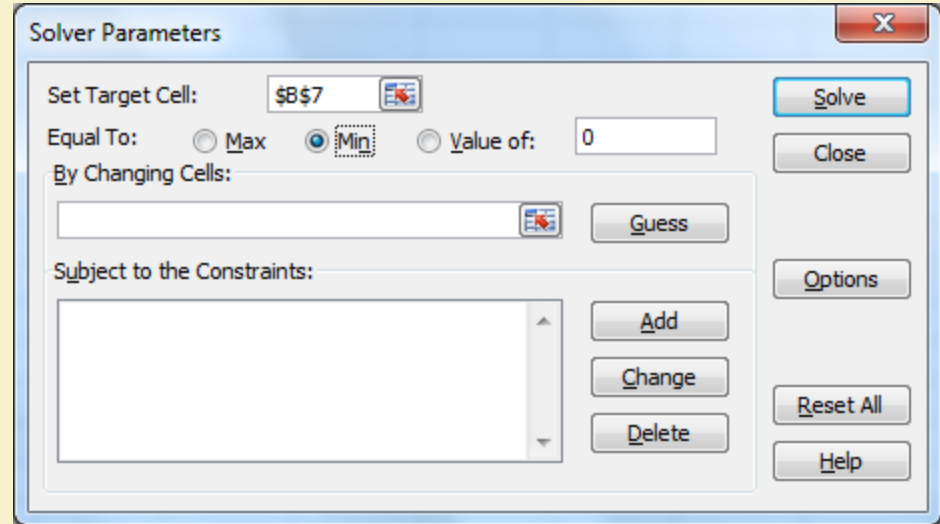
Steps to Solve the Problem Using Excel Solver

We are ready to invoke Solver by choosing Data > Solver.

You will see a dialog box whose first entry is the information for the target cell (i.e. the objective function).

Click cursor into the this entry box and click into cell B7 (formula for objective function).

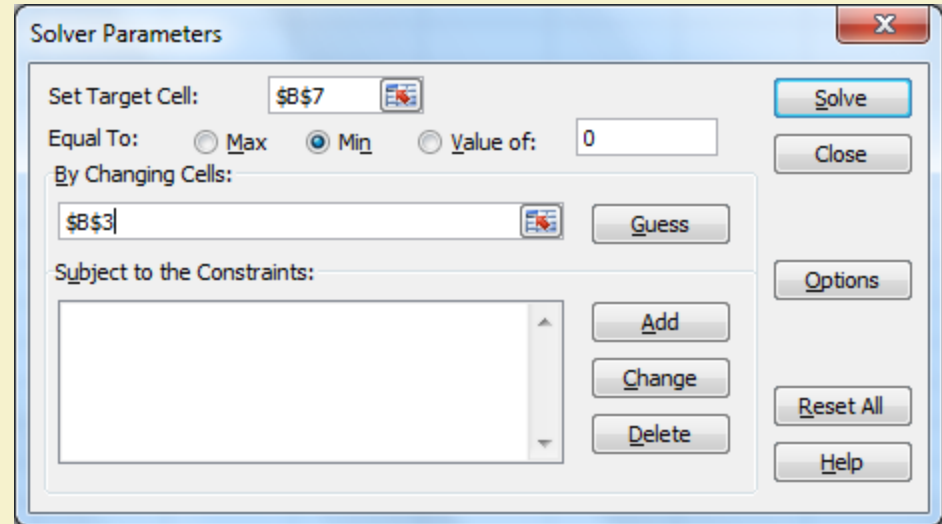
Check the button to minimize.



Steps to Solve the Problem Using Excel Solver

Next click cursor to the By Changing Cells entry box.

Enter the cell reference for the x variable by selecting the cell B3.

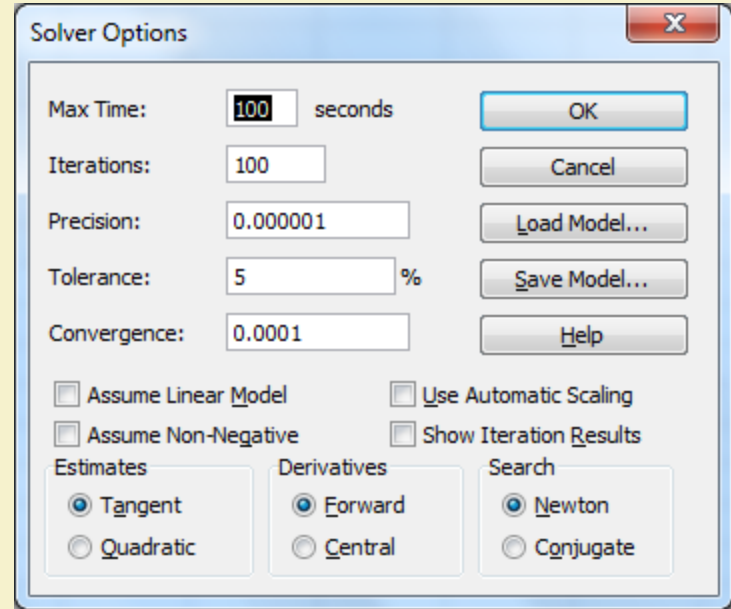


The image shows the 'Solver Parameters' dialog box in Microsoft Excel. The 'Set Target Cell:' field contains '\$B\$7'. The 'Equal To:' section has three radio buttons: 'Max' (unselected), 'Min' (selected), and 'Value of:' (unselected). The 'Value of:' field contains '0'. The 'By Changing Cells:' field contains '\$B\$3'. Below this is a list box for 'Subject to the Constraints:' which is currently empty. To the right of the list box are three buttons: 'Add', 'Change', and 'Delete'. On the far right of the dialog are several buttons: 'Solve', 'Close', 'Options', 'Reset All', and 'Help'.

Steps to Solve the Problem Using Excel Solver

Click into the Options box.

The given problem is nonlinear. Do not check the checkbox for Assume Linear Model.



The image shows the 'Solver Options' dialog box in Microsoft Excel. The dialog box has a title bar with a close button (X). The settings are as follows:

- Max Time: 100 seconds
- Iterations: 100
- Precision: 0.000001
- Tolerance: 5 %
- Convergence: 0.0001
- ☐ Assume Linear Model
- ☐ Assume Non-Negative
- ☐ Use Automatic Scaling
- ☐ Show Iteration Results
- Estimates: ☒ Tangent, ☐ Quadratic
- Derivatives: ☒ Forward, ☐ Central
- Search: ☒ Newton, ☐ Conjugate

Buttons on the right: OK, Cancel, Load Model..., Save Model..., Help.

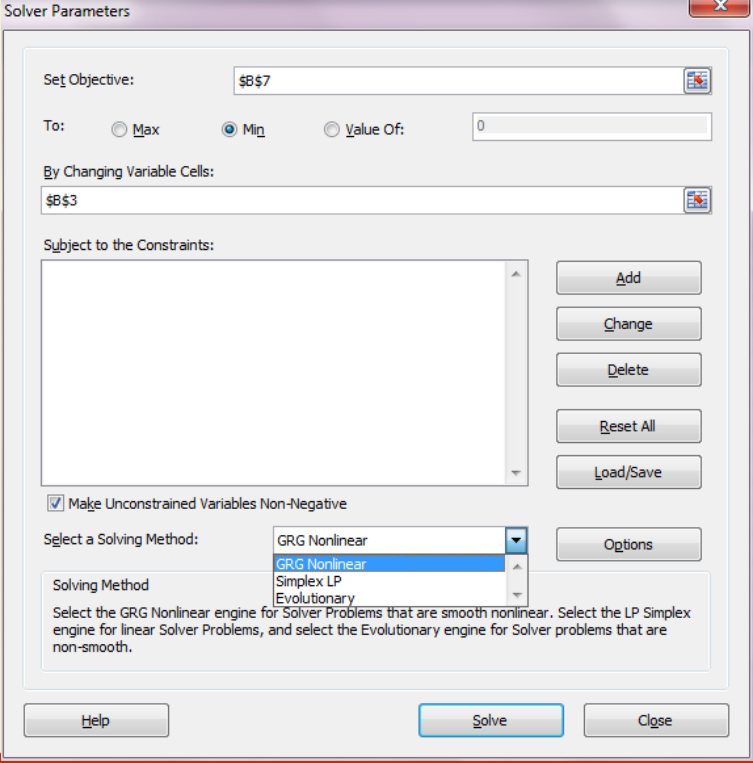
Steps: Excel Solver: Newer Version

We are ready to invoke Solver by choosing Data > Solver.

You will see a dialog box whose first entry is the information for the target cell (set objective function). Then choose Min. Then choose Changing variable Cell (x)

Make unconstrained variable non-negative ($x \geq 0$).

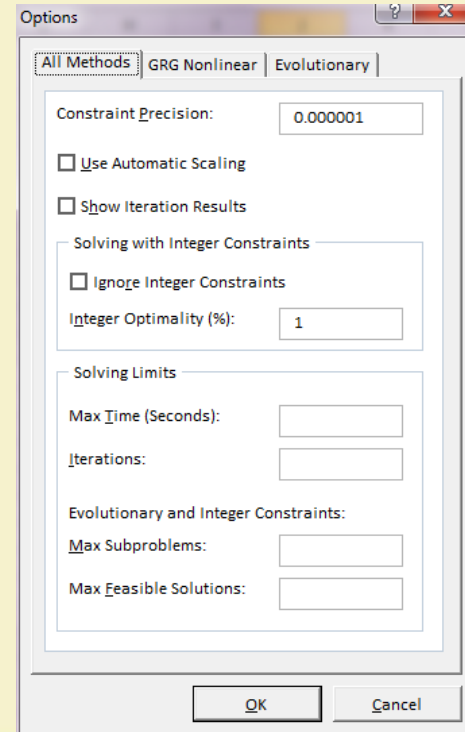
Select a Solving Method.



The image shows the 'Solver Parameters' dialog box in Microsoft Excel. The 'Set Objective:' field contains '\$B\$7'. The 'To:' section has three radio buttons: 'Max' (unselected), 'Min' (selected), and 'Value Of:' (unselected) with a text box containing '0'. The 'By Changing Variable Cells:' field contains '\$B\$3'. The 'Subject to the Constraints:' section is empty, with buttons for 'Add', 'Change', 'Delete', 'Reset All', and 'Load/Save' to its right. Below this, there is a checked checkbox for 'Make Unconstrained Variables Non-Negative'. The 'Select a Solving Method:' dropdown menu is open, showing 'GRG Nonlinear' (selected), 'Simplex LP', and 'Evolutionary'. Below the dropdown, there is a text box with instructions: 'Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.' At the bottom, there are buttons for 'Help', 'Solve', and 'Close'.

Steps: Excel Solver: Newer Version

Click into the Options box.

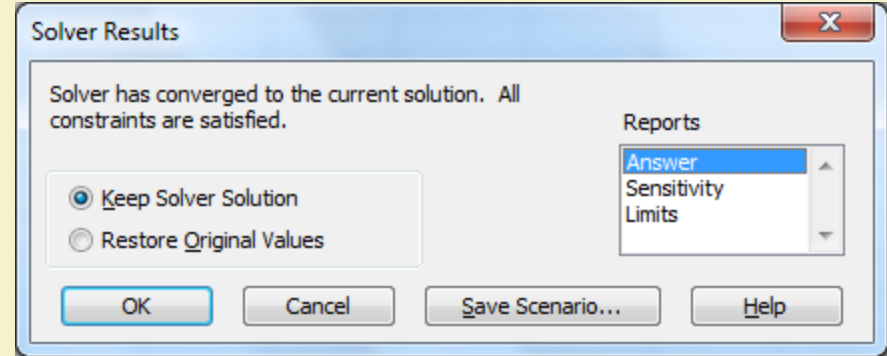


Steps to Solve the Problem Using Excel Solver

Click OK in the Options dialog box.

Click Solve in the Solver dialog box. You will get a dialog box stating that Solver found a solution.

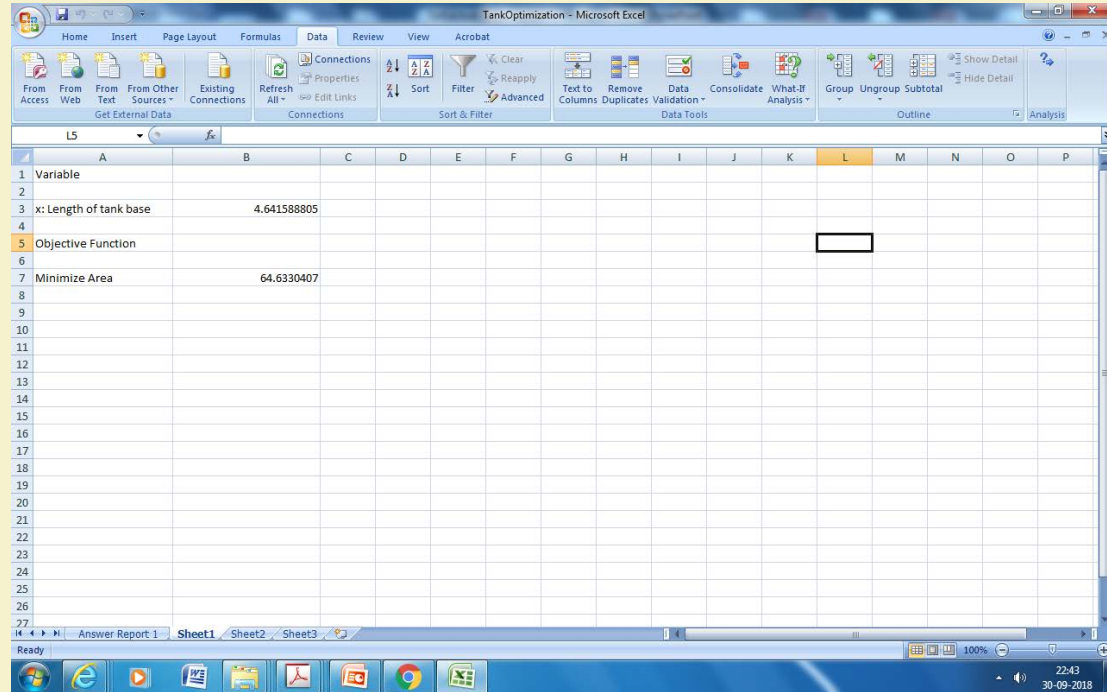
Check the Keep Solver Solution button and also select the Answer report.



Steps to Solve the Problem Using Excel Solver

Click OK.

Go back and examine the cells with the Variable and Objective Function. They should now contain the optimal solution for the problem.



Optimization With Excel Solver: Solution

1	Variable																	
2																		
3	x: Length of tank base	4.641588805																
4																		
5	Objective Function																	
6																		
7	Minimize Area	64.6330407																
8																		
9																		
10																		
11																		
12																		
13																		
14																		
15																		
16																		
17																		
18																		
19																		
20																		
21																		
22																		
23																		
24																		
25																		
26																		
27																		

Variable

x: Length of tank base 4.641588805

Objective Function

Minimize Area 64.6330407

Optimization With Excel Solver: Solution

Click on the worksheet labeled Answer Report to see a summary of the solution.

The screenshot displays the Microsoft Excel interface with the 'Answer Report' worksheet selected. The report provides a summary of the Solver solution for the 'TankOptimization.xlsx' file. The report includes the following sections:

- Target Cell (Min):** A table showing the original and final values for the target cell.
- Adjustable Cells:** A table showing the original and final values for the adjustable cells.
- Constraints:** A table showing the constraints applied to the solution.

Cell	Name	Original Value	Final Value
\$B\$7	Minimize Area	201	64.6330407

Cell	Name	Original Value	Final Value
\$B\$3	x: Length of tank base	1	4.641588805

Constraint
NONE

The bottom of the screenshot shows the Windows taskbar with various application icons and the system clock indicating 23:00 on 30-09-2018.

Optimization With Excel Solver: Solution

Worksheet: [TankOptimization.xlsx]Sheet1

Report Created: 30-09-2018 22:42:36

Worksheet: [TankOptimization.xlsx]Sheet1
Report Created: 30-09-2018 22:42:36

Target Cell (Min)			
Cell	Name	Original Value	Final Value
\$B\$7	Minimize Area	201	64.6330407

Adjustable Cells			
Cell	Name	Original Value	Final Value
\$B\$3	x: Length of tank base	1	4.641588805

Constraints			
Cell	Name	Original Value	Final Value
NONE			

Target Cell (Min)

Cell	Name	Original Value	Final Value
\$B\$7	Minimize Area	201	64.6330407

Adjustable Cells

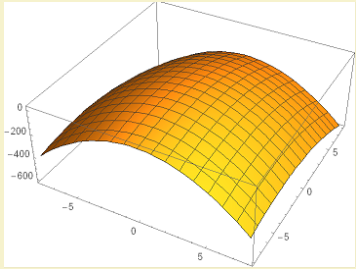
Cell	Name	Original Value	Final Value
\$B\$3	x: Length of tank base	1	4.641588805

Constraints

NONE

Optimization in Chemical Engineering

Thank You





IIT KHARAGPUR



NPTEL ONLINE
CERTIFICATION COURSES

OPTIMIZATION IN CHEMICAL ENGINEERING

Software Tools for Optimization

WEEK – 12: LECTURE – 57)

Dr. Debasis Sarkar

Department of Chemical Engineering
Indian Institute of Technology Kharagpur

Software Tools for Optimization

Week 12:

- MATLAB, EXCEL Solver for Optimization

Optimization With Excel: Example - 1

A Single Variable Unconstrained Optimization Problem

Optimization With Excel Solver: Example

Problem:

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 m^3 . Find the dimension of the tank that will require least amount of material (minimum cost).

Problem Formulation:

Let x = length of side of base
 y = height of tank

Amount of material required will depend on the total surface area of the tank.

$$A = x^2 + 4xy$$

$$\text{Now, Volume} = x^2 y = 50$$

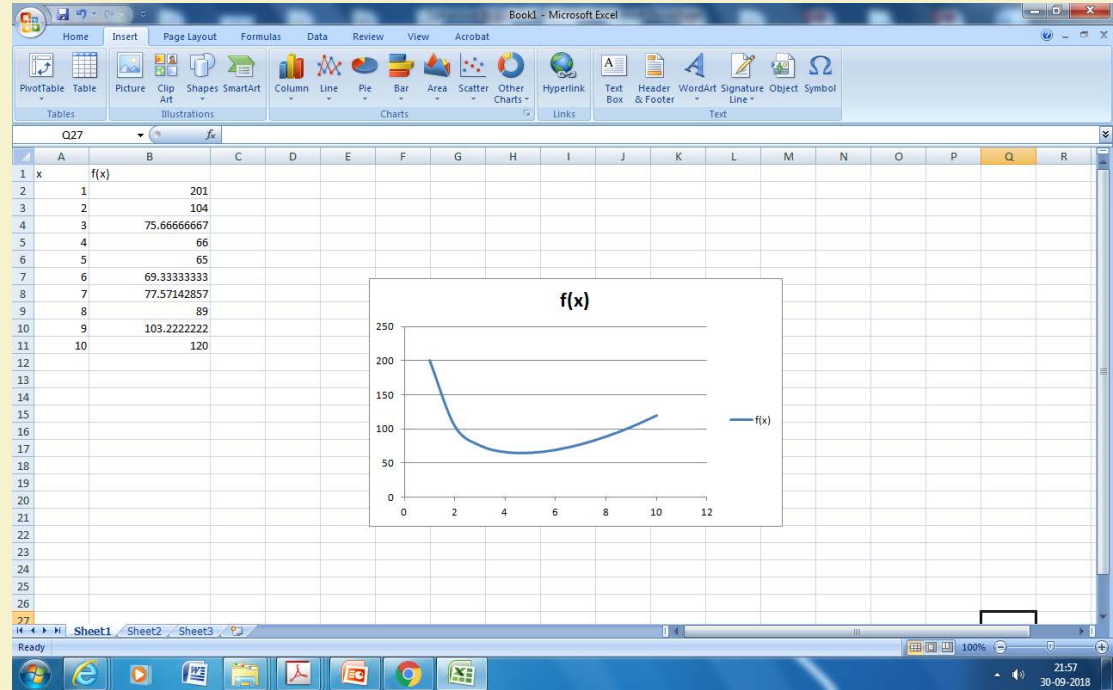
$$\Rightarrow y = \frac{50}{x^2}$$

$$\text{Minimize}_x A = x^2 + \frac{200}{x}$$

$$\text{Thus, } A = x^2 + 4x \left(\frac{50}{x^2} \right) = x^2 + \frac{200}{x}$$

Optimization With Excel Solver: Plot the Function

$$\text{Minimize}_x A = x^2 + \frac{200}{x}$$



Optimization With Excel Solver: Excel Basics

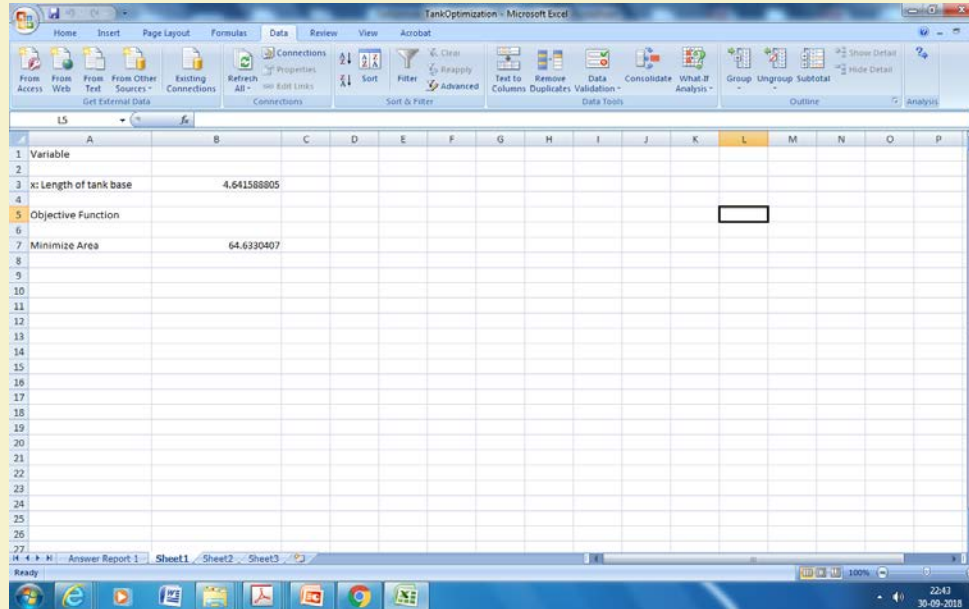
All the calculations in the spreadsheet are done with cell references. We must set up cell entries for the variable and the function we are optimizing.

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*.

Solve the Problem Using Excel Solver: Demonstration

Optimization With Excel Solver: Solution



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Variable															
2																
3	x: Length of tank base	4.641588805														
4																
5	Objective Function															
6																
7	Minimize Area	64.6330407														
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																

Variable

x: Length of tank base 4.641588805

Objective Function

Minimize Area 64.6330407

Optimization With Excel: Example - 2

A Multi-Variable Unconstrained Optimization Problem

Optimization With Excel Solver: Example - 2

$$\text{Minimize}_{x,y,z} f(x, y, z) = x^2 + 2y^2 + 2z^2 + 2xy + 2yz$$

Initial guess: $(x, y, z) = (1, 1, 1)$

True solution: $(x, y, z) = (0, 0, 0)$

Optimization With Excel: Example - 3

Nonlinear Constrained Optimization Problem

Optimization With Excel Solver: Example - 3

We wish to construct a closed storage tank (width = x , depth = y , height = z) with exactly 2700 m² metal sheet. The width of the tank should be double of its depth. What will be the dimension of the tank so that its volume is maximum?

Problem Formulation:

$$\text{Maximize } V = xyz$$

$$\text{Subject to: } 2xy + 2yz + 2xz = 2700$$

$$x = 2y$$

Optimization With Excel Solver: Example - 3

Solver Parameters

Set Objective:

To: ☒ Max ☐ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Buttons: Add, Change, Delete, Reset All, Load/Save, Options, Help, Solve, Close

Optimization With Excel Solver: Example - 3

The screenshot shows a Microsoft PowerPoint presentation titled 'OptLecture 57 [Compatibility Mode] - Microsoft PowerPoint'. The active slide is titled 'Optimization With Excel Solver: Example - 3' and describes a 'Nonlinear Constrained Optimization Problem'. The slide content includes:

- Variables: x, y, z
- Objective: Maximize $V = 29.99999991x + 14.99999996y + 20.00000012z$
- Constraints:
 - Constraint 1: $x + y + z \leq 9000$
 - Constraint 2: $x \leq 2700$
 - Constraint 3: $y \leq 2700$

The slide also includes a 'Thank You' message and a 'Click to add notes' prompt.

The embedded Excel spreadsheet (Book1 - Microsoft Excel) shows the following data:

	A	B	C	D	E	F	G	H	I	J	K	L
1	Variables											
2	x	29.99999991										
3	y	14.99999996										
4	z	20.00000012										
5	Objective											
6	Maximize V	9000										
7	Constraints											
8	Constraint 1	2700	EQ	2700								
9	Constraint 2	29.99999991	EQ	30								
10	Constraint 3											
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

Optimization With Excel Solver: Example - 3

Variables

x	29.99999991
y	14.99999996
z	20.00000012

Objective

Maximize V	9000
------------	------

Constraints

Constraint 1	2700	EQ	2700
Constraint 2	29.99999991	EQ	30
Constraint 3			

Microsoft Excel 14.0 Answer Report
Worksheet: [Book1]Sheet1
Report Created: 2018-10-03 11:35:45

Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
Solver Engine

Engine: GRG Nonlinear
Solution Time: 0.062 Seconds.
Iterations: 5 Subproblems: 0

Solver Options

Max Time Unlimited, Iterations Unlimited, Precision 0.000001
Convergence 0.0001, Population Size 100, Random Seed 0, Derivatives Central
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Max)

Cell	Name	Original Value	Final Value
\$B\$7	Maximize V	1	9000

Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$2	x	1	29.99999991	Contin
\$B\$3	y	1	14.99999996	Contin
\$B\$4	z	1	20.00000012	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$B\$10	Constraint 2	29.99999991	\$B\$10=\$D\$10	Binding	0
\$B\$9	Constraint 1	2700	\$B\$9=\$D\$9	Binding	0

Optimization With Excel Solver: Example – 3 Answer Report

Optimization With Excel Solver: Example - 4

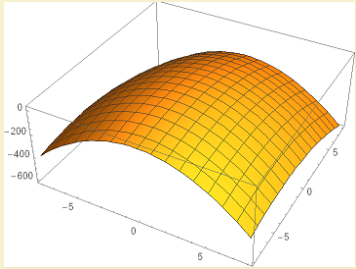
$$\text{Minimize } f = \frac{2}{xy^2}$$

$$\text{Subject to: } x^2 + y^2 - 6 = 0$$

$$\text{True solution: } x = \sqrt{2}, y = 2$$

Optimization in Chemical Engineering

Thank You





IIT KHARAGPUR



NPTEL ONLINE
CERTIFICATION COURSES

OPTIMIZATION IN CHEMICAL ENGINEERING

Software Tools for Optimization

(WEEK – 12: LECTURE – 58)

Dr. Debasis Sarkar

**Department of Chemical Engineering
Indian Institute of Technology Kharagpur**

Software Tools for Optimization

Week 12:

- MATLAB, EXCEL Solver for Optimization

Solution of LPP Using MS Excel Solver

Example:

$$\text{Maximize } f = x_1 - x_2 + 2x_3$$

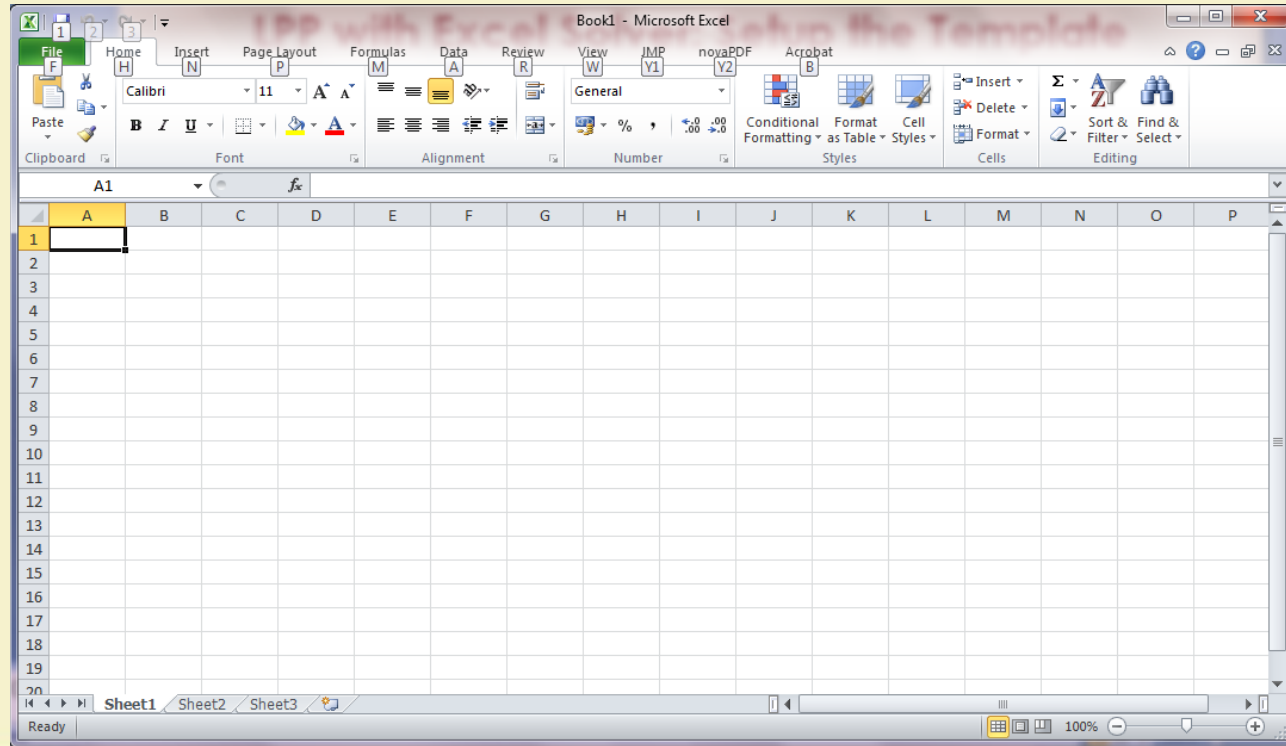
$$\text{Subject to: } 2x_1 + 3x_2 \leq 500$$

$$x_1 + x_2 + x_3 = 200$$

$$x_2 + 10x_3 \geq 100$$

$$x_1 \geq 0, x_2 \geq 30, x_3 \leq 4$$

Solution of LPP Using MS Excel Solver



LPP with Excel Solver: Setup the Template

After formulating the problem, we can now enter it into Excel.

A good approach to entering the problem into Excel is to use Column A to fill labels such as Upper Bound, Value, Lower Bound, Objective function, and Constraints. Expand the width of column A if necessary. In Columns B onwards, type variable names, RHS constraints, etc.

In cell A1, let us type something to identify this linear programming problem.

In Row 1, starting at column B and moving right, enter a name for each variable. Use one cell for one variable name. The labels can be descriptive, such as “Regular Fuel” , “Premium Fuel”, etc. The labels can also be generic, such as “Variable 1,” “Variable 2,” etc.

Move right, skip a cell and type “Evaluations”. Then skip a cell and type “RHS Constants”.

LPP with Excel Solver: Setup the Template

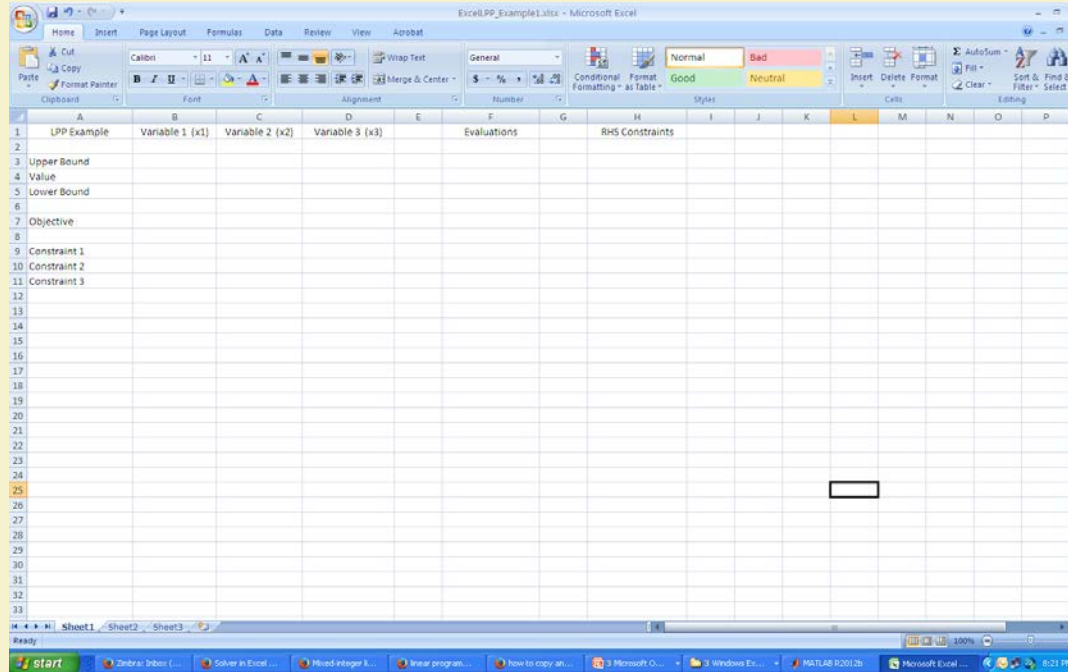
In cell A3, type “Upper Bound”. This row will contain upper bounds for the variables. You will be filling column A with labels.

In cell A4, type “Value”. This row will contain the values of the variables. This row will be adjusted by the solver in solving the problem.

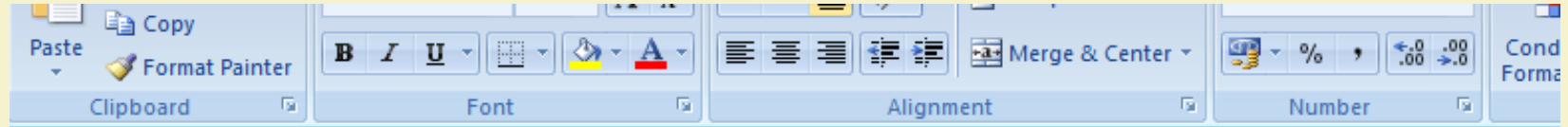
In cell A5, type “Lower Bound”. This row will contain the lower bounds for the variables.

In cell A7, type “Objective”. This row contains the cost coefficients in the objective function. Starting at cell A9 and moving downwards, add one label for each constraint. Each label can have a specific name (“Storage,” “Time,” etc) or a generic name such as “Constraint 1,” “Constraint 2,” etc.

LPP with Excel Solver: Setup the Template



LPP with Excel Solver: Setup the Template



	A	B	C	D	E	F	G	H
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (X3)		Evaluations		RHS Constants
2								
3	Upper Bound							
4	Value							
5	Lower Bound							
6								
7	Objective							
8								
9	Constraint 1							
10	Constraint 2							
11	Constraint 3							
12								

LPP with Excel Solver: Enter Data

Put values for Upper Bounds, and Lower Bounds.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (x3)		Evaluations		RHS Constraints								
2																
3	Upper Bound	1E+25	1E+25	4												
4	Value															
5	Lower Bound	0	30	0												
6	Objective															
7	Constraint 1															
8	Constraint 2															
9	Constraint 3															
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																
31																
32																
33																

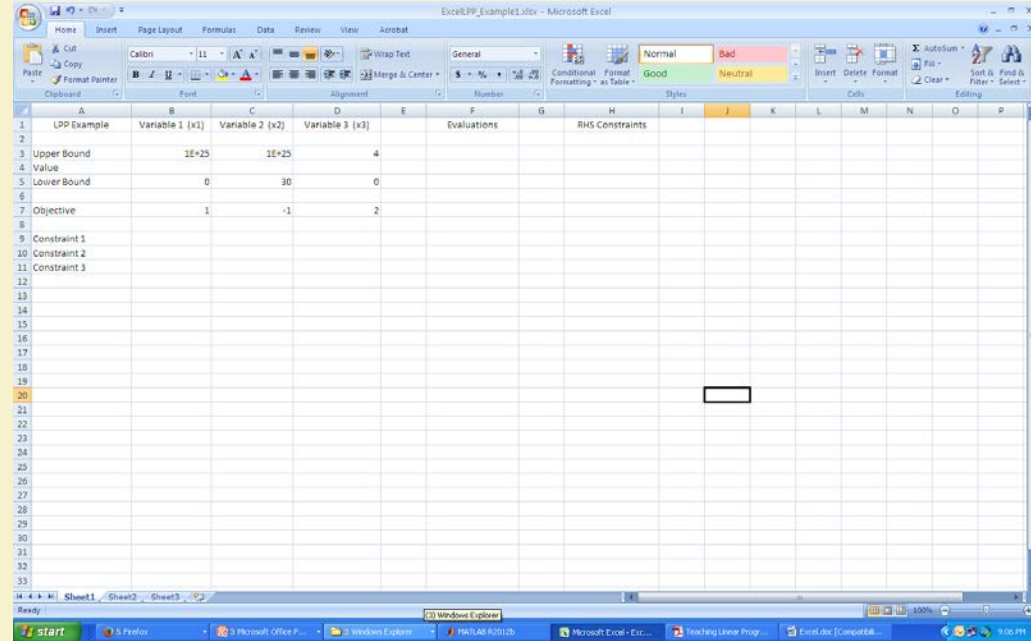
LPP with Excel Solver: Enter Data

J25								
	A	B	C	D	E	F	G	H
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (X3)		Evaluations		RHS Constants
2								
3	Upper Bound	1E+25	1.00E+25	4				
4	Value	0	0	0				
5	Lower Bound	0	30	0				
6								
7	Objective							
8								
9	Constraint 1							
10	Constraint 2							
11	Constraint 3							
12								

LPP with Excel Solver: Enter Data

Click on the cell B7 (“Objective” row). Row 7 will contain the cost coefficients for each variable. Enter zero if there is no cost coefficient for a variable.

Proceed to the right to fill Row 7
("Objective" row) with cost
coefficients until every column with a
variable name has a cost coefficient.



LPP with Excel Solver: Enter Data

M26 fx								
	A	B	C	D	E	F	G	H
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (X3)		Evaluations		RHS Constan
2								
3	Upper Bound	1E+25	1.00E+25	4				
4	Value	0	0	0				
5	Lower Bound	0	30	0				
6								
7	Objective	1	-1	2				
8								
9	Constraint 1							
10	Constraint 2							
11	Constraint 3							
12								

LPP with Excel Solver: Enter Constraint Coefficients

Start at Row 9 (“Constraint” row).
Enter the constraint coefficient of
each variable in the cell with the
matching column name.

Now skip two columns and enter
the sign of the constraint in the
cell. Enter either “<=”, “=”, or “>=”.
You can also enter: LE, EQ, or GE.
Now enter the number on the
right hand side of the constraint
equation.

The screenshot shows an Excel spreadsheet titled 'ExcelLPP_Example1.xlsx'. The data is organized as follows:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (x3)		Evaluations		RHS Constraints								
2	Upper Bound	1E+25	1E+25	4												
3	Value															
4	Lower Bound	0	30	0												
5	Objective	1	-1	2												
6																
7	Constraint 1	2	3	0		LE		500								
8	Constraint 2	1	1	1		EQ		200								
9	Constraint 3	0	1	10		GE		100								
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																
31																
32																
33																

LPP with Excel Solver: Enter Constraint Coefficients

<div> <div> From Access From Web From Text From Other Sources Existing Connections Refresh All Properties Edit Links Connections Sort Filter Reapply Advanced Text to Columns Remove Duplicates Data Validation </div> </div>									
G20 fx									
	A	B	C	D	E	F	G	H	
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (X3)		Evaluations		RHS Constants	
2									
3	Upper Bound	1E+25	1.00E+25	4					
4	Value	0	0	0					
5	Lower Bound	0	30	0					
6									
7	Objective	1	-1	2					
8									
9	Constraint 1	2	3	0			LE	500	
10	Constraint 2	1	1	1			EQ	200	
11	Constraint 3	0	1	10			GE	100	
12									

LPP with Excel Solver: Processing Objective Function

Now you have to put formula under “Evaluations” column for processing objective function.

Find the cell in Row 7 (“Objective”) that is also in the column labeled “Evaluations” and click on it. Type “=SUMPRODUCT(”, but do not press the Enter key.

Click on cell B4 (containing “Value”) and hold, dragging right across the row until every column with a variable name is inside the selection. Release the mouse button.

Press the comma key.

Click on cell B7 (containing “Objective”) and hold, dragging right across the row until every column with a variable name is inside the selection. Release the mouse button.

Type “)” and press the Enter key. The number zero should appear in the cell.

LPP with Excel Solver: Processing Constraint Functions

Now you have to put formula under “Evaluations” column for processing constraints.

Start at Row 9 (containing Constraint 1). Find the cell in current row that is also in the column labeled “Evaluations” and click on it. Type “=SUMPRODUCT(”.

Click on cell B4 (containing “Value”) and hold, dragging right across the row until every column with a variable name is inside the selection. Release the mouse button.

Press the comma key.

Click on the cell in the current row that is also in column B and hold, dragging right across the row until every column with a variable name is inside the selection. Release the mouse button. Type “)” and press the Return key. The number zero should appear in the cell.

Repeat this for all constraints.

LPP with Excel Solver: Processing Objective and Constraint Functions

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (x3)		Evaluations		RHS Constraints								
2																
3	Upper Bound	1E+25	1E+25	4												
4	Value															
5	Lower Bound	0	30	0												
6																
7	Objective	1	-1	2		0										
8																
9	Constraint 1	2	3	0		0	LE	500								
10	Constraint 2	1	1	1		0	EQ	200								
11	Constraint 3	0	1	10		0	GE	100								
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																
31																
32																
33																

LPP with Excel Solver: Processing Objective and Constraint

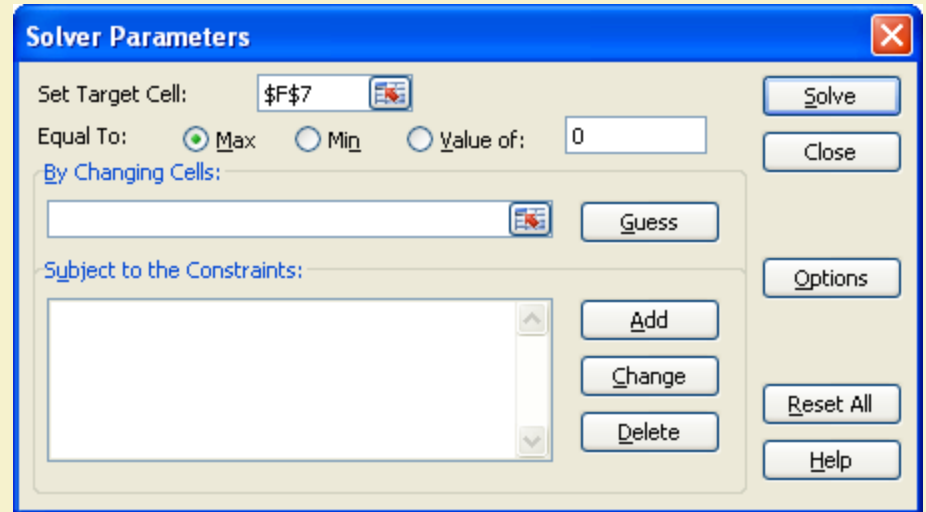
F22								
	A	B	C	D	E	F	G	H
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (X3)		Evaluations		RHS Constants
2								
3	Upper Bound	1E+25	1.00E+25	4				
4	Value	0	0	0				
5	Lower Bound	0	30	0				
6								
7	Objective	1	-1	2		0		
8								
9	Constraint 1	2	3	0		0	LE	500
10	Constraint 2	1	1	1		0	EQ	200
11	Constraint 3	0	1	10		0	GE	100
12								

LPP with Excel Solver: Use Solver

Now that the data entry section is done, you are ready to solve your problem.

From Data tab, click on Solver and the solver dialog appears.

Click on the cell in the objective row (Row 7) under the column heading “Evaluations.” The reference of the cell should be in the “Set Target Cell:” box.



LPP with Excel Solver: Use Solver

Solver Parameters

Set Objective:

To: ☒ Max ☐ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

Add

Change

Delete

Reset All

Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Options

Solving Method

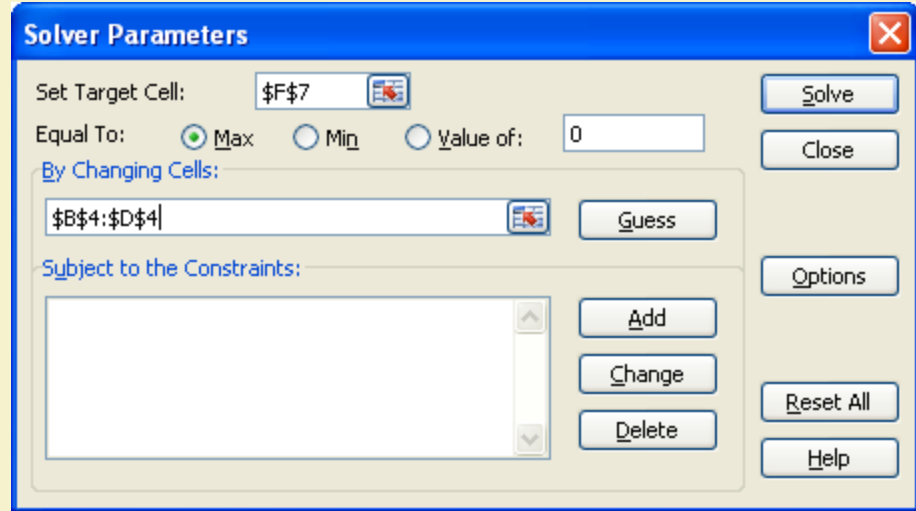
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Help Solve Close

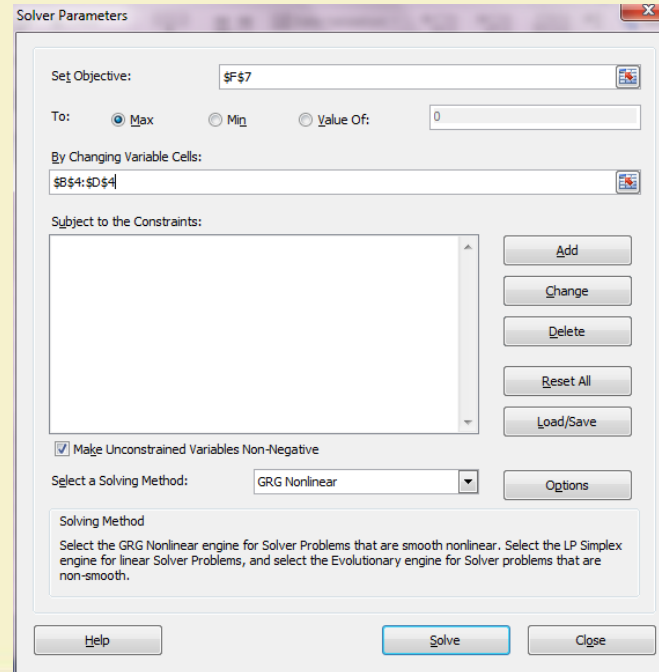
LPP with Excel Solver: Use Solver: Set Target/Changing Function

In the “Equal To:” section, decide whether you want to maximize or minimize the value in the cell by selecting the corresponding radio button.

Click inside the text box directly under the text “By Changing Cells:”. Select the adjustable cells, which is our “Value” row (Row 4).



LPP with Excel Solver: Use Solver: Set Target/Changing Function



The image shows the 'Solver Parameters' dialog box in Microsoft Excel. The 'Set Objective:' field is set to '\$F\$7'. The 'To:' section has three radio buttons: 'Max' (selected), 'Min', and 'Value Of:'. The 'Value Of:' field is set to '0'. The 'By Changing Variable Cells:' field is set to '\$B\$4:\$D\$4'. The 'Subject to the Constraints:' section is empty. To the right of this section are buttons for 'Add', 'Change', 'Delete', 'Reset All', and 'Load/Save'. Below the constraints section is a checkbox labeled 'Make Unconstrained Variables Non-Negative' which is checked. The 'Select a Solving Method:' dropdown is set to 'GRG Nonlinear'. To the right of this dropdown is an 'Options...' button. At the bottom of the dialog, there is a 'Solving Method' section with text explaining the different engines: 'Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.' At the very bottom are buttons for 'Help', 'Solve', and 'Close'.

Solver Parameters

Set Objective:

To: ☒ Max ☐ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Buttons: Add, Change, Delete, Reset All, Load/Save, Options, Help, Solve, Close

LPP with Excel Solver: Use Solver: Set Bounds

In the “Subject to the Constraints:” box, click “Add”. This is where the solver picks up on constraints. Let us first set the Upper Bounds.

Click the icon with the red arrow under the “Cell Reference:” text. This icon the leftmost of the two identical icons. Click and hold over cell B4 (“Value”), and drag to the right until all variables have been selected. Release the mouse button. Click the icon with the red arrow to go back to the constraint window. Select “<=” from dropdown menu.

Click the icon with the red arrow under the “Constraint:” text. This icon the rightmost of the two identical icons with red arrows. Click and hold over cell B3 (“Upper Bound”), and drag to the right until all variables have been selected. Release the mouse button.

Similarly, complete for the Lower Bounds. Choose $\geq$ from the dropdown menu.

LPP with Excel Solver: Use Solver: Set Constraints

Click the icon with a red arrow under the “Cell Reference:” text.

Click the cell in a constraint row that is also in the column under the “Evaluations” heading. Click the icon with the red arrow to go back to the constraints window.

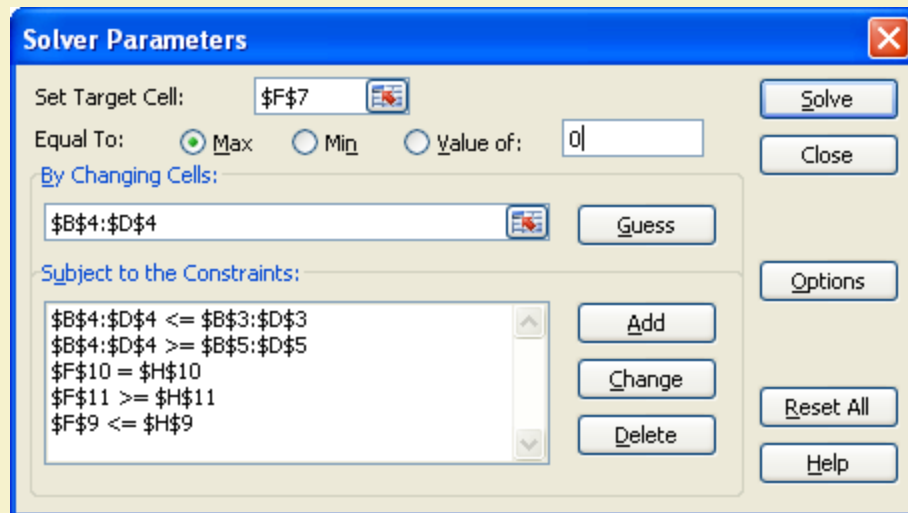
Select the matching entry ($\leq$, $=$, $\geq$) from the drop down list.

Click the icon with a red arrow under the “Constraint:” text. Click the cell in the same row as the cell you clicked above but in the column after the “RHS Constraint” heading.

Click the icon with the red arrow to return to the constraint window.

Click the “Add” button.

LPP with Excel Solver: Use Solver



The image shows the 'Solver Parameters' dialog box in Microsoft Excel. The 'Set Target Cell' is '\$F\$7'. The 'Equal To' section has three radio buttons: 'Max' (selected), 'Min', and 'Value of:'. The 'Value of' field contains '0'. The 'By Changing Cells' field contains '\$B\$4:\$D\$4'. The 'Subject to the Constraints' list contains five constraints: '\$B\$4:\$D\$4 <= \$B\$3:\$D\$3', '\$B\$4:\$D\$4 >= \$B\$5:\$D\$5', '\$F\$10 = \$H\$10', '\$F\$11 >= \$H\$11', and '\$F\$9 <= \$H\$9'. The 'Guess' button is next to the 'By Changing Cells' field. The 'Add', 'Change', and 'Delete' buttons are next to the constraints list. The 'Solve', 'Close', 'Options', 'Reset All', and 'Help' buttons are on the right side of the dialog box.

Solver Parameters

Set Target Cell: 

Equal To: ☒ Max ☐ Min ☐ Value of:

By Changing Cells: 

Subject to the Constraints:

-
-
-
-
-

LPP with Excel Solver: Use Solver

Solver Parameters

Set Objective:

To: ☒ Max ☐ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

\$B\$4:\$D\$4 <= \$B\$3:\$D\$3

\$B\$4:\$D\$4 >= \$B\$5:\$D\$5

\$F\$10 = \$H\$10

\$F\$11 >= \$H\$11

\$F\$9 <= \$H\$9

Add

Change

Delete

Reset All

Load/Save

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method

Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

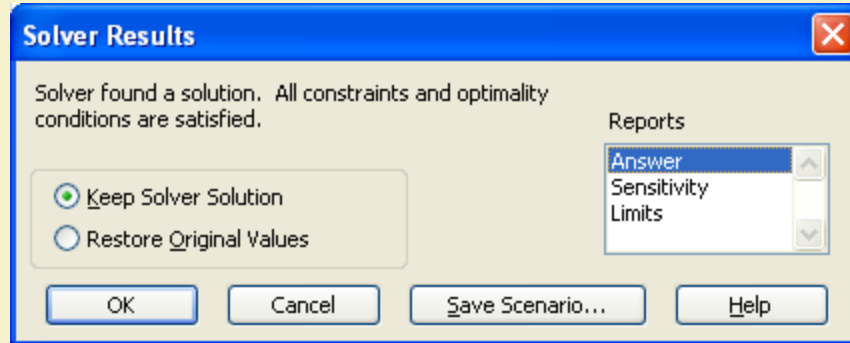
Help Solve Close

LPP with Excel Solver: Use Solver

Click the “Solve” button. Microsoft Excel will find the optimal solution to the problem that you specified.

Click “Keep Solver Solution”
and Click on “Answer”
under Reports.

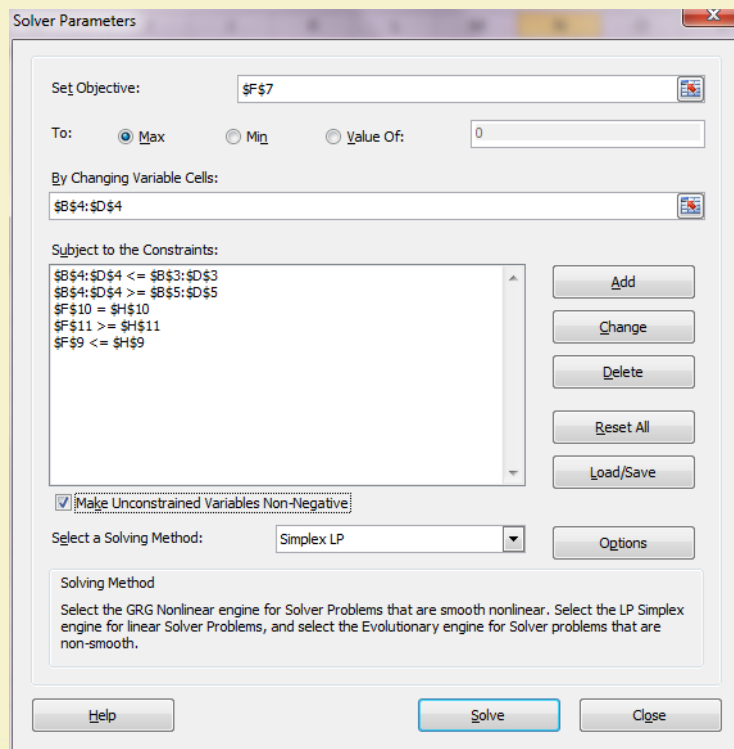
Click on Ok.



LPP with Excel Solver: Use Solver

Choose Simplex LP from the dropdown menu.

Click the “Solve” button.



The image shows the 'Solver Parameters' dialog box in Microsoft Excel. The 'Set Objective:' field contains '\$F\$7'. The 'To:' section has three radio buttons: 'Max' (selected), 'Min', and 'Value Of:'. The 'By Changing Variable Cells:' field contains '\$B\$4:\$D\$4'. The 'Subject to the Constraints:' list contains four constraints: '\$B\$4:\$D\$4 <= \$B\$3:\$D\$3', '\$B\$4:\$D\$4 >= \$B\$5:\$D\$5', '\$F\$10 = \$H\$10', '\$F\$11 >= \$H\$11', and '\$F\$9 <= \$H\$9'. To the right of the list are buttons for 'Add', 'Change', 'Delete', 'Reset All', and 'Load/Save'. Below the constraints list is a checked checkbox for 'Make Unconstrained Variables Non-Negative'. The 'Select a Solving Method:' dropdown is set to 'Simplex LP'. Below this is a 'Solving Method' section with explanatory text. At the bottom are 'Help', 'Solve', and 'Close' buttons.

Solver Parameters

Set Objective:

To: ☒ Max ☐ Min ☐ Value Of:

By Changing Variable Cells:

Subject to the Constraints:

- \$B\$4:\$D\$4 <= \$B\$3:\$D\$3
- \$B\$4:\$D\$4 >= \$B\$5:\$D\$5
- \$F\$10 = \$H\$10
- \$F\$11 >= \$H\$11
- \$F\$9 <= \$H\$9

☒ Make Unconstrained Variables Non-Negative

Select a Solving Method:

Solving Method

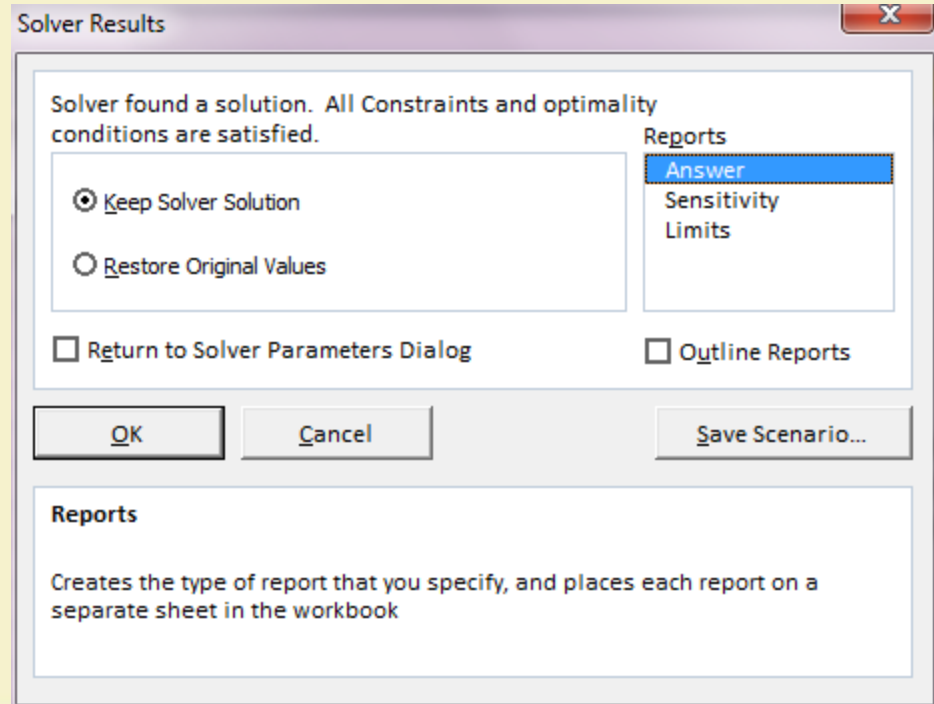
Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.

Buttons: Add, Change, Delete, Reset All, Load/Save, Options, Help, Solve, Close

LPP with Excel Solver: Use Solver

Microsoft Excel will find the optimal solution to the problem that you specified.

Click “Keep Solver Solution” and
Click on “Answer” under Reports.
Click on Ok.



LPP with Excel Solver: Solution

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (x3)		Evaluations		RHS Constraints								
2																
3	Upper Bound	1E+25	1E+25	4												
4	Value	136.0000002	60	4												
5	Lower Bound	0	30	0												
6																
7	Objective	1	-1	2		84.00000023										
8																
9	Constraint 1	2	3	0		452.0000005	LE	500								
10	Constraint 2	1	1	1		200.0000002	EQ	200								
11	Constraint 3	0	1	10		100	GE	100								
12																
13																
14																
15																
16																
17																
18																
19																
20																
21																
22																
23																
24																
25																
26																
27																
28																
29																
30																
31																
32																
33																

LPP with Excel Solver: Solution

<div> <div> From Access From Web From Text From Other Sources Existing Connections Refresh All Properties Edit Links Connections Sort Filter Advanced Text to Columns Remove Duplicates Data Validation </div> <div> N14 fx </div> </div>									
	A	B	C	D	E	F	G	H	I
1	LPP Example	Variable 1 (x1)	Variable 2 (x2)	Variable 3 (X3)		Evaluations		RHS Constants	
2									
3	Upper Bound	1E+25	1.00E+25	4					
4	Value	136	60	4					
5	Lower Bound	0	30	0					
6									
7	Objective	1	-1	2		84			
8									
9	Constraint 1	2	3	0		452	LE	500	
10	Constraint 2	1	1	1		200	EQ	200	
11	Constraint 3	0	1	10		100	GE	100	

Microsoft Excel 14.0 Answer Report
 Worksheet: [ExcelLPP_Example.xlsx]Sheet1
 Report Created: 2018-10-04 21:57:17
 Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
 Solver Engine
 Engine: Simplex LP
 Solution Time: 0 Seconds.
 Iterations: 3 Subproblems: 0
 Solver Options
 Max Time Unlimited, Iterations Unlimited, Precision
 0.000001
 Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume
 NonNegative

LPP with Excel Solver: Answer Report

Objective Cell (Max)

Cell	Name	Original Value	Final Value
\$F\$7	Objective Evaluations	0	84

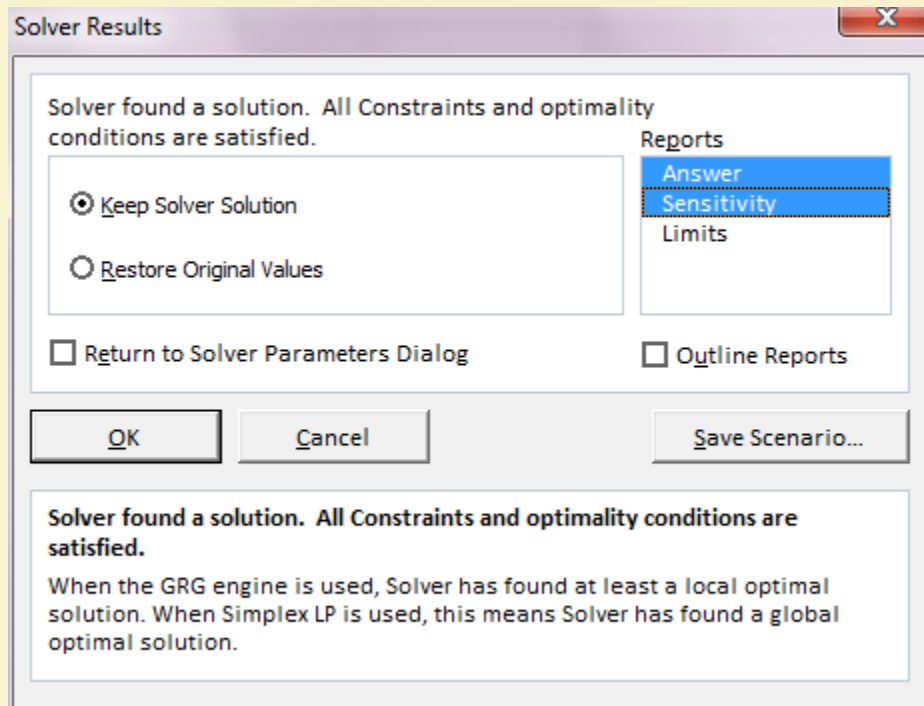
Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$4	Value Variable 1 (x1)	0	136	Contin
\$C\$4	Value Variable 2 (x2)	0	60	Contin
\$D\$4	Value Variable 3 (X3)	0	4	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$F\$10	Constraint 2 Evaluations	200	\$F\$10≤\$H\$10	Binding	0
\$F\$11	Constraint 3 Evaluations	100	\$F\$11≥\$H\$11	Binding	0
\$F\$9	Constraint 1 Evaluations	452	\$F\$9≤\$H\$9	Not Binding	48
\$B\$4	Value Variable 1 (x1)	136	\$B\$4≤\$B\$3	Not Binding	1E+25
\$C\$4	Value Variable 2 (x2)	60	\$C\$4≤\$C\$3	Not Binding	1E+25
\$D\$4	Value Variable 3 (X3)	4	\$D\$4≤\$D\$3	Binding	0
\$B\$4	Value Variable 1 (x1)	136	\$B\$4≥\$B\$5	Not Binding	136
\$C\$4	Value Variable 2 (x2)	60	\$C\$4≥\$C\$5	Not Binding	30
\$D\$4	Value Variable 3 (X3)	4	\$D\$4≥\$D\$5	Not Binding	4

LPP with Excel Solver: Solution



LPP with Excel Solver: Sensitivity Report

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
\$B\$4	Value Variable 1 (x1)	136	0	1	1E+30	2
\$C\$4	Value Variable 2 (x2)	60	0	-1	2	1E+30
\$D\$4	Value Variable 3 (X3)	4	21	2	1E+30	21

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
\$F\$10	Constraint 2 Evaluations	200	1	200	24	136
\$F\$11	Constraint 3 Evaluations	100	-2	100	48	30
\$F\$9	Constraint 1 Evaluations	452	0	500	1E+30	48

Sensitivity analysis gives you insight in how the optimal solution changes when you change the coefficients of the model.

Solution of LPP Using MS Excel Solver

Demonstration:

$$\text{Maximize } f = x_1 - x_2 + 2x_3$$

$$\text{Subject to: } 2x_1 + 3x_2 \leq 500$$

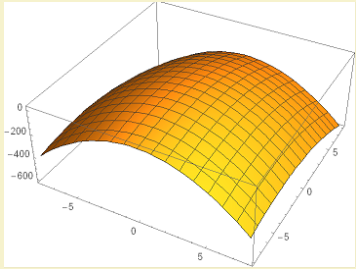
$$x_1 + x_2 + x_3 = 200$$

$$x_2 + 10x_3 \geq 100$$

$$x_1 \geq 0, x_2 \geq 30, x_3 \leq 4$$

Optimization in Chemical Engineering

Thank You





IIT KHARAGPUR



NPTEL ONLINE
CERTIFICATION COURSES

OPTIMIZATION IN CHEMICAL ENGINEERING

Software Tools for Optimization

(WEEK – 12: LECTURE – 59)

Dr. Debasis Sarkar

**Department of Chemical Engineering
Indian Institute of Technology Kharagpur**

Software Tools for Optimization

Week 12:

- MATLAB, EXCEL Solver for Optimization

Solution of LPP Using MS Excel Solver

Demonstration:

$$\text{Maximize } f = x_1 - x_2 + 2x_3$$

$$\text{Subject to: } 2x_1 + 3x_2 \leq 500$$

$$x_1 + x_2 + x_3 = 200$$

$$x_2 + 10x_3 \geq 100$$

$$x_1 \geq 0, x_2 \geq 30, x_3 \leq 4$$

Microsoft Excel 14.0 Answer Report
 Worksheet: [ExcelLPP_Example.xlsx]Sheet1
 Report Created: 2018-10-04 21:57:17
 Result: Solver found a solution. All Constraints and optimality conditions are satisfied.
 Solver Engine
 Engine: Simplex LP
 Solution Time: 0 Seconds.
 Iterations: 3 Subproblems: 0
 Solver Options
 Max Time Unlimited, Iterations Unlimited, Precision
 0.000001
 Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume
 NonNegative

LPP with Excel Solver: Answer Report

Objective Cell (Max)

Cell	Name	Original Value	Final Value
\$F\$7	Objective Evaluations	0	84

Variable Cells

Cell	Name	Original Value	Final Value	Integer
\$B\$4	Value Variable 1 (x1)	0	136	Contin
\$C\$4	Value Variable 2 (x2)	0	60	Contin
\$D\$4	Value Variable 3 (X3)	0	4	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
\$F\$10	Constraint 2 Evaluations	200	\$F\$10<=\$H\$10	Binding	0
\$F\$11	Constraint 3 Evaluations	100	\$F\$11>=\$H\$11	Binding	0
\$F\$9	Constraint 1 Evaluations	452	\$F\$9<=\$H\$9	Not Binding	48
\$B\$4	Value Variable 1 (x1)	136	\$B\$4<=\$B\$3	Not Binding	1E+25
\$C\$4	Value Variable 2 (x2)	60	\$C\$4<=\$C\$3	Not Binding	1E+25
\$D\$4	Value Variable 3 (X3)	4	\$D\$4<=\$D\$3	Binding	0
\$B\$4	Value Variable 1 (x1)	136	\$B\$4>=\$B\$5	Not Binding	136
\$C\$4	Value Variable 2 (x2)	60	\$C\$4>=\$C\$5	Not Binding	30
\$D\$4	Value Variable 3 (X3)	4	\$D\$4>=\$D\$5	Not Binding	4

LPP with Excel Solver: Sensitivity Report

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
\$B\$4	Value Variable 1 (x1)	136	0	1	1E+30	2
\$C\$4	Value Variable 2 (x2)	60	0	-1	2	1E+30
\$D\$4	Value Variable 3 (X3)	4	21	2	1E+30	21

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
\$F\$10	Constraint 2 Evaluations	200	1	200	24	136
\$F\$11	Constraint 3 Evaluations	100	-2	100	48	30
\$F\$9	Constraint 1 Evaluations	452	0	500	1E+30	48

Sensitivity analysis gives you insight in how the optimal solution changes when you change the coefficients of the model.

LPP with Excel Solver: Sensitivity Report

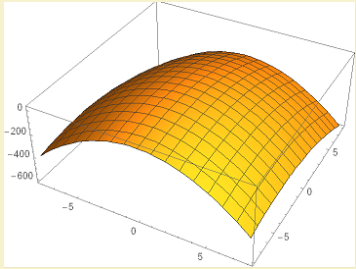
A reduced cost tells us how much an objective function coefficient must be improved before the corresponding decision variable gets a value different from zero.

Objective function coefficient ranges.

Excel defines a shadow price as the amount by which the objective function value changes when the corresponding constraints right side increases by one unit.

Optimization in Chemical Engineering

Thank You





IIT KHARAGPUR



NPTEL ONLINE
CERTIFICATION COURSES

OPTIMIZATION IN CHEMICAL ENGINEERING

Software Tools for Optimization

(WEEK – 12: LECTURE – 60)

Dr. Debasis Sarkar

**Department of Chemical Engineering
Indian Institute of Technology Kharagpur**

Software Tools for Optimization

Week 12:

➤ MATLAB, EXCEL Solver for Optimization

Today's Topic:

An introduction to Solution of Integer Programming Problems

Optimization Problems with Integer Variables

Many optimization problems (such as plant operation, design, scheduling, etc) involve variables that take only integer values (0, 1, 2, etc). For example, optimum number of trays, number of processing units, etc.

Again, in some problems decision variables take only 0 or 1 value. For example, to use a particular type of reactor or not.

Sometimes we can treat integer variables as if they were continuous and round the optimal solution to the nearest integer value. Say $150.3 \rightarrow 150$. But what about 1.3?

Also, this procedure leads to a suboptimal solution.

Optimization Problems with Integer Variables

Mixed Integer Programming (MIP) problem:

Here the objective function depends on two sets of decision variables: x and y . x is a vector of continuous variables and y is a vector of integer variables. **Two types: MILP, MINLP**

Integer Programming Problems (IP):

A problem involving only integer variables is classified as an integer programming (IP) problem

Binary Integer Programming (BIP):

A special case of IP is binary integer programming (BIP), in which all of the variables take are either 0 or 1 values.

Optimization Problems with Integer Variables: Examples

The Knapsack Problem: We have n objects. Each has different weight and value. Select a subset of the objects such that their total weight does not exceed W (the capacity of the knapsack) and their total value is a maximum. Note the use of 1 or 0 variable.

Blending problem: There is a list of possible ingredients to be blended into a product. The list contains the weight, value, cost, and analysis of each ingredient. Select from the list a set of ingredients so as to have a blend with satisfactory total weight and analysis at minimum cost. Note the use of 1 or 0 variable.

Also, Plant Location Problem, The Travelling Salesman Problem: involves (0 or 1) variables.

Branch and Bound Method using LP Relaxation

Branch and bound (BB) is a class of methods for linear and nonlinear mixed-integer programming. If carried out systematically up to completion, it is guaranteed to find an optimal solution to linear and convex nonlinear problems.

Consider a general MILP problem in which all the integer variables are binary (either 0 or 1). We can relax the "0 or 1" constraint to "anywhere between 0 and 1" and can get a standard LPP. This is called the LP relaxation of the MILP.

The first step of BB method is to solve this LP relaxation problem. If the solution contains all integer values, then this is the solution for the original MILP. If not, one or more decision variables will have fractional value. Then BB chooses one of these variables in its branching step and then creates two LP sub-problems by fixing this variable first at 0, then at 1.

Branch and Bound Method using LP Relaxation

If either of these sub-problems has a solution with all integer values, it need not be investigated further. If its objective value is better than the best value found thus far, it replaces this best value. If either sub-problem is infeasible, it need not be investigated further. Otherwise, we find another fractional variable and repeat the steps.

Binary Integer Programming Problems: Branch and Bound Method using LP Relaxation: Example

$$\text{Maximize } f = 86x_1 + 4x_2 + 40x_3$$

$$\text{Subject to: } 774x_1 + 76x_2 + 42x_3 \leq 875$$

$$67x_1 + 27x_2 + 53x_3 \leq 875$$

$$x_1, x_2, x_3 = (0,1)$$

Edgar, Himmelblau, and
Lasdon (2nd Edition)

Branch and Bound Method

Upper bound = 129.1

Lower bound = $-\infty$

No incumbent

1

$$0 \leq x_1 \leq 1$$

$$0 \leq x_2 \leq 1$$

$$0 \leq x_3 \leq 1$$

$$x^* = (1, 0.776, 1)$$

$$f = 129.10$$

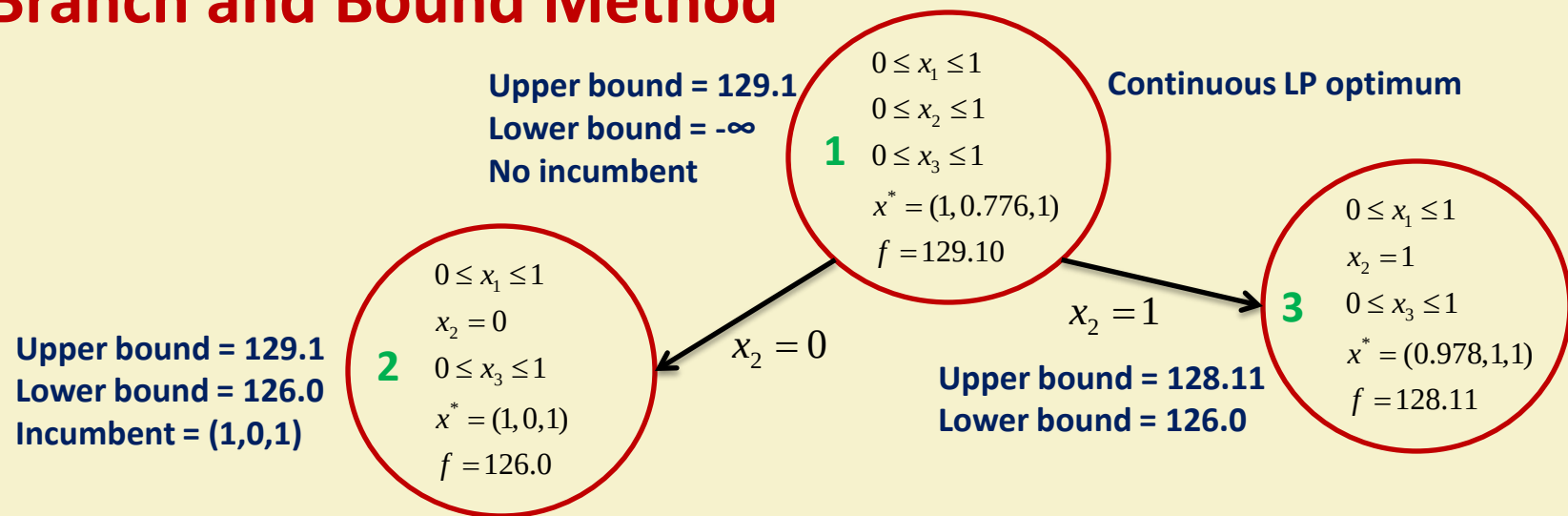
Continuous LP optimum

The first step is to solve the LP relaxation of the binary IP. The optimal solution has one fractional (non-integer) variable (x_2) and an objective function value of 129.1.

Because the feasible region of the relaxed problem includes the feasible region of the initial IP problem, 129.1 is an upper bound on the value of the objective function of the IP.

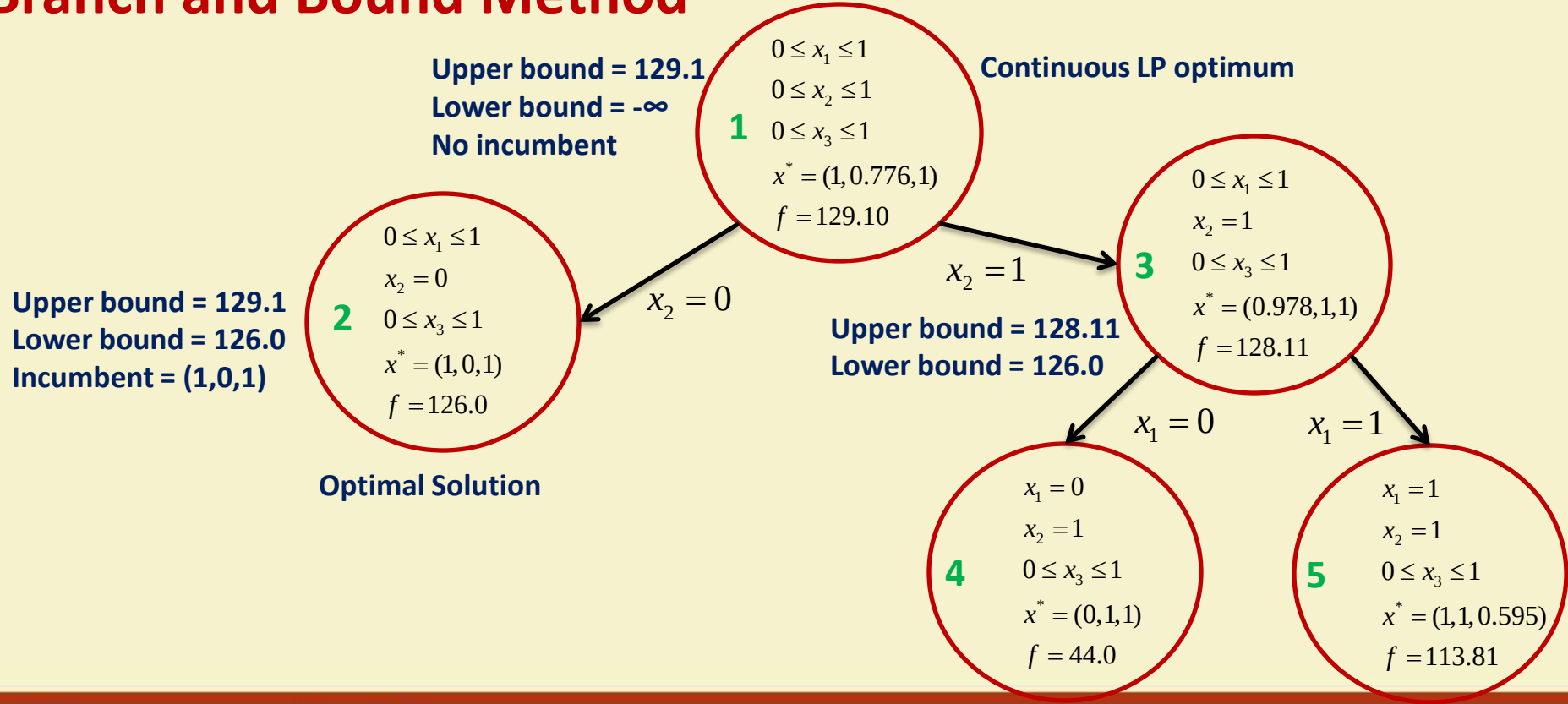
The lower bound is set to $-\infty$.

Branch and Bound Method



At node 1, only x_2 is fractional variable. Thus any feasible integer solution must satisfy either $x_2 = 0$ or $x_2 = 1$. We create two new relaxations represented by nodes 2 and 3 by imposing these two integer constraints. The process of creating these two relaxed sub-problems is called branching. Two new sub-problems are now solved by LP method.

Branch and Bound Method



Optimization in Chemical Engineering

Thank You

