Working with Templates

1 The Idea of Templates

The idea of templates can be traced back to the Greek mathematician Heron of Alexandria, who lived 2,000 years ago. Heron wrote several books, including a few meant for mechanical engineers. In these books, he presented solutions to practical engineering problems in such an illustrative manner that readers could solve similar problems simply by substituting their data in clearly designated places in his calculations.[1] In effect, his solutions were **templates** that others could use to solve similar problems with ease and confidence.

Heron's templates helped engineers by removing the tedium required to find the right formulas and the right sequence of calculations to solve a given problem. But the tedium of hand calculations endured. Over the years, abacuses, slide rules, electromechanical calculators, and electronic calculators lessened it. But even electronic calculators have a lot of buttons to be pressed, each presenting the chance for error. With the advent of computers and spreadsheets, even that tedium has been overcome.

A **spreadsheet template** is a specially designed workbook that carries out a particular computation on any data, requiring little or no effort beyond entering the data in designated places. Spreadsheet templates completely remove the tedium of computation and thus enable the user to concentrate on other aspects of the problem, such as sensitivity analysis or decision analysis. **Sensitivity analysis** refers to the examination of how the solution changes when the data change. **Decision analysis** refers to the evaluation of the available alternatives of a decision problem in order to find the best alternative. Sensitivity analyses are useful when we are not sure about the exact value of the data, and decision analyses are useful when we have many decision alternatives. In most practical problems, there will be uncertainty about the data; and in all decision problems, there will be two or more decision alternatives. The templates can therefore be very useful to students who wish to become practical problem solvers and decision makers.

Another kind of tedium is the task of drawing charts and graphs. Here too spreadsheet templates can completely remove the tedium by automatically drawing necessary charts and graphs.

The templates provided with this book are designed to solve statistical problems using the techniques discussed in the book and can be used to conduct sensitivity analyses and decision analyses. To conduct these analyses, one can use powerful features of Excel–the Data|Table command, the Goal Seek command, and the Solver macro are explained in this chapter. Many of the templates contain charts and graphs that are automatically created.

The Dangers of Templates and How to Avoid Them

As with any other powerful tool, there are some dangers with templates. The worst danger is the **black box** issue: the use of a template by someone who does not know the concepts behind what the template does. This can result in continued ignorance about those concepts as well as the application of the template to a problem to which it should not be applied. Clearly, students should learn the concepts behind a template before using it, so this textbook explains all the concepts before presenting the templates. Additionally, to avoid the misuse of templates, wherever possible, the necessary conditions for using a template are displayed on the template itself.

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[1] Morris Klein, *Mathematics in Western Culture* (New York: Oxford University Press, 1953), pp. 62–63.

Another danger is that a template may contain errors that the user is unaware of. In the case of hand calculations, there is a good chance that the same error will not be made twice. But an error in a template is going to recur every time it is used and with every user. Thus template errors are quite serious. The templates provided with this book have been tested for errors over a period of several years. Many errors were indeed found, often by students, and have been corrected. But there is no guarantee that the templates are error-free. If you find an error, please communicate it to the authors or the publisher. That would be a very good service to a lot of people.

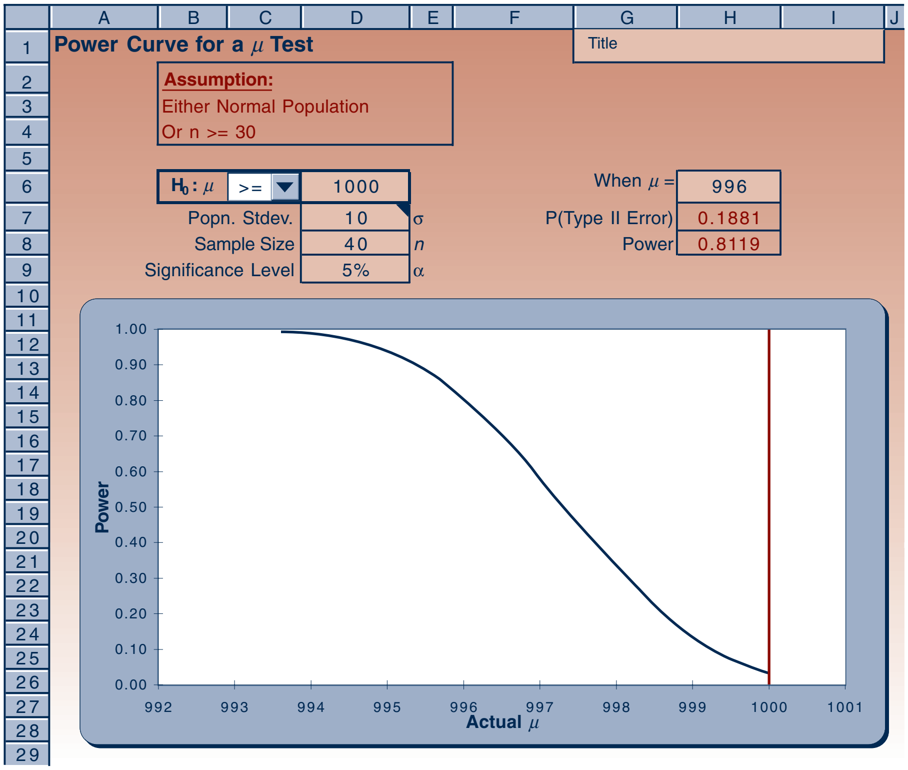
A step that has been taken to minimize the dangers is the avoidance of macros. *No macros* have been used in any of the templates. The user can view the formula in any cell by clicking on that cell and looking at the formula bar. By viewing all the formulas, the user can get a good understanding of the calculations performed by the template. An added advantage is that one can detect and correct mistakes or make modifications more easily in formulas than in macros.

Conventions Employed in the Templates

Figure 1 is a sample template that computes the power of a hypothesis test (from Chapter 7). The first thing to note is the name of the workbook and the name of the sheet where you can locate this template. These details are given in square brackets immediately following the caption. This particular template is in the workbook named "Testing Population Mean.xls" and within that workbook this template is on the sheet named "Power." If you wish, you may open the template right now and look at it.

Several conventions have been employed to facilitate proper use of the templates. On the Student CD, *the areas designated for data entry are generally shaded in green.*

FIGURE 1 **A Sample Template**
[Testing Population Mean.xls; Sheet: Power]



In Figure 1, the cell H6[2] and the range D6:D9[3] appear shaded in green, and therefore are meant for data entry. The range G1:I1, also shaded in green, can be used for entering a title for the problem solved on the template.

Important results appear in red fonts; in the present case the values in the cells H7 and H8 are results and they appear in red (on the computer screen). Intermediate results appear in black. In the present case, there is no such result.

Instructions and necessary assumptions for the use of a template appear in magenta. On this template, the assumptions appear in the range B2:E4.[4] The user should make sure that the assumptions are satisfied before using the template. To avoid crowding of the template with all kinds of instructions, some instructions are placed in **comments** behind cells. A red marker at the upper right corner of a cell indicates the presence of a comment behind that cell. Placing the pointer on that cell will pop up the comment. Cell D7 in the figure has a comment. Such comments are usually instructions that pertain to the content of that cell.

A template may have a **drop-down box**, in which the user will need to make a selection. There is a drop-down box in the figure in the location of cell C6. Drop-down boxes are used when the choice has to be one of a few possibilities. In the present case, the choices are the symbols =, <=, and >=. In the figure >= has been chosen. The user makes the choice based on the problem to be solved.

A template may have a **chart** embedded in it. The charts are very useful for visualizing how one variable changes with respect to another. In the present example, the chart depicts how the power of the test changes with the actual population mean μ. An advantage with templates is that such charts are automatically created, and they are automatically updated when data change.

2 Working with Templates

If you need an introduction to Excel basics, read the "Introduction to Excel Basics.[2]"

Protecting and Unprotecting a Sheet

The computations in a template are carried out by **formulas** already entered into many of its cells. To protect these formulas from accidental erasure, all the cells except the (blue-shaded) data cells are "**locked**." The user can change the contents of only the unlocked data cells. If for some reason, such as having to correct an error, you want to change the contents of a locked cell, you must first **unprotect** the sheet. To unprotect a sheet, use the Unprotect Sheet command under the Changes group on the Review tab. Once you have made the necessary changes, make it a habit to reprotect the sheet using the Protect Sheet command under the Changes group on the Review tab. When protecting a sheet in this manner, you will be asked for a **password**. *It is better not to use any password.* Just leave the password area blank. If you use a password, you will need it to unprotect the sheet. If you forget the password, you cannot unprotect the sheet.

Entering Data into the Templates

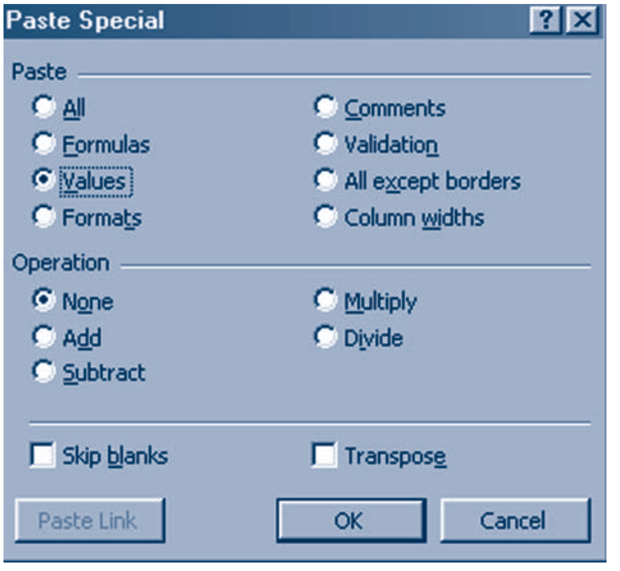
A good habit to get into is to *erase all old data* before entering new data into a template. To erase the old data, select the range containing the data and press the Delete key on the keyboard. *Do not type a space to remove data.* The computer will treat the space character as data and will try to make sense out of it rather than ignore it. This can give rise to error messages or, worse, erroneous results. Always use the Delete key to delete any data. Also make sure that you erase only the old data and nothing else.

[2] H6 refers to the cell at the intersection of Row 6 and Column H.

[3] Range D6:D9 refers to the rectangular area from cell D6 to cell D9.

[4] Range B2:E4 refers to the rectangular area with cell B2 at top left and cell E4 at bottom right.

FIGURE 2 Dialog Box of Paste Special Command

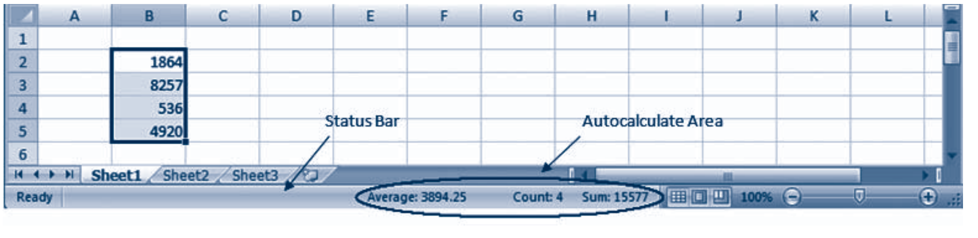


At times your new data may already appear on another spreadsheet. If so, copy that data using the Copy command on the Home tab. Select the area where you want it pasted and use the **Paste Special** command. In the dialog box that appears (see Figure 2), select Values under Paste and None under Operation and then click the OK button. This will avoid any unwanted formulas or formats in the copied data getting pasted into the template. Sometimes the copied data may be in a *row,* but you may want to paste it into a *column,* or vice versa. In this case, the data need to be transposed. When you are in the Paste Special dialog box, additionally, select the Transpose box under Operation.

3 The Autocalculate Command

The bar at the bottom of a spreadsheet screen image is known as the **status bar.** In the status bar there is an area, known as the **Autocalculate** area, that can be used to quickly calculate certain statistics such as the sum or the average of several numbers. Figure 3 shows a spreadsheet in which a range of cells has been selected by dragging the mouse over them. In the Autocalculate area, the average of the numbers in the selected range appears. If the numbers you want to add are not in a single range, use the CTRL+click method to select more than one range of cells.

FIGURE 3 The Autocalculate Area in the Status Bar



4 The Data|Table Command

When a situation calls for comparing many alternatives at once, a tabulation of the results makes the comparison easy. Many of the templates have built-in comparison tables. In others, an exercise may ask you to create one yourself. On the Data tab, in the Data Tools group, click What-If Analysis, and then click Data Table to create such tables.

In Figure 4, sales figures of a company have been calculated for years 2004 to 2008 using an annual growth rate of 2%, starting with 316 in year 2004. [In cell C5, the formula `=B5*(1+$C$2)` has been entered and copied to the right.] Suppose we are not sure about the growth rate and believe it may be anywhere between 2% and 7%. Suppose further we are interested in knowing what the sales figures would be in the years 2007 and 2008 at different growth rates. In other words, we want to input many different values for the growth rate in cell C2 and see its effect on cells E5 and F5. It is best seen as a table shown in the range D8:F13. To create this table,

- Enter the growth rates 2%, 3%, etc., in the range D8:D13.
- Enter the formula `=E5` in cell E8 and `=F5` in cell F8.
- Select the range D8:F13.
- On the Data tab, in the Data Tools group, click What-If Analysis, and then click Data Table.
- In the dialog box that appears, in the Column Input Cell box, type `C2` and press Enter. (We use the Column Input Cell rather than Row Input Cell because the input values are in a column, in the range D8:D13.)
- The desired table now appears in the range D8:F13. It is worth noting here that this table is "live," meaning that if any of the input values in the range D8:D13 are changed, the table is immediately updated. Also, the input values could have been calculated using formulas or could have been a part of another table to the left.

In general, the effect of changing the value in *one* cell on the values of one or more other cells can be tabulated using the Data Table command of What-If Analysis. At times, we may want to tabulate the effect of changing *two* cells. In this case we can tabulate the effect on only one other cell. In the previous example, suppose that

FIGURE 4 Creating a Table

	A	B	C	D	E	F
1						
2	Annual growth rate		2%			
3						
4	Year	2004	2005	2006	2007	2008
5	Sales	316	322	329	335	342
6						
7				Growth Rate	2007 Sales	2008 Sales
8				2%	335	342
9				3%	345	356
10				4%	355	370
11				5%	366	384
12				6%	376	399
13				7%	387	414

FIGURE 5 **Creating a Two-Dimensional Table**

	A	B	C	D	E	F	G
1							
2	Annual growth rate		2%				
3							
4	**Year**	**2004**	**2005**	**2006**	**2007**	**2008**	
5	**Sales**	316	322	329	335	342	
6							
7					**2004 Sales**		
8		342	**316**	**318**	**320**	**322**	**324**
9		**2%**	342	344	346	349	351
10		**3%**	356	358	360	362	365
11	**Growth**	**4%**	370	372	374	377	379
12	**Rate**	**5%**	384	387	389	391	394
13		**6%**	399	401	404	407	409
14		**7%**	414	417	419	422	425

in addition to the growth rate we are not sure about the starting sales figure of 316 in year 2004, and we believe it could be anywhere between 316 and 324. Suppose further that we are interested only in the sales figure for year 2008. A table varying both the growth rate and 2004 sales has been calculated in Figure 5.

To create the table in Figure 5,

- Enter the input values for growth rate in the range B9:B14.
- Enter the input values for 2004 sales in the range C8:G8.
- Enter the formula `=F5` in cell B8. (This is because we are tabulating what happens to cell F5.)
- Select the range B8:G14.
- On the Data tab, in the Data Tools group, click What-If Analysis, and then click Data Table.
- In the dialog box that appears enter `B5` in the Row Input Cell box and `C2` in the Column Input Cell box and press `Enter`.

The table appears in the range B8:G14. This table is “live” in that when any of the input values is changed the table updates automatically. The appearance of `342` in cell B8 is distracting. It can be hidden by either changing the text color to white or formatting the cell with `;;`. Suitable borders also improve the appearance of the table.

5 The Goal Seek Command

The **Goal Seek** command can be used to change a numerical value in any cell, called the **changing cell**, to make the numerical value in another cell, called the **target cell**, reach a “goal.” Clearly, the value in the target cell must depend on the value in the changing cell for this scheme to work. In the previous example, suppose we are interested in finding the growth rate that would attain the goal of a sales value of 400 in year 2008. (We assume the sales in 2004 to be 316.) One way to do it is to manually change the growth rate in cell C2 up or down until we see 400 in cell F5. But that would be tedious, so we automate it using the Goal Seek command as follows:

- Select What-If Analysis in the Data Tools group on the Data tab. Then select the Goal Seek command. A dialog box appears.
- In the Set Cell box enter `F5`.
- In the To Value box enter `400`.

- In the By Changing Cell box enter `C2`.
- Click OK.

The computer makes numerous trials and stops when the value in cell F5 equals 400 accurate to several decimal places. The value in cell C2 is the desired growth rate, and it shows up as 6.07%.

6 The Solver Macro

The Solver tool is a giant leap forward from the Goal Seek command. It can be used to make the value of a target cell equal a predetermined value or, more commonly, reach its maximum or minimum possible value, by changing the values in *many* other changing cells. In addition, some constraints can be imposed on the values of selected cells, called **constrained cells**, such as restricting a constrained cell's value to be, say, between 10 and 20. Note that the Solver can accommodate many changing cells and many constrained cells, and is thus a very powerful tool.

Solver Installation

Since the Solver macro is very large, it will not be installed during the installation of Excel or Office software unless you specifically ask for it to be installed. Before you can use the Solver, you therefore have to determine if it has been installed in your computer and "added in." If it hasn't been, then you need to install it and add it in.

To check if it has already been installed and added in, click on the Data tab (and make sure the menu is opened out fully). If the command "Solver . . ." appears in the menu, you have nothing more to do. If the command does not appear in the menu, then the Solver has not been installed or perhaps has been installed but not added in. Click on the Microsoft Office button, and then click Excel Options. Then click Add-ins. In the Manage box, select Excel Add-ins, click Go. Then in the Add-ins Available box, select the Solver Add-ins check box. Click OK. If Solver is not listed in the Add-ins Available box, click Browse to locate it.

If the file is present, open it. This action will add in the Solver and after that the "Solver . . ." command will appear under the Tools menu. If the Solver.xla file is not available, it means the Solver has not been installed in the computer. You have to get the original Excel or Office CD, go through the setup process, and install the Solver files. Find the Solver.xla file (c:\Program files\Microsoft Office\office\library\Solver\Solver.xla) and open it. After that, the "Solver . . ." command will appear under the Tools menu. If you are using Excel in your workplace and the Solver is not installed, then you may have to seek the help of your Information Systems department to install it.

In all the templates that use the Solver, the necessary settings for the Solver have already been entered. The user merely needs to press **Solve** in the Solver dialog box (see Figure 7), and when the problem is solved, the user needs to click Keep Solver Solution in a message box that appears.

Just to make you a little more comfortable with the use of the Solver, let's consider an example. A production manager finds that the cost of manufacturing 100 units of a product in batches of x units at a time is $4x + 100/x$. She wants to find the most economic batch size. (This is a typical economic batch size problem, famous in production planning.) In solving this problem, we note that there is a constraint, namely, x must be between 0 and 100. Mathematically, we can express the problem as

$$\begin{aligned} &\text{Minimize} && 4x + 100/x \\ &\text{Subject to} && x >= 0 \\ & && x <= 100 \end{aligned}$$

FIGURE 6 **Solver Application**

	A	B	C	D
1				
2		Batch size	10	
3		Cost	50	=4*C2+100/C2

We set up the problem as shown in Figure 6:

- In cell C3 the formula `=4*C2+100/C2` has been entered. The batch size in cell C2 can be manually changed and corresponding cost can be read off from cell C3. A batch size of 20, for instance, yields a cost of 85; a batch size of 2 yields a cost of 58. To find the batch quantity that has the least cost, we use the Solver as follows.
- Under the Analysis group on the Data tab, select the Solver… command.
- In the Solver dialog box, enter `C3` in the Set Cell box.
- Click Minimum (because we want to minimize the cost).
- Enter `C2` in the Changing Cells box.
- Click Add to add a constraint.
- In the dialog box that appears, click the left-hand-side box and enter `C2`.
- In the middle drop down box, select `>=`.
- Click the right-hand-side box, enter `0`, and click Add. (We click on the Add button because we have one more constraint to add.)
- In the new dialog box that appears click the left-hand-side box and enter `C2`.
- In the middle drop down box, select `<=`.
- Click the right-hand-side box, enter `100`, and click OK. (The Solver dialog box should reappear as in Figure 7.)
- Click Solve.

The Solver carries out a sophisticated computation process internally and finds the solution, if one exists. When the solution is found, the Solver Results dialog box

FIGURE 7 **The Solver Dialog Box**

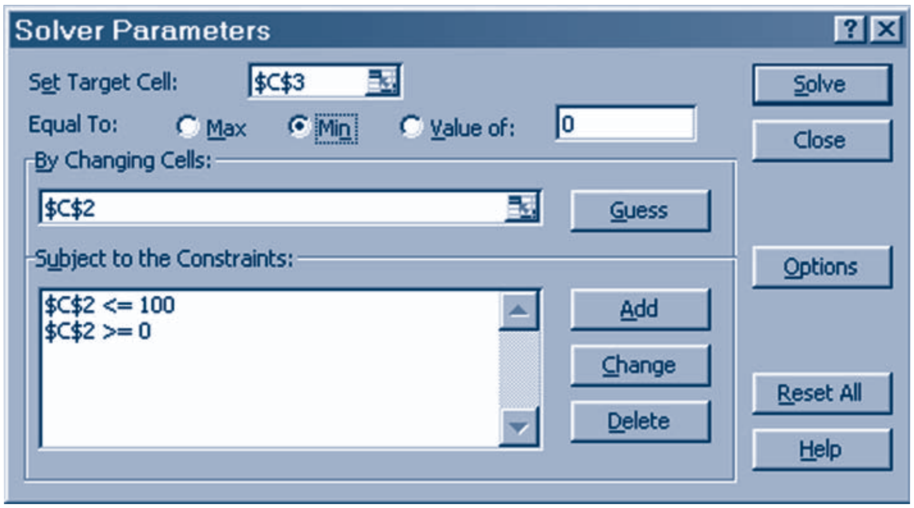
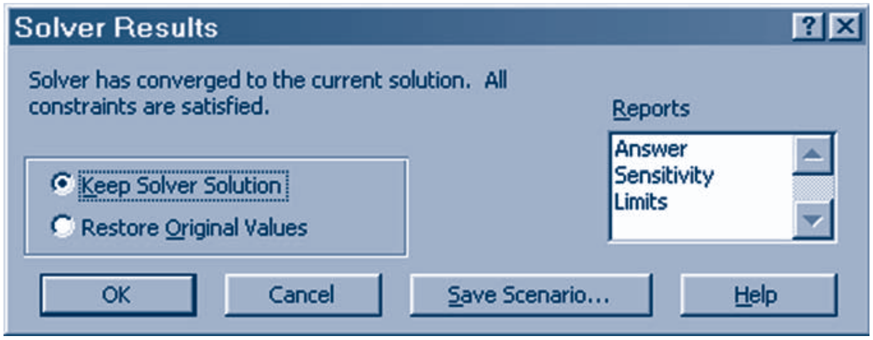


FIGURE 8 **Solver Solution Dialog Box**



appears (see Figure 8). It asks if you want to keep the solution or retain the original values for batch quantity and cost. Select Keep Solver Solution and click OK. The solution is a batch size of 5, which has the least cost of 40. The full solution appears on the spreadsheet.

Some comments about the Solver are appropriate here. First, it is a very powerful tool. A great variety of problems can be modeled on a spreadsheet and solved using this tool.

Second, not all problems may be solvable, particularly when the constraints are so restrictive that no feasible solution can be reached. In this case, some constraints must be removed or relaxed. Another possibility is that the solution may diverge to positive or negative infinity. In this case, the Solver will flash a message about divergence and abort the calculation.

Third, a problem may have more than one solution. In this case, the Solver will find only one of them and stop.

Fourth, the problem may be too large for the Solver. Although the manuals claim that a problem with 200 variables and 200 constraints can be solved, restricting the problem size to not more than 50 variables and 50 constraints may be safer.

Last, entering the constraints has some syntax rules and some shortcuts. A constraint line may read `A1:A20 <= B1:B20`. This is a shortcut for A1 <= B1; B1 <= B2; and so on. In effect, 20 constraints have been entered in one line. Also, `A1:A20 <= 100` would imply A1 <= 100; A2 <= 100; and so on. One of the syntax rules is that the left-hand side of a constraint, as entered into the Solver, cannot be a number but must be a reference to a cell or a range of cells. For instance, C2 <= 100 cannot be entered as 100 >= C2, although they mean the same thing.

For further details about the Solver tool, you may consult online help or the Excel manual.

EXAMPLE 1

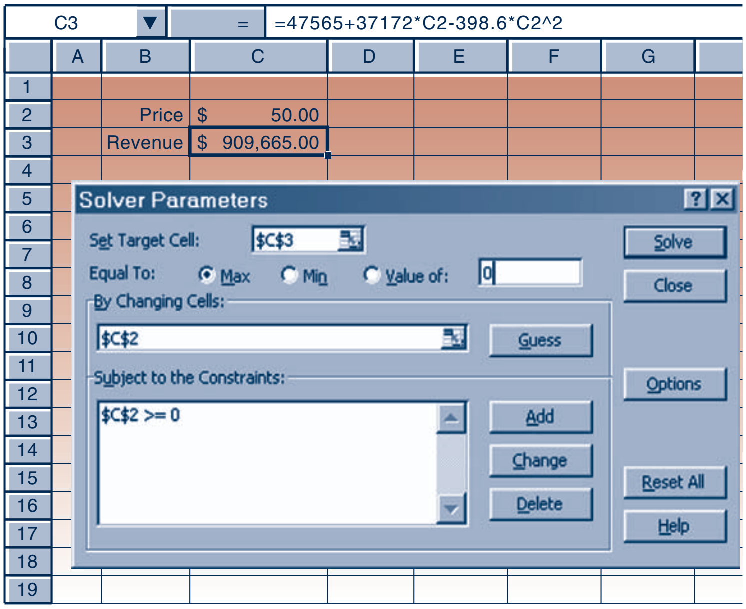
The annual sales revenue in dollars from a product varies with its price in dollars, p, according to the formula

$$\text{Annual sales revenue} = 47{,}565 + 37{,}172p - 398.6p^2$$

a. Find the annual sales revenue when the price is \$50.00.

b. Find the price that would maximize the annual sales revenue. What is the maximized revenue?

FIGURE 9 **Example 1**



Solution The spreadsheet setup is shown in Figure 9. The formula in cell C3 appears in the formula bar at the top of the figure.

a. Entering a value of $50.00 in cell C2 gives the annual sales revenue as $909,665.00.

b. The Solver parameters are set up as shown in the figure. When the Solve button is pressed, we find that the price that would maximize revenue is $46.63. The maximized revenue at this price is $914,196.70.

7 Some Formatting Tips

If you find a cell filled with ########, you know that the cell is not wide enough to display its contents. To see the contents, you should unprotect the sheet and widen the column. (Reprotecting the sheet after that is a good habit.)

Excel displays very large numbers and very small numbers in **scientific format**. For example, the number 1,234,500,000 will be displayed as `1.2345E+09`. The "E+09" at the end means that the decimal point needs to be moved 9 places to the right. In the case of very small numbers Excel once again uses the scientific format. For example, the number 0.0000012345 will be displayed as `1.2345E-06` where the "E−06" signifies that the decimal point is to be moved 6 places to the left.

If you do not wish to see the numbers in scientific format, widening the column might help. In the case of very small numbers you may format the cell, using the Format Cells command in the Cells group on the Home tab to display the number in decimal form with any desired number of decimal places. For all probability values that appear in the templates, four decimal places are recommended.

Many templates contain graphs. The axes of the graphs are set to rescale automatically when the plotted values change. Yet, at times, the scale on an axis may have to be adjusted. To adjust the scale, you have to first unprotect the sheet. Then double-click on the axis and format the scale as needed. (Once again, reprotect the sheet when you are done.)

8 Saving the Templates

All the templates discussed in this textbook are available on the CD. They are stored in the folder named Templates. It is recommended that you save these templates in your computer's hard drive in a suitably named folder, say, c:\Stat Templates.

REVIEW ACTIVITIES

1. While working with a template, you find that a cell displays ######## instead of a numerical result. What should you do to see the result?

2. While working with a template a probability value in a cell appears as 4.839E−04. What should you do to see it as a number with four decimal places?

3. The scale on the axis of a chart in a template starts at 0 and ends at 100. What should you do to make it start at 50 and end at 90?

4. You want to copy a *row* of data from a spreadsheet into a *column* in the data area of a template. How should this be done?

5. Why are the nondata cells in a template locked? How can they be unlocked? Mention a possible reason for unlocking them.

6. How can you detect if a cell has a comment attached to it? How can you view the comment?

7. Suppose an error has been found in the formula contained in a particular cell of a template, and a corrected formula has been announced. Give a step-by-step description of how to incorporate the correction on the template.

8. How many target cells, changing cells, and constrained cells can be there when the Solver is used?

9. How many target cells, changing cells, and constrained cells can be there when the Goal Seek command is used?

10. What is the "black box" issue in the use of templates? How will you, as a student, avoid it?

11. Find the average of the numbers 78, 109, 44, 38, 50, 11, 136, 203, 117, and 34 using the AutoCalculate feature of Excel.

12. A company had sales of $154,000 in the year 2005. The annual sales are expected to grow at a rate of 4.6% every year.

a. What is the projected sales total for the year 2008?

b. If the annual growth rate is 5%, what is the projected sales total for the year 2008?

c. At what rate should the sales grow if the projected sales figure for the year 2008 is to be $200,000?

13. The productivity of an automobile assembly-line worker who works x hours per week, measured in dollars per day, is given by the formula

$$1248.62 + 64.14x - 0.92x^2$$

a. What is the productivity of a worker who works 40 hours per week?

b. Use the Solver to find the number of hours per week that yields the maximum productivity.

14. For a meal at a restaurant your check is $43.80. Use the Tip Amount.xls template to answer the following questions.

a. You wish to give a 15% tip. What is the total amount you pay? What is the tip amount?

b. If you paid $50.00, what percentage of the check amount did you give as a tip?