

Introduction to Mathcad

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April 12, 2005

Preface

The Mathcad environment offers a blend of computation, visualization, symbolic manipulation and documentation to provide a "self-documenting" worksheet for problem investigation and solution. In fact, the document you are reading was composed entirely in Mathcad.

There's a lot to learn if you want to get the most out of Mathcad, and we strongly encourage you to examine the Tutorials and QuickSheets available from the Mathcad Resources area of the software installation (see the Help menu or the Resources drop-down selector). In order to get up to speed with simple computations and documentation, this introduction examines the following aspects of using Mathcad:

- The basic rules for typing text and mathematical expressions.
- The various forms of the "equals" symbol as it is used in evaluation and assignment.
- The left-to-right and top-to-bottom sequencing of calculations.
- Some common Mathcad techniques, shortcuts and hints, you will really want to know.

Getting Started With Simple Text and Calculation

A Mathcad worksheet looks much like a document opened in a conventional WYSIWYG word processor, however precisely what you type has important effects upon the actions Mathcad takes. At a very basic level, a Mathcad worksheet is a collection of various regions (containing text, equations, graphics and other items) arranged in a single or multiple page document. When you first examine a Mathcad worksheet, you'll notice a red plus sign, **+**, which indicates the current location at which a new region can be inserted. You can use the mouse or keyboard arrow keys to move this input indicator to any location on the spreadsheet, including an unoccupied locale (to begin entering a new region) or an already occupied spot (to edit or modify an existing region).

To begin to enter pure text, such as each of the regions you've seen so far in this document, you can either...

- Press the double quote key, **"**, then continue to type, or
- Press the space bar either as the first character or immediately following an initial word.

To conclude a text region, select some other region with the mouse or press the following...

- **Ctrl-Shift-Enter** (to close a text region)

You'll know you are typing into a text region if the cursor (a vertical bar, |) is red. In a calculation or math region, the cursor will be a blue bar, |.

To see all or a few different arithmetic operators to insert into the Mathcad document click on **View** from the toolbar, in the menu hold the mouse over **Toolbars** and select **Math**. Now in the toolbar you will see symbols for...

- Calculator
- Vector and Matrix
- Evaluation
- Calculus
- Boolean
- Programming
- Graphing
- Greek
- Keywords

By clicking on the symbol a new small window comes up with all the basic math functions for that category.

If you start a new region with any other keystrokes, Mathcad will attempt to interpret your input as a mathematical assignment or computation. We can try some examples now. In this worksheet, I have high-lighted each Mathcad mathematical/computation region in light gray background. Every other region is text, including specific keystroke sequences required to obtain the mathematics/computation shown adjacent.

Type the following in a new region: $3+4/5=$ (note, no spaces between keys). You should obtain the following results.

$$3 + \frac{4}{5} = 3.8$$

Note that once you pressed the "=" keystroke, Mathcad completed the calculation for you (that is, the "3.8" was automatically generated by Mathcad. To exit from a calculation region, all that you need to do is press the Enter key. Be sure that you have started a new region, don't just add the mathematics into a text region (Mathcad won't do any computation or completion of formulae for you in that case).

Next example, type this in a new region: $3+4 /5=$ (note the space after the 4).

$$\frac{3+4}{5} = 1.4$$

Notice the effect of the space following the 4. You'll soon get the hang of carefully moving around elements of your calculations by carefully inserted spaces.

Here's another example, note the spaces after the 2's: $5/2 + \sqrt{5/2}^2 - 4=$

$$\frac{5}{2} + \sqrt{\left(\frac{5}{2}\right)^2} - 4 = 4$$

Next, re-type this example by eliminating all of the spaces following the 2's, that is, type the following: $5/2+\sqrt{5/2}^2-4=$

$$\frac{5}{2 + \sqrt{\frac{5}{2^{2-4}}}} = 0.773$$

Dealing With the Variety of "Equal" Signs

So far, we have dealt with only one form of the "=" keystroke. You'll soon need to master three very specific and different uses of this symbol:

- Evaluation, the simple "="
- Definition and assignment, the colon form, " := "
- Equal-to-Operator, the Ctrl-= "=" form.

Evaluation is obtained with a single keystroke, just the "=" key, and the result is an immediate evaluation and display, as in our first examples. Here's one more computation... I need to find a root of the polynomial x^2+4x+6 :

$$\frac{-4}{2} + \sqrt{\left(\frac{4}{2}\right)^2 - 6} = -2 + 1.414i \quad (\text{Type } -4/2 + \sqrt{4/2^2 - 6} \text{ then Enter})$$

"Evaluation" implies immediate computation and results, where in this case Mathcad did all of the work to compute and display the root at $-2+1.414i$ (complex valued).

In order to begin using variable names, we need to define and initialize the variable. Considering the quadratic formula example shown above, I could define a variable x and assign or initialize it with the default value of 1 as follows:

$$x := 1 \quad (\text{Type this as } x:1 \text{ then exit with the Enter key})$$

Note that the "assignment equals" is entered by typing just the colon key. This same operation can be repeated to "re-assign" a value to the variable.

$$x := \frac{-4}{2} + \sqrt{\left(\frac{4}{2}\right)^2 - 6} \quad (\text{Type } x:-4/2 + \sqrt{4/2^2 - 6})$$

The green wavy line under the x variable name in this second definition is a reminder from Mathcad that the variable was previously defined, and we just wiped out its previous value. That's okay, in this case, because now I want to see if it satisfies...

$$x^2 + 4 \cdot x + 6 = 0 \quad (\text{Type } x^2 + 4 \cdot x + 6 =)$$

This last evaluation verifies that indeed x is a root of the polynomial.

You will also encounter the "definition and assignment equals" when defining a function.

$$p(x) := x^2 + 4 \cdot x + 6 \quad (\text{Type } p(x):x^2 + 4 \cdot x + 6)$$

We are free to now evaluate $p(x)$ for any argument replacing x in the parentheses:

$$p(1) = 11 \quad p(0) = 6 \quad p(-2) = 2 \quad p(x) = 0$$

Each of the evaluations shown above is entered in a separate math/calculation region of the worksheet. To separate a row of such computations nicely, press the Tab key twice to exit the computation just completed and begin a new region immediately to the right: (i.e., that row was typed as follows:

$$p(1)= \text{TabTab } p(0)= \text{TabTab } p(-2)= \text{TabTab } p(x)=$$

The third and final version of the equal sign is the "equality operator," which we obtain by entering the keystrokes Ctrl+= (the Ctrl key held down while pressing and releasing "="). We find critical use of this operator when solving simultaneous equations in what Mathcad refers to as Given/Find equation block. Consider the following example:

a := 1 **b := 1** (Type as a:1 Tab b:1 to provide initial guesses)

Given (Type as Given)

$3 \cdot a + 4 \cdot b = -2$ (Type as 3*a+4*b Ctrl= -2) note 3 spaces between b and Ctrl=

$-a + b = 3$ (Type as -a+b Ctrl= 3)

Find(a, b) = $\begin{pmatrix} -2 \\ 1 \end{pmatrix}$ (Type as Find(a,b)=)

a = 1 **b = 1** (Type as a= TabTab b= and note, still assigned as 1)

Note that the "equality operator" is displayed as a bold equal sign. It does not result in assignment of one side of the expression to the other, but rather enforces a desired condition (the numerical equivalence) of the right and left sides. ALSO: the equation block MUST be surrounded by the Given/Find combination (beware of the capital letters). Because I chose to use an "evaluation equals" at the Find step, the actual values of a and b have not been modified/re-assigned from their original guesses. If an "assignment equal" were used instead, a and b would be correspondingly re-assigned.

Here's one more example of the Given/Find equation block, with a nonlinear equation pair this time. There exist two locations at which the two circles of the equation block intersect. Our guesses are critical to finding a particular solution:

$$x := 1 \quad y := 1$$

Given

$$(x - 1)^2 + (y - 2)^2 = 2^2$$

Circle of radius 2 centered at (1,2)

$$(x + 1)^2 + y^2 = 3^2$$

Circle of radius 3 centered at (-1,0)

$$\text{Find}(x, y) = \begin{pmatrix} 1.989 \\ 0.261 \end{pmatrix}$$

To seek out the other solution to the intersecting circles, start with a guess in the second quadrant (negative x, in this case):

$$x := -1 \quad y := 1$$

Given

$$(x - 1)^2 + (y - 2)^2 = 2^2$$

$$(x + 1)^2 + y^2 = 3^2$$

$$\text{Find}(x, y) = \begin{pmatrix} -0.739 \\ 2.989 \end{pmatrix}$$

$x = -1$ $y = 1$ BEWARE! x and y have not be re-assigned yet!

Sequencing Calculations by Relative Location of Regions

Mathcad is very precise with regard to the order of calculation entry and evaluation. As with most English documents, your Mathcad worksheet regions should be organized Left-to-Right, Top-to-Bottom in sequence of progressing assignment and computation. Failing to do this may result in unexpected "answers." Consider the following example:

x = -1

(This is x as assigned earlier in this worksheet)

x = -1

$\frac{1}{x} = -1$

(Just above the new assignment)

$$x := \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1 + \frac{1}{1}}}}}}}}$$

x = 0.618

(Just below the new assignment)

$$\frac{1}{x} = 1.618$$

(Below and right, good!)

It is essential that you progress to the right and below, not above, a previous computation or assignment in order to guarantee that it's value will be available.

Some Shortcuts and Hints

Here are a few quick examples of popular syntax elements in Mathcad:

Subscripts in Variable Names

$x_A := 12$ $y_4 := x_A \cdot 8$ (Typed as `x.A:12 Tab y.4:x.A*8`)

Summary: to get a subscript, type a period (dot), and, if necessary, use the space keystroke to move out of the subscript field (can be many characters long, if needed). BEWARE: Do not use the toolbar subscript/superscript in mathematics/calculation regions. It will "look" right, but it won't compute.

Greek Letters in Mathematics

$\alpha := 0.5$ $\beta := \sqrt{1 - \alpha^2}$ $\beta = 0.866$

Use the Geek menu $\alpha\beta$ to select greek characters or
(Type as `aCtrl+g:0.5 Tab`
`bCtrl+g:\1-aCtrlg^2 Tab`
`bCtrl+g=`)

Summary: to enter Greek letters, Use the Greek menu $\alpha\beta$ or type the English alphabet equivalent, then position the cursor immediately to the right of the character and press Ctrl and g at the same time. If you press this sequence twice, you'll toggle back to the original character.

Matrices and Vectors

A linear algebra formulation for a set of linear simultaneous equations can be rapidly expressed with matrices and vectors. Repeating the solution for a and b shown above in the first Given/Find block,...

$A := \begin{pmatrix} 3 & 4 \\ -1 & 1 \end{pmatrix}$ $y := \begin{pmatrix} -2 \\ 3 \end{pmatrix}$ $x := A^{-1} \cdot y$ $x = \begin{pmatrix} -2 \\ 1 \end{pmatrix}$

(Typed as `A:Ctrl-m 3 Tab 4 Tab -1 Tab 1 Space Tab`
`y:Ctrl-m -2 Tab 3 Space Tab`
`x:A^-1 Space Space *y Tab`
`x=`)

Summary: the sequence Ctrl-m inserts a matrix and brings up a dialog box to describe the dimensions of that matrix (so in the example above, you would have to enter the row and column dimensions of A and y correspondingly following the Ctrl-m keystrokes).

Further Reading

You are strongly encouraged to start up Mathcad and "kick its tires." The Help menu and Resource area provide a long list of tutorials and example applications. Remember, as with any computational tool, the user is responsible for verifying the results. You should qualify every computation with a critical eye for reasonableness. If it's not in the ballpark, re-visit what you've asked the computer to do. One of you isn't on the same page! Happy Mathcad-ing!

