Chapter 8
Variables and Constants

This chapter describes valid Mathcad variable names, function names, and numbers, including predefined variables like π.

Mathcad handles imaginary and complex numbers as easily as it does real numbers. Mathcad variables can have imaginary or complex values, and most Mathcad built-in functions can take complex arguments. This chapter describes how to use complex numbers in Mathcad.

In addition to handling real and complex numbers, Mathcad supports *strings* in math: arbitrary sequences of characters such as letters, numbers, and punctuation marks. This chapter describes how to create strings and use them in variable definitions.

The following sections make up this chapter:

Names

Valid variable and function names; how to type Greek letters.

Predefined variables

List of variables that have values when you start Mathcad.

Numbers

Real, imaginary, hexadecimal, and octal numbers; dimensional values.

Complex numbers

How to use complex numbers in Mathcad.

Strings

How to create and use string variables and string expressions in Mathcad.

Names

Mathcad lets you use almost any expression as a variable or function name.

Names in Mathcad can contain any of the following characters:

- Uppercase and lowercase letters.
- The digits 0 through 9.
- The underscore (_).
- a prime symbol (**'**). Note that this is not the same as an apostrophe. You'll find the prime symbol on the same key as the tilde (**~**).
- percent (**%**).
- Greek letters. To insert a Greek letter, type the equivalent roman letter and press [**Ctrl**]**G**. The section "How to type Greek letters" on page 161 contains a table of equivalent roman letters.
- The infinity symbol ∞, generated by typing [**Ctrl**]**Z**.
- Any other character provided you type [**Ctrl**][**Shift**]**P** before typing that character. This is discussed further in the section "Using an operator symbol in a name."
- Any math expression appearing between the brackets generated by typing [**Ctrl**][**Shift**]**O**. This is discussed further in the section "Chemistry notation" on page 163.

The following restrictions apply to variable names:

- A name cannot start with one of the digits 0 through 9. Mathcad interprets anything beginning with a number as either an imaginary number ($2i$ or $3j$), an octal or hexadecimal number (5o or 7h), or as a number *times* a variable ($3 \cdot x$).
- The infinity symbol, ∞, can only appear as the first character in a name.
- Any characters you type after a period (**.**) will appear as a subscript. This is discussed in the section "Literal subscripts" on page 162.
- All characters in a name must be in the same font, have the same point size, and be in the same style (italic, bold, etc.). Greek letters can, however, appear in any variable name.
- Mathcad does not distinguish between variable names and function names. Thus, if you define *f*(*x*), and later on you define the variable *f*, you will find that you cannot use *f*(*x*) anywhere below the definition for *f*.
- Certain names are already used by Mathcad for built-in constants, functions, and unit. (For a list of constants and functions, see Appendix A, "Reference." For a list of units, see Appendix B, "Unit Tables.") Although you can redefine these names, keep in mind that their built-in meanings will no longer exist after the definition.

For example, if you define a variable *mean*, Mathcad's built-in function *mean*(**v**) can no longer be used.

Mathcad distinguishes between uppercase and lowercase letters. For example, *diam* is a different variable from *DIAM*. Mathcad also distinguishes between names in different fonts, as discussed in Chapter 6, "Equation and Result Formatting." Thus, *Diam* is also a different variable from ***Diam***. The following are examples of valid names:

alpha	**b**
xyz700	**A1_B2_C3_D4%%%**
F1'	**a%%**

How to type Greek letters

There are two ways to type a Greek variable name in Mathcad:

- Type the roman equivalent from the table below. Then press [**Ctrl**]**G**.
- Click on the appropriate letter on Greek Symbol Palette. To see this palette, click on the button labeled "αβ" on the Math Palette.

Note that although many of the uppercase Greek letters look like ordinary capital letters, they are *not* the same. Mathcad distinguishes between Greek and roman letters. If you use a Greek letter in place of the corresponding roman letter in a variable or function name, Mathcad will not recognize the two as equivalent.

Note: Because it is used so frequently, the Greek letter π can also be typed by pressing [**Ctrl**]**P**.

The following table lists all the Greek letters and their roman equivalents. These are the same roman equivalents used in the Symbol font. To insert an uppercase Greek letter, use the uppercase roman equivalent. To insert a lowercase Greek letter, use the lowercase roman equivalent.

Name	Uppercase	Lowercase	Roman equivalent
alpha	Α	α	A
beta	Β	β	B
chi	Χ	χ	C
delta	Δ	δ	D
epsilon	Ε	ε	E
eta	Η	η	H
gamma	Γ	γ	G
iota	Ι	ι	I
kappa	Κ	κ	K
lambda	Λ	λ	L
mu	Μ	μ	M
nu	Ν	ν	N

omega	Ω	ω	W
omicron	O	o	O
phi	Φ	ϕ	F
phi(alternate)		φ	J
pi	Π	π	P
psi	Ψ	ψ	Y
rho	P	ρ	R
sigma	Σ	σ	S
tau	T	τ	T
theta	Θ	θ	Q
theta(alternate)	ϑ		J
upsilon	Y	υ	U
xi	Ξ	ξ	X
zeta	Z	ζ	Z

Literal subscripts

If you include a period in a variable name, Mathcad displays whatever follows the period as a subscript. You can use these *literal subscripts* to create variables with names like vel_{init} and u_{air}.

To create a literal subscript, follow these steps:

- Type the portion of the name that appears before the subscript.

- Type a period, followed by the portion of the name that is to become the subscript.

Do not confuse literal subscripts with *array* subscripts. Although they appear similar—a literal subscript appears below the line, like an array subscript, but with a slight space before the subscript—they behave quite differently in computations. A literal subscript, created by typing a period, is really just part of a variable name. An array subscript represents a reference to an array element. Array subscripts are generated with the left bracket key ([). See Chapter 10, "Vectors and Matrices," for a description of how to use subscripts with arrays.

Using an operator symbol in a name

When you're in a math region, certain keystrokes insert math operators rather than the characters you see imprinted on the keys. For example, when you type "$" in a math

region, Mathcad displays a summation symbol with placeholders, not a dollar sign. Although this feature makes it easier to type math expressions, it also excludes certain characters from use in variable names.

To circumvent this problem, Mathcad lets you temporarily enter text mode while you're still in a math expression. When you're in text mode, all the keys lose their mathematical meaning. This lets you type exactly what you see imprinted on the keys on your keyboard. For example, here's how you define the variable *a*$ to be equal to "1":

- Type **a**. Do not type **$** yet since, at this point, the "$" key will insert a summation sign.

- Type [**Ctrl**][**Shift**]**P** to enter a "text" mode.

- Now go ahead and type **$**. The insertion point turns red to show that you're in text mode.

- Type [**Ctrl**][**Shift**]**P** again to return to math mode.

- Type **:1** to complete the definition. Since you're now back in math mode, the ":" key has recovered its mathematical meaning.

Chemistry notation

Ordinarily, a name cannot contain other operators within it. There may be times, however, when you want to define a name which contains superscripts, subscripts, or other operators as part of it. For example, you may want assign a value to the variable named H_2O. To do this:

- Press [**Ctrl**][**Shift**]**O**. This inserts a pair of brackets with a placeholder between them.

- Type **H[2**.

- Press the [**Space**] key to place the H_2 between the editing lines.

- Now type **O**.

- Press **:** and type a value in the placeholder. Mathcad always uses brackets as part of a variable name defined in this way.

Predefined variables

Mathcad includes several variables that, unlike ordinary variables, are already defined when you start Mathcad. These variables are called *predefined* or *built-in variables*. Predefined variables either have a conventional value, like π and *e*, or are used as system variables to control how Mathcad works, like ORIGIN and TOL.

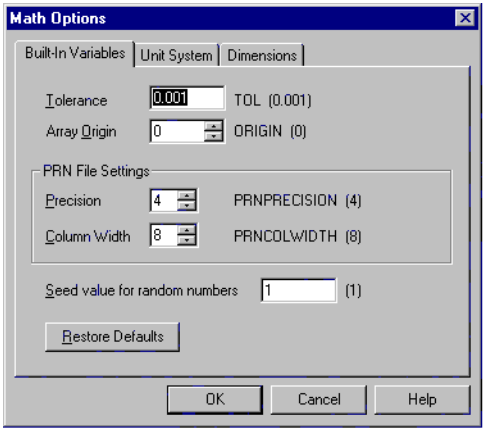
	Variable = default value	Definition and use
	$\pi = 3.14159...$	Pi. Mathcad uses the value of π to 15 digits in numerical calculations. In symbolic calculations, π is exact. To type π, press [**Ctrl**]**P**.
	$e = 2.71828...$	The base of natural logarithms. Mathcad uses the value of *e* to 15 digits in numerical calculations. In symbolic calculations, *e* is exact.
	$\infty = 10^{307}$	Infinity. In numerical calculations, this is an actual number of finite magnitude. In symbolic calculations, this represents a true infinity. To type ∞, press [**Ctrl**]**Z**.
	$\% = 0.01$	Percent. Use this in expressions like $10 \cdot \%$ or as a scaling unit in the placeholder at the end of an equation with an equals sign.
	$TOL = 10^{-3}$	Numerical tolerance for the various approximation algorithms (integrals, equation solving, etc.). See the sections on the specific operations for details.
	$ORIGIN = 0$	Array origin: the index of the first element of an array.
	$PRNCOLWIDTH = 8$	Column width used when writing files with the *WRITEPRN* function.
	$PRNPRECISION = 4$	Number of significant digits used when writing files with the *WRITEPRN* function.
	$FRAME = 0$	Used to drive animation. Set to zero when no animation is in progress.
Pro	CWD = "<system path>"	String corresponding to the directory of the worksheet.
Pro	**in***n* = 0, **out***n* = 0	Input and output variables (**in0**, **in1**, **out0**, **out1**, etc.) in a Mathcad component in a MathConnex system. See the *MathConnex Getting Started Guide* for details.

In addition to the predefined variables in the table above, Mathcad treats the names of all built-in units as predefined variables. See Chapter 9, “Units and Dimensions,”for more on using units in your calculations; a list of built-in units is in Appendix B, “Unit Tables.”

Although Mathcad’s predefined variables already have values when you start Mathcad, you can still redefine them. For example, if you want to use a variable called *e* with a value other than the one Mathcad provides, enter a new definition, like $e := 2$. The variable *e* takes on the new value everywhere in the worksheet below the new definition.

Mathcad's predefined variables are defined for all fonts, sizes, and styles. This means that if you redefine *e* as shown above, you can still use **e**, for example, as the base for natural logarithms. Note, however, that Greek letters are not included. This means that “ε”, although it is typed as “e” in the Symbol font, is not the same number as *e*.

You can control the values of TOL, ORIGIN, PRNPRECISION, and PRNCOLWIDTH without having to explicitly define them in your worksheet. To do so, choose **Options** from the **Math** menu, and click on the Built-In Variables tab, as shown below:



To set new starting values for any of these variables, enter a new value in the appropriate text box and click “OK.” Then choose **Calculate Worksheet** from the **Math** menu to ensure that all existing equations take the new values into account.

The numbers in brackets to the right of the variable names represent the default values for those variables. To restore these default values, click on the “Restore Defaults” button and then click “OK.”

Numbers

This section describes the various types of numbers that Mathcad uses and how to enter them into equations.

Types of numbers

Mathcad interprets anything beginning with a digit as a number. A digit can be followed by:

- other digits
- a decimal point
- digits after the decimal point
- one of the letters **h** or **o**, for hex and octal numbers, **i** or **j** for imaginary numbers, and **M**, **L**, **T**, **Q**, **K**, **C**, or **S** for numbers carrying units. These are discussed in more detail below.

Note that Mathcad uses the period (.) to signify the decimal point. The comma (**,**) is used both to show iteration and to separate values in an input table. These topics are discussed in Chapter 11, "Range Variables."

Imaginary numbers

To enter an imaginary number, follow it with *i* or *j*, for example, 1*i* or 2.5*j*. You cannot use *i* or *j* alone to represent the imaginary unit. You must always type **1i** or **1j**. If you don't, Mathcad will think you are referring to a variable named either *i* or *j*. See the section "Complex numbers" on page 167.

Dimensional values

Dimensional values are numbers associated with one of the Mathcad dimensions: in the SI system, *mass*, *length*, *time*, *current*, *temperature*, *luminous intensity*, and *substance*. Mathcad uses these dimensions to keep track of units for dimensional analysis and unit conversions. See Chapter 9, "Units and Dimensions."

To enter a dimensional value, type a number followed by an upper or lowercase **M** for mass, **L** for length, **T** for time, **I** for current, **K** for temperature, **C** for luminous intensity, and **S** for substance. For example, **4.5M** represents 4.5 mass units. Because Mathcad by default treats most expressions involving a number followed immediately by a letter to mean implied multiplication of a number by a variable name, as described in Chapter 3, "Editing Equations," you will need to backspace over the implied multiplication operator to create expressions like **4.5M**.

Octal integers

To enter a number in octal, follow it with the upper or lowercase letter **O**. For example, **25636o** represents 11166 in decimal. Octal numbers must be integers less than 2^{31}.

Hexadecimal integers

To enter a number in hexadecimal, follow it with the upper or lowercase letter **H**. For example, **2b9eh** represents 11166 in decimal. To represent digits above 9, use the upper or lowercase letters **A** through **F**. To enter a hexadecimal number that begins with a letter, you must begin it with a leading zero. If you don't, Mathcad will think it's a variable name. For example, use **0a3h** rather than **a3h** to represent the decimal number 163 in hexadecimal. Hexadecimal numbers must be integers less than 2^{31}.

Exponential notation

To enter very large or very small numbers in exponential notation, just multiply a number by a power of 10. For example, to represent the number $3 \cdot 10^8$, type **3*10^8**.

Combining types of numbers

You can freely combine all types of numbers with various operators. Figure 8-1 shows some examples.

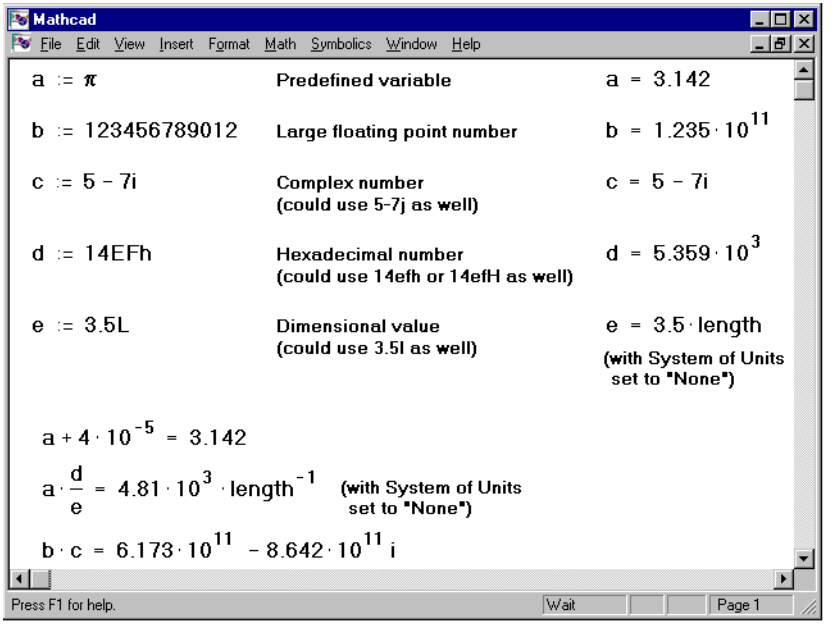


Figure 8-1: Combining different types of numbers.

Complex numbers

As described in the preceding section, Mathcad accepts complex numbers of the form $a + bi$, where a and b are ordinary numbers. You can use j instead of i if you prefer that notation.

Complex numbers can also arise if you enter an expression with a complex result. Even a Mathcad expression that involves only real numbers can have a complex value. For example, if you evaluate $\sqrt{-1}$, Mathcad will return i.

Although you can enter imaginary numbers followed by either i or j, Mathcad normally displays them followed by i. To have Mathcad display imaginary numbers with j, choose **Number** from the **Format** menu, click on the "Global" option button, and set

"Imaginary" to *j*. See Chapter 6, "Equation and Result Formatting," for a full description of the numerical formatting options.

When typing complex numbers, remember that you cannot use *i* or *j* alone to represent the imaginary unit. You must always type **1i** or **1j**. If you don't, Mathcad will interpret the *i* or *j* as a variable. When the cursor is outside an equation that shows 1*i* or 1*j*, Mathcad hides the superfluous 1.

Complex operators and functions

Mathcad has the following functions and operators for working with complex numbers:

Re(*z*)	Real part of a number *z*.
Im(*z*)	Imaginary part of a number *z*.
arg(*z*)	Angle in complex plane from real axis to *z*. This returns a result between $-\pi$ and π radians.
$\lvert z \rvert$	The magnitude of the number *z*. To take the magnitude of an expression, click on it and press the vertical-bar key "**|**".
$\bar{z}$	Complex conjugate of *z*. To apply the conjugate operator to an expression, select the expression, then press the double-quote key (**"**). The conjugate of the complex number $a + b \cdot i$ is $a - b \cdot i$.

Figure 8-2 shows some examples of how to use complex numbers in Mathcad.

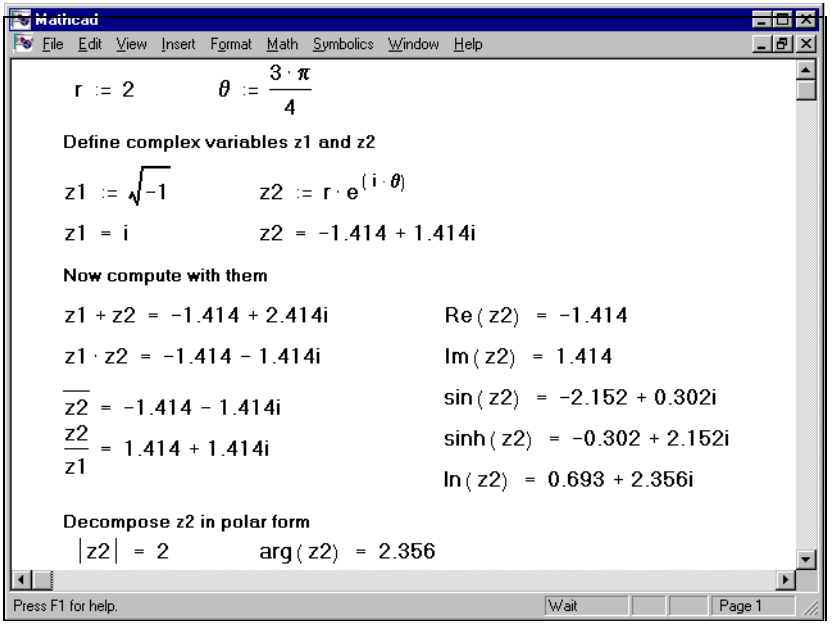


Figure 8-2: Complex numbers in Mathcad.

Multivalued functions

When complex numbers are available, many functions and operators we think of as returning unique results become multivalued. The impact of this on logarithmic and exponential functions is discussed more fully in Chapter 13, “Built-in Functions.”

As a general rule, when a function or operator is multivalued, Mathcad always returns the value making the smallest positive angle relative to the positive real axis in the complex plane. This is the principal value.

For example, when asked to evaluate $(-1)^{1/3}$, Mathcad will return $.5 + .866i$ despite the fact that we commonly think of the cube root of –1 as being –1. This is because the number $.5 + .866i$ makes an angle of only 60 degrees from the positive real axis. The number –1, on the other hand, is all the way on the other side, 180 degrees from the positive real axis.

The single exception to this rule is the *n*th root operator described in Chapter 12, “Operators.” This operator always returns a real root whenever one is available. Figure 8-3 compares these two alternatives.

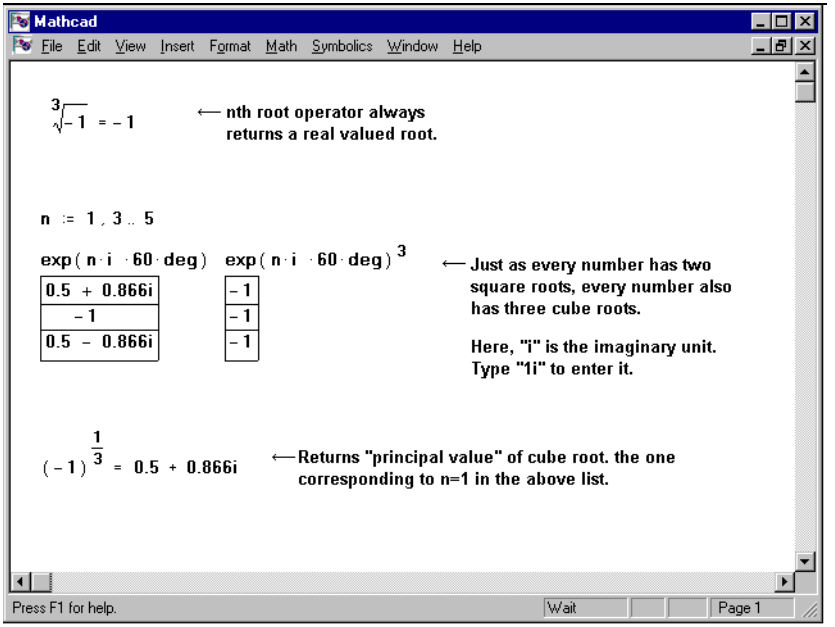


Figure 8-3: Finding real valued roots of a negative number.

Strings

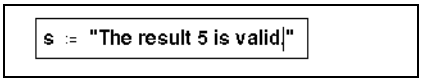
Although in most cases the math expressions or variables you work with in Mathcad are real and complex numbers, you can also work with *string expressions* (also called *string literals* or *string variables*). String expressions can include any character you can type at the keyboard, including letters, numbers, punctuation, and spacing, as well as a variety of special symbols as listed in the table of ASCII codes in Appendix A, "Reference." Strings differ from variable names or numbers because Mathcad always displays them between double quotes. You may assign a string expression to a variable name, use a string expression as an element of a vector or matrix, or use a string expression as the argument to a function.

To create a string expression in math:

- Click on an empty math placeholder in a math expression, usually on the right-hand side of a variable definition.

- Type the double-quote (**"**) key. Mathcad displays a pair of quotes and an insertion line between them.

- Type any combination of letters, numbers, punctuation, or spaces. Click outside the expression or press the right arrow key (→) when you are finished.



To enter a special character corresponding to one of the ASCII codes, do the following:

- Click to position the insertion point in the string.
- Hold down the [**Alt**] key, and type the number "0" followed immediately by the number of the ASCII code *using the numeric keypad at the right of the keyboard* in number-entry mode.
- Release the [**Alt**] key to see the symbol in the string.

For example, to enter the degree symbol (**°**) in a string, press down [**Alt**] and type "0176" using the numeric keypad.

Notice that the double-quote key (**"**) has a variety of meanings in Mathcad, depending on the exact location of the cursor in your worksheet. When you type this key in a blank placeholder, Mathcad begins a string expression. As described in "Complex numbers" on page 167, typing the double-quote key *after* you have selected a math expression creates the complex conjugate of the selected expression. And typing the double-quote key when you see a crosshair cursor in a blank space in the worksheet begins a text region, as described in Chapter 5, "Text." So when you want to enter a string variable, you must *always* have a blank placeholder selected.

Editing of strings differs from editing of other math expressions because you must use the arrow keys or click outside the string to move out of a string expression. Pressing [**Space**] or [**Tab**], which can be used in other expressions to change the position of the editing lines, is interpreted as just another character in string.

Figure 8-4 shows examples of strings in math expressions. Valid strings include expressions such as "The Rain in Spain Falls Mainly on the Plain," "Invalid input: try a number less than -5," and "Meets stress requirements." A string expression in Mathcad, while not limited in size, always appears as a single line of text in your worksheet. Note that a string such as "123," created in the way described above, is understood by Mathcad to be a string of characters rather than the number 123.

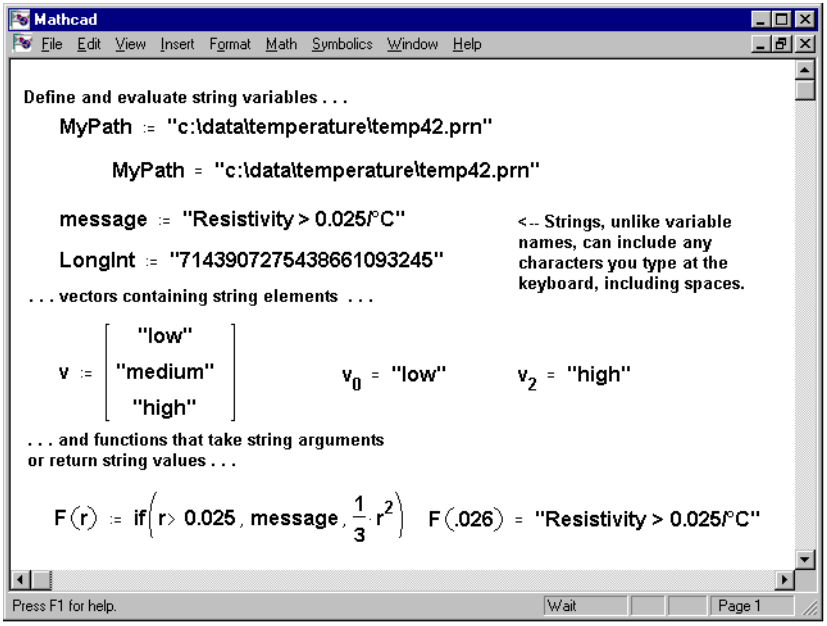


Figure 8-4: Using strings in math expressions.

Most of Mathcad's arithmetic operators and built-in functions expect numeric arguments and will issue error messages when you use string expressions with them. As described in Chapter 12, “Operators,” however, you can use Mathcad’s boolean operators to compare strings. Mathcad also includes a set of specialized string-manipulation functions as described in Chapter 13, “Built-in Functions.” String expressions are especially useful for generating custom error messages in user-defined functions (see the example at the bottom of Figure 8-4) and in programs, as described in Chapter 18, “Programming.” Use string expressions also to specify system paths for arguments to Mathcad’s data and graphics input and output functions, as described in Chapter 19, “Data Management,” and Chapter 28, “Importing and Exporting Graphics.”