



Chapter 9

Units and Dimensions

Units of measurement, while not required in Mathcad equations, can help detect errors and enhance the display of computed results. Mathcad's unit capabilities take care of many of the usual chores associated with using units and dimensions in scientific calculation. Once you enter the appropriate definitions, Mathcad automatically performs unit conversions and flags incorrect and inconsistent dimensional calculations.

This chapter describes how to use units and dimensions in Mathcad, including unit conversions and dimensional checking.

The following sections make up this chapter.

Computing with units

How to use units in an equation and how Mathcad catches any dimensional inconsistencies.

Displaying units of results

How Mathcad displays units and how to convert from one unit to another.

Built-in units

Choosing a system of units; defining your own units in terms of fundamental dimensions.

Changing dimension names

How to change the names of Mathcad's fundamental dimensions.

Computing with units

When you first start Mathcad, a complete set of units is available for your calculations. You can treat these units just like built-in variables. To assign units to a number, just multiply it by the name of the unit. For example, type expressions like the following:

```
mass:75*kg
acc:100*m/s^2
acc_g:9.8*m/s^2
F:mass*(acc + acc_g)
```

Figure 9-1 shows how these equations appear in a worksheet.

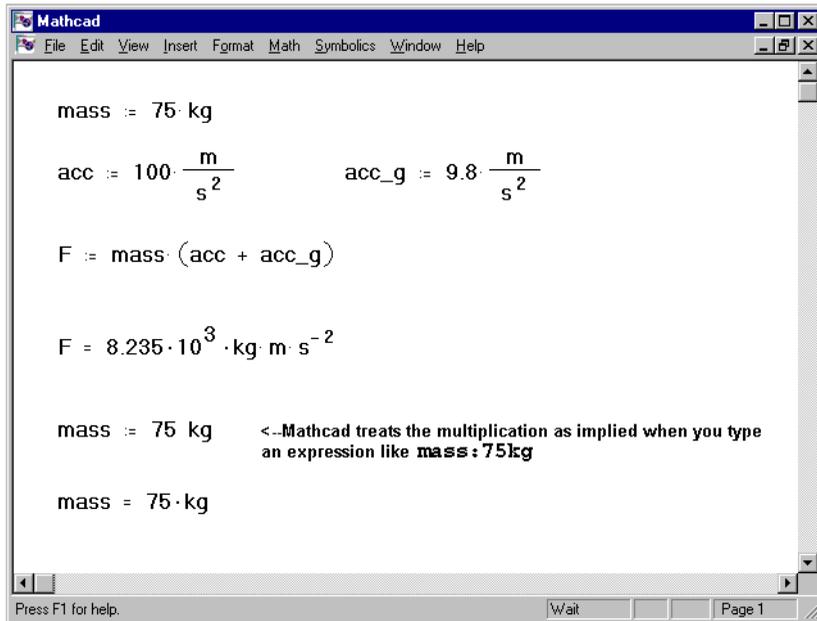


Figure 9-1: Equations using units.

If you define a variable which consists of a number followed immediately by a unit name, you can omit the multiplication symbol and Mathcad will treat the multiplication as implied, as you can see in the bottom-most example in Figure 9-1.

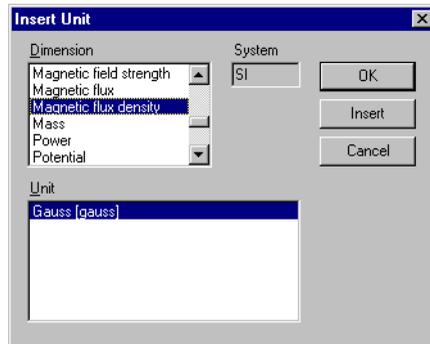
Mathcad recognizes most units by their common abbreviations. A list of all of Mathcad's built-in units is in Appendix B, "Unit Tables." By default Mathcad uses units from the SI unit system (also known as the International System of Units) in your worksheets. See the section "Built-in units" on page 181 for more information about selecting a unit system.

You can also use the Insert Unit dialog box to insert one of Mathcad's built-in units into any placeholder. The Insert Unit dialog box offers the following advantages:

- You won't have to remember the abbreviation Mathcad uses for a unit.
- You'll see at a glance all available units appropriate to the result you've clicked on.
- You can't make any typing mistakes.

To use the Insert Unit dialog box:

- Click in the empty placeholder and choose **Unit** from the **Insert** menu. Mathcad opens a dialog box with two scrolling lists.



- The list at the bottom shows built-in units, along with their Mathcad names, corresponding to whatever physical quantity is selected in the top scrolling list. For convenience, when “Dimensionless” is selected at the top, a list of all available built-in units shows on the bottom.
- If necessary, use the top scrolling list to display only those units corresponding to a particular physical quantity. This makes it easier to find a particular unit or to see what choices are appropriate.
- In the bottom list, double-click on the unit you want to insert, or click on the unit you want and then click the “Insert” button. Mathcad inserts that unit into the empty placeholder.

For some engineering units—such as *hp*, *cal*, *BTU*, and *Hz*—Mathcad adopts one common definition for the unit name but allows you to use insert one of several alternative unit names, corresponding to alternative definitions of that unit, in your results. The alternative names are presented, where available, along with the standard unit name in the unit list at the bottom of the Insert Unit dialog box. Mathcad’s preferred unit name is denoted in square brackets, and the alternative names are given in parentheses. In the case of horsepower, for example, Mathcad uses the U.K. definition of the unit for the name *hp* but gives you several variants, such as water horsepower, metric horsepower, boiler horsepower, and electric horsepower.

Note that Mathcad performs some dimensional analysis by trying to match the dimensions of your selected result with one of the common physical quantities in the top scrolling list. If it finds a match, you'll see all the built-in units corresponding to the highlighted physical quantity in the bottom scrolling list. If nothing matches, Mathcad simply lists all available built-in units on the bottom.

Dimensional checking

Whenever you enter an expression involving units, Mathcad checks it for dimensional consistency. If you add or subtract values with incompatible units, or violate other principles of dimensional analysis, Mathcad displays an appropriate error message.

For example, suppose you had defined acc as $100 \cdot m/s$ instead of $100 \cdot m/s^2$ as shown in Figure 9-2. Since acc is in units of velocity and acc_g is in units of acceleration, it is inappropriate to add them together. When you attempt to do so, Mathcad displays an error message.

Unit errors are usually caused by one of the following:

- An incorrect unit conversion.
- A variable with the wrong units, as shown in Figure 9-2.
- Units in exponents or subscripts (for example $v_3 \cdot acre$ or $2^3 \cdot ft$).
- Units as arguments to inappropriate functions (for example, $\sin(0 \cdot henry)$).

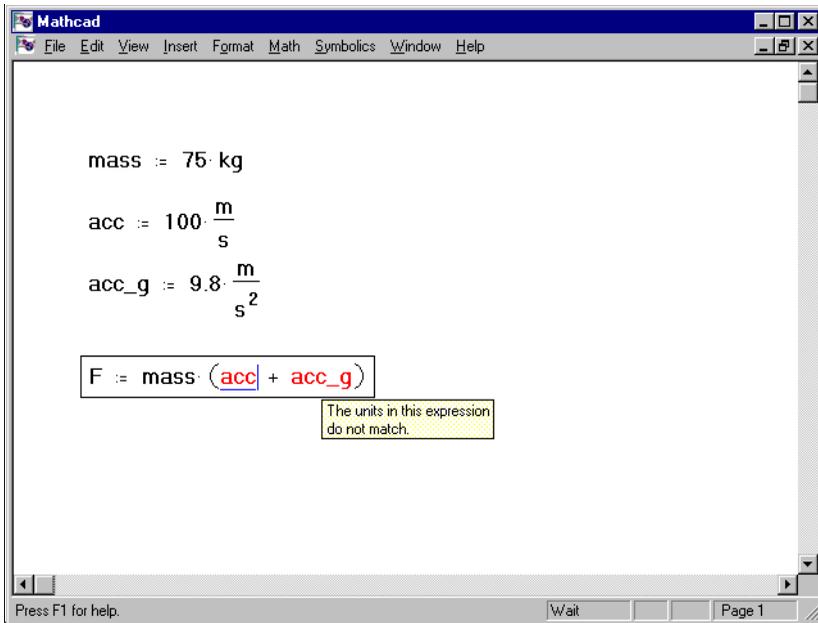


Figure 9-2: An equation with incompatible units.

Defining your own units

Although Mathcad recognizes many common units, you may need to define your own unit if:

- that unit isn't in the list of built-in units in Appendix B, "Unit Tables."
- you prefer to use your own abbreviation instead of that shown in Appendix B, "Unit Tables."

You define your own units in terms of existing units in exactly the same way you would define a variable in terms of an existing variable. Figure 9-3 shows how to define new units as well as how to redefine existing units.

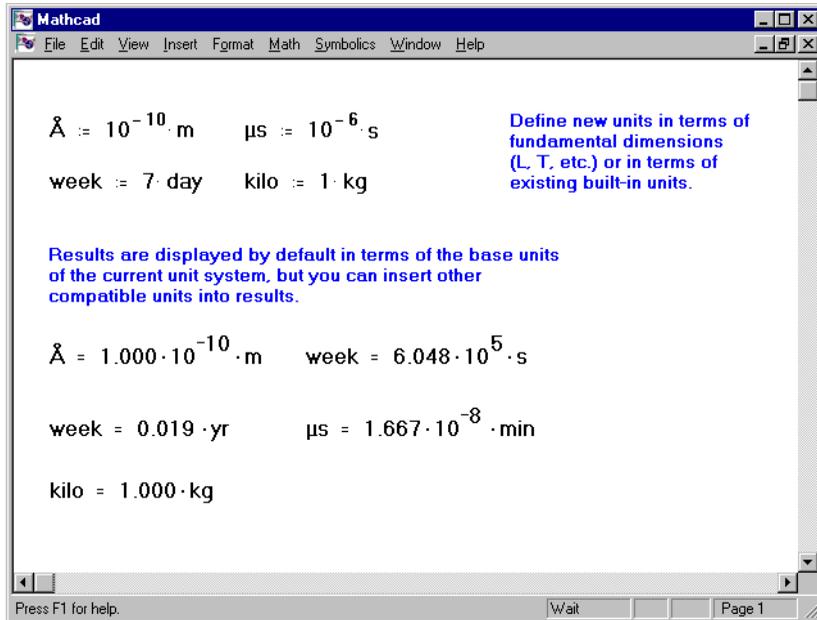


Figure 9-3: Defining your own units.

Since units behave just like variables, you may run into unexpected conflicts. For example, if you define the variable m in your worksheet, you won't be able to use the built-in unit m for meters anywhere below that definition. However, Mathcad will automatically display the unit m in any results involving meters.

Displaying units of results

Mathcad automatically displays results in terms of the fundamental units of the unit system you're working with. Mathcad offers several choices of unit system: SI, CGS, MKS, U.S. customary units, or no unit system. If you're using SI units, the default system in Mathcad, the base units are *meter*, *kilogram*, *second*, *ampere*, *Kelvin*, *candela*, and *mole*. If you're using the CGS system, for example, the base units are *centimeter*, *gram*, *second*, *coulomb*, and *Kelvin*. For details about the base units in MKS and U.S. customary units see Appendix B, "Unit Tables."

You can have Mathcad redisplay a particular result in terms of any of Mathcad's built-in units. To do so:

- Click in the result. You'll see an empty placeholder to its right. This is the *units placeholder*.
- Click on the units placeholder and choose **Unit** from the **Insert** menu. Mathcad opens the Insert Unit dialog box. This is described in detail in “Computing with units” on page 174.
- Double-click on the unit in terms of which you want to display the result. Mathcad inserts this unit in the units placeholder.

Another way to insert a unit is to type it directly into the units placeholder. This method is more general since it works not only for built-in units but for units you've defined yourself and for combinations of units.

For example, in Figure 9-1, F is displayed in terms of the fundamental units kg , m and s . To change this to *dyne*:

- Click in a displayed result to see the units placeholder to its right. Then click on this units placeholder.

$$F = 8235 \cdot \text{kg} \cdot \text{m} \cdot \text{s}^{-2} \quad \square$$

- In the units placeholder, type **dyne**.

$$F = 8235 \cdot \text{kg} \cdot \text{m} \cdot \text{s}^{-2} \cdot \text{dyne} \quad \square$$

- Click outside the equation. Mathcad displays the answer in terms of the units you entered.

$$F = 8.235 \cdot 10^8 \cdot \text{dyne}$$

Unit conversions

There are two ways to convert from one set of units to another:

- By using the Insert Unit dialog box, or
- By typing the new units in the units placeholder itself.

If you want to display the result in terms of one of Mathcad's built-in units, the simplest method is to use the Insert Unit dialog box:

- Click on the unit you want to replace.
- Choose **Unit** from the **Insert** menu.
- In the scrolling list of units, double-click on the unit in terms of which you want to display the result.

As a quick shortcut, or if you want to display the result in terms of something not available through the Insert Unit dialog box—for example, a unit you defined yourself or an algebraic combination of units—you can edit the units placeholder directly. For example, to express the result in the previous example in terms of force-pounds rather than dynes:

- Click in the name of the unit you want to replace.

$$F = 8.235 \cdot 10^8 \cdot \text{dyne}$$

- Delete the unit name by drag-selecting it and pressing [Del].

$$F = 8235 \cdot \text{ }$$

- Type in the name of the new unit and click outside the equation.

$$F = 1851.301 \cdot \text{lbf}$$

Figure 9-4 shows F displayed both in terms of its fundamental SI units and in terms of several combinations of units.

When you enter an inappropriate unit in the units placeholder, Mathcad will display whatever combination of base units that make the result have the right units. For example, in the last equation in Figure 9-4, you see that $\text{kW} \cdot \text{s}$ is not a unit of force. Mathcad therefore inserts m^{-1} to cancel the extra length dimension.

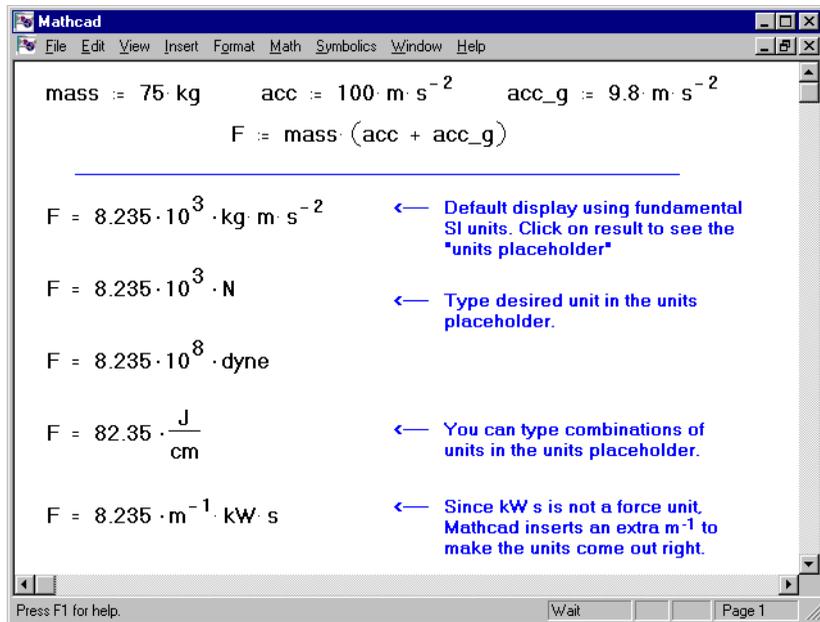


Figure 9-4: A calculated result displayed in terms of different units.

Whenever you enter units in the units placeholder, Mathcad divides the value to be displayed by whatever you enter in the units placeholder. This ensures that the complete displayed result—the number *times* the expression you entered for the placeholder—is a correct value for the equation.

Conversions involving an offset in addition to a multiplication, for example gauge pressure to absolute pressure, cannot be performed directly with Mathcad's unit conversion mechanism.

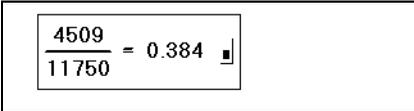
In particular, when working with temperature, keep in mind that you cannot use Mathcad's unit conversions to convert between Fahrenheit and Centigrade. You can, however, perform conversions of this type by defining suitable functions. See Chapter 7, "Equations and Computation," for more on defining your own functions.

Scaling results

The techniques described in this chapter are not restricted to units. You can put any variable, constant, or expression in a units placeholder. Mathcad will then redisplay the result in terms of the value of whatever is in the units placeholder. Just remember that whenever you type something in the units placeholder, Mathcad will change the calculated result so that the complete displayed result—the number *times* the expression you entered in the placeholder—is correct.

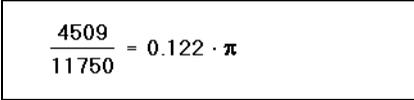
For example, you can use the units placeholder to display a result as a multiple of π . To do so:

- Click on the units placeholder.



A screenshot of a Mathcad window showing the equation $\frac{4509}{11750} = 0.384$. To the right of the number 0.384 is a small square icon with a vertical line, representing the units placeholder.

- Click on π on the symbol palette. Then click outside the equation. Mathcad shows the result in terms of π .



A screenshot of a Mathcad window showing the equation $\frac{4509}{11750} = 0.122 \cdot \pi$. The result is now expressed as a multiple of the Greek letter pi.

You can also use the units placeholder for dimensionless units like degrees and radians. Mathcad treats the unit *rad* as a constant equal to 1, so if you have a number or an expression in radians, you can type *deg* into the units placeholder to convert the result from radians to degrees. To convert an expression in degrees to radians, simply press the equal sign to evaluate it; Mathcad displays the results by default in radians. You may insert the unit name *rad* in the units placeholder if you wish. Figure 9-5 shows some examples of these techniques of converting and scaling results involving degrees and radians.

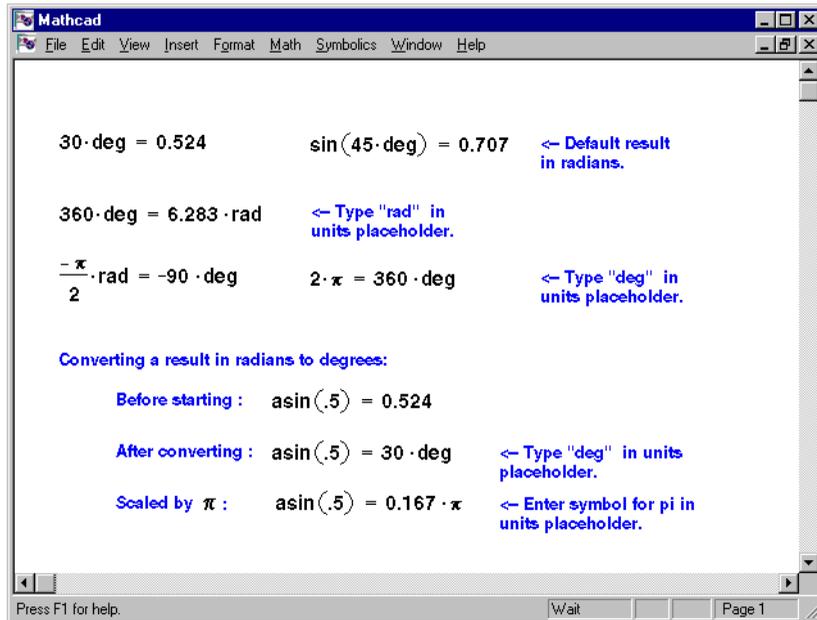
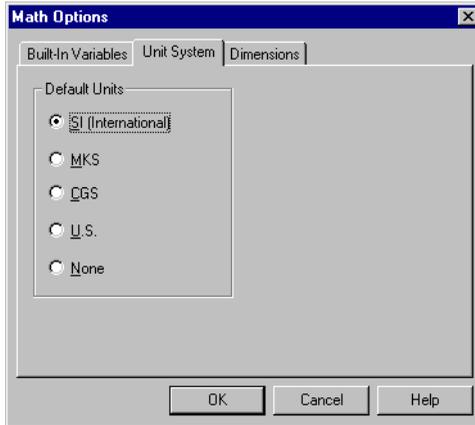


Figure 9-5: Using dimensionless units in placeholders.

Built-in units

When you start Mathcad, the SI system of units is automatically loaded by default. This means that when you use the equal sign to display a result having units, Mathcad automatically displays the units in the result in terms of some combination of the SI base units: *meter, kilogram, second, ampere, Kelvin, candela, and mole*. You can of course convert this combination of base units into a different unit by typing that unit into the units placeholder, as discussed in “Displaying units of results” on page 177. However, until you do so, Mathcad uses the fundamental units of the SI unit system to display your result.

You can have Mathcad display results in terms of the fundamental units of any of the other built-in unit systems in Mathcad: CGS, US customary, MKS, or no unit system at all. To do so, choose **Options** from the **Math** menu and click on the Unit System tab. You will see a dialog box like the one shown below:



Click on the button corresponding to the default units in which you want to display results. The table below summarizes what each button does.

SI	Displays results in terms of m , kg , s , A , K , cd , and $mole$.
MKS	Displays results in terms of m , kg , sec , $coul$, and K .
CGS	Displays results in terms of cm , gm , sec , $coul$, and K .
U.S.	Displays results in terms of ft , lb , sec , $coul$, and K .
None	Displays results in terms of fundamental dimensions of length, mass, time, charge, and absolute temperature. All built-in units are disabled.

The SI unit system, widely used by scientists and engineers in many countries, is the preferred unit system in Mathcad and the one available to you by default in new Mathcad worksheets. SI provides two additional base units over the other systems, one for luminosity (*candela*) and one for substance (*mole*), and the base SI electrical unit (*ampere*) differs from the base electrical unit in the other systems (*coulomb*).

The standard SI unit names—such as A for *ampere*, L for *liter*, s for *second*, and S for *siemens*—are generally available only in the SI unit system. Many other unit names are available in all the available systems of units. For example, when CGS is selected, you'll still be able to use kg and lb even though these are not, strictly speaking, part of the CGS system of units. For a listing of which units are available in each system, see Appendix B, “Unit Tables.” Mathcad includes most units common to scientific and engineering practice. Where conventional unit prefixes such as m - for *milli*-, n - for *nano*-, etc. are not understood by Mathcad, you can easily define custom units such as μm as described in “Defining your own units” on page 176. For examples of units with prefixes not already built into Mathcad, see the QuickSheets in the Resource Center.

If you click “None” in the Unit System tab of the Math Options dialog box, there will be no built-in units at all. You can, however, still define and use your own units. To do so, you use the special built-in constants: $1L$, $1M$, $1T$, $1Q$, and $1K$. These represent the dimensions *length*, *mass*, *time*, *charge*, and absolute *temperature*; you may also use the constants $1U$ and $1S$ for *luminosity* and *substance*. When you click “None,” Mathcad

displays answers in terms of the fundamental dimensions of *length*, *mass*, *time*, *charge*, and *temperature* rather than in terms of any system of units. Figure 9-6 shows how to define units using these built-in constants and how to carry out the analysis in Figure 9-1 after having done so. Notice that if you type the expression **kg : 1M** in your worksheet Mathcad will display $kg := 1 M$, treating the multiplication as implied on the right-hand side; so you will need to backspace over the implied multiplication to delete it to create the constant *IM*.

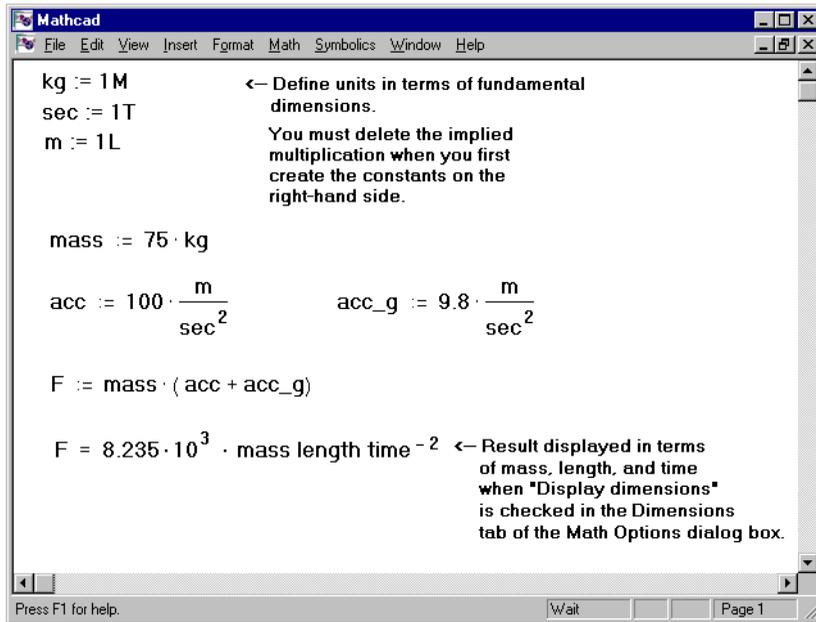


Figure 9-6: Using the constants *1L*, *1M*, and *1T* to define a system of units.

Even if you are working in one of Mathcad's built-in unit systems, you can always choose to see results in your worksheet displayed in terms of fundamental dimensions like *mass* and *length* rather than the base units of the unit system. To do so:

- Choose **Options** from the **Math** menu. Click on the Dimensions tab.
- Click on the check box beside "Display dimensions."
- Click "OK."

Changing dimension names

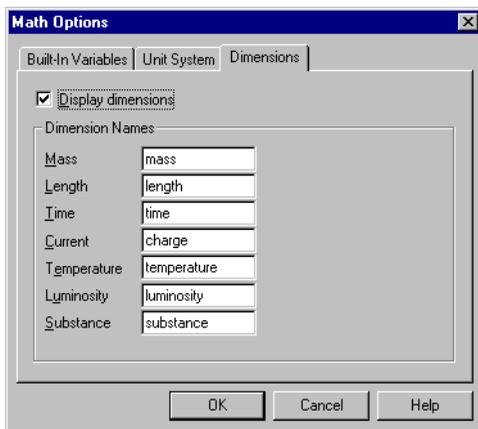
The previous section showed how you can display a result in terms of the fundamental units of either of four systems of units or in terms of the fundamental physical dimensions of *mass*, *length*, *time*, *charge*, *temperature*, *luminosity*, and *substance*. (The

latter two dimensions are used only in the SI unit system.) This section describes how to go even further and actually change the names of the fundamental dimensions altogether.

This may be useful if the nature of your work makes another set of fundamental dimensions more appropriate. Thus, a commodities trader may prefer to use *bushels* and *currency* rather than *charge* and *temperature*; a car salesman might define *trucks* and *sedans* rather than *length* and *mass*. In short, a dimension is nothing more than a way of tagging numbers so you can keep better track of them. It just so happens that in most physical problems, it's convenient to name these dimensions according to the fundamental dimensions in the SI unit system.

To change the names of the dimensions:

- Choose **Options** from the **Math** menu.
- Click on the Dimensions tab, as shown below:



- Click on the check box beside “Display dimensions” if it is not already checked.
- To change a dimension name, edit the name shown in the appropriate text box.
- Click “OK.”

Renaming the dimensions in this dialog box changes the dimension names only for the Mathcad worksheet you are working on. To make these dimension names available in other worksheets, you can save your worksheet as a template as described in Chapter 4, “Worksheet Management.”