Name _____ **Lab Section** _____ **Date** _____

Overview:
This laboratory experiment introduces the Mathcad programming environment.

Introduction:
The Mathcad programming environment will be explored experimentally by means of completing some simple exercises.

Procedure:
1. Turn on the computer and allow it to boot into the Windows operating system. Log in using your KSU student account.

2. Start Mathcad by *left-clicking* **Start** → **All Programs** → **PTC Mathcad** → **Mathcad Prime**.

3. To perform any mathematical calculation, simply click on the screen at any convenient point to establish a crosshair on the display (the location of the first entry). Then type in the mathematical operation as shown in Figure 1.
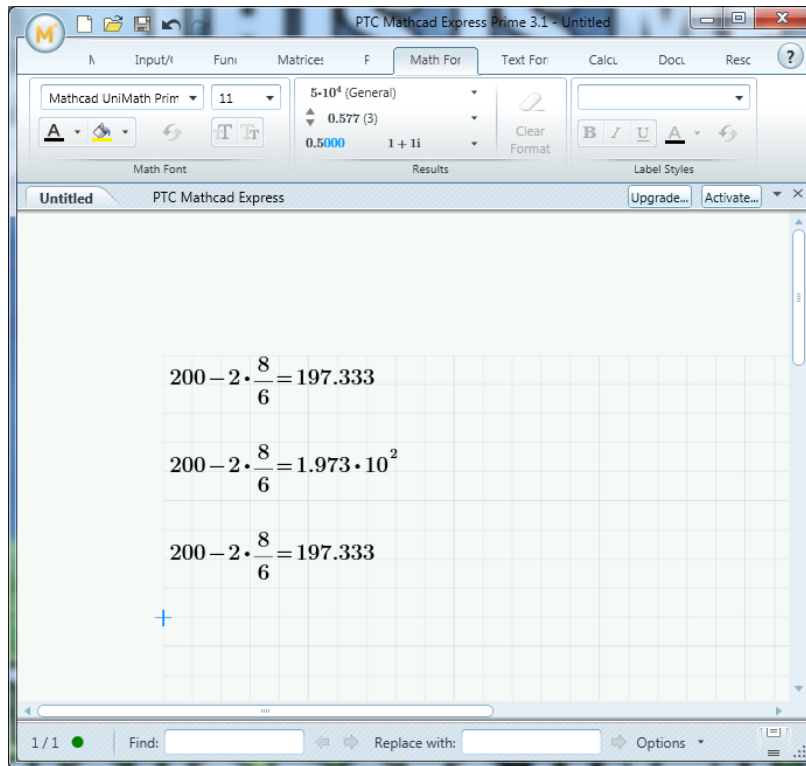
Figure 1. Using Mathcad to perform a basic mathematical operation.

4. The instant the equal sign is selected, the result, **197.333**, will appear. The multiplication is obtained by using the asterisk (*) appearing at the top of the number 8 key. The division is set by the / key at the bottom right of the keyboard. The equal sign can be selected from the top right of the keyboard.

5. Note that the format of the three results for the same equation is different. Mathcad allows the result to be formatted by the use. To change the format, click on the first result, then click on the **Math Formatting**, and select **General**. Change the format of the second result to **Scientific**. Change the format of the third result to Engineering. Why do the first and third results look the same? Scroll down before starting the next step.

6. As an example in which variables must be defined, the resistance of a 200-ft length of copper wire with a diameter of 0.01 in. will be determined (you will learn more about resistivity in ECET 1101 Circuits I. First, as shown in Figure 2, the variables for resistivity, length, and diameter must be defined. This is accomplished by first clicking on the **Math** tab, selecting the **Symbols** dropdown and then clicking on the letter rho (ρ) in the Lowercase Greek list followed by a combined **Shift-colon (Shift :)** operation. A colon and an equal sign will appear, after which **10.37** is entered. For all calculations to follow, the value of ρ has been defined. A left click on the screen will then remove the rectangular enclosure and place the variable in memory.
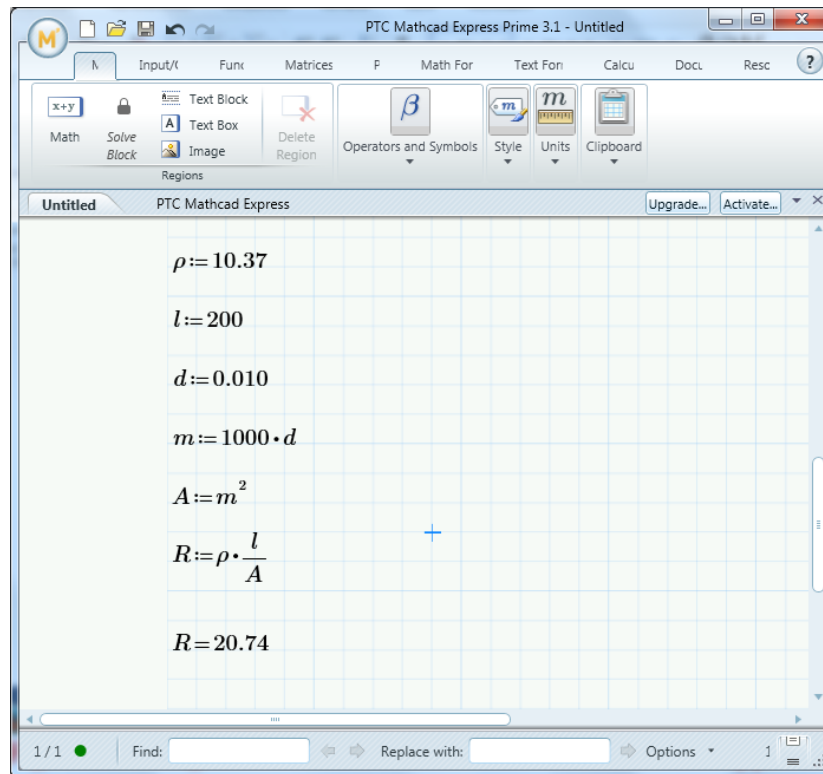

Figure 2. Using Mathcad to calculate the resistance of a copper conductor.

7. Proceed in the same way to define the length l (lowercase L) and the diameter d. Next the diameter in millimeters is defined by multiplying the diameter in inches by 1000, and the area is defined by the diameter in millimeters squared. On the next line of Figure 2, the values of m and A were defined by simply typing m followed by the keyboard equal sign and then A followed by the keyboard equal sign.

   Note the m had to be defined before the expression for A and the variable d was defined before m. The power of 2 was obtained by first selecting the superscript symbol (^) at the top of the number 6 on the keyboard and then entering the number 2 in the Mathcad bracket. Or you can simply type the letter m and choose $\boxed{x^n}$ from the **Operators** dropdown. In fact, all the operations of multiplication, division, etc., required to determine the resistance R can be lifted from the **Operators** dropdown.

8. The equation for the resistance R is defined in terms of the variables, and the result is obtained. The true value of developing in the above sequence is the fact that you can place the program in memory and, when the need arises, call it up and change a variable or two – the result will appear immediately. There is no need to reenter all the definitions – just change the numerical value. Again, scroll down before starting the next step.

9. Examples from the text for ECET 1101 Circuits I and ECET 2111 Circuits II (*Introductory Circuit Analysis*, Boylestad) are a great way to practice Mathcad skills. Here, we'll work Example 6.12 on pages 178-179. As shown in Figure 3, the known parameters and quantities of the network are entered first, followed by an equation for the unknown resistor R_3.
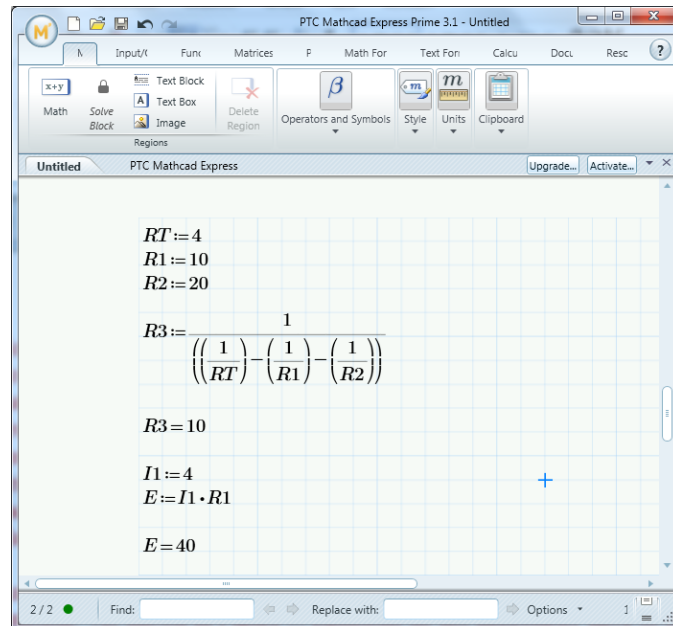
Figure 3. Using Mathcad to confirm the results of Example 6.12.

10. Mathcad can be used to perform matrix arithmetic (matrix manipulation is used a lot in ECET 4610 Control Systems and ECET 3630 Signals and Systems Analysis). For example, create three matrices *A*, *B*, and *C* as shown in Figure 4. To create a matrix, click on the Matrices/Tables tab and select the Insert Matrix dropdown. Once you have created the matrices, evaluate [*A*] + [*B*], [*A*] − [*B*], 3[*A*], [*A*][*B*] and [*A*][*C*] as shown.
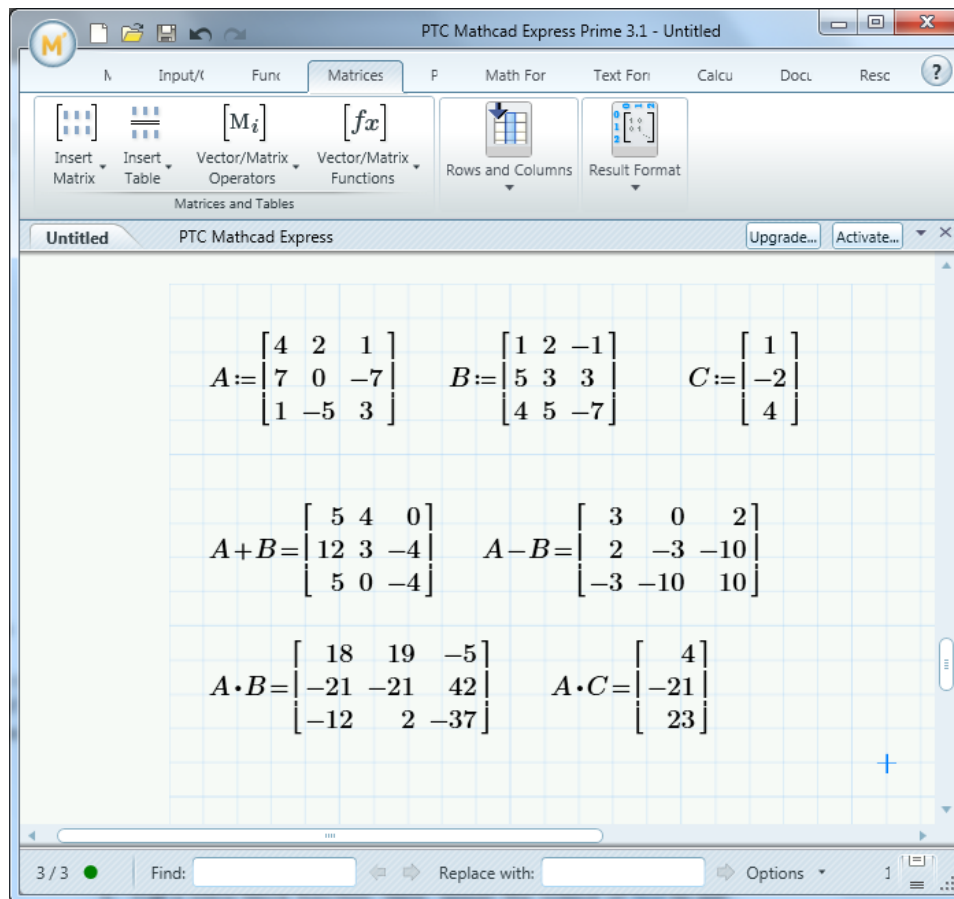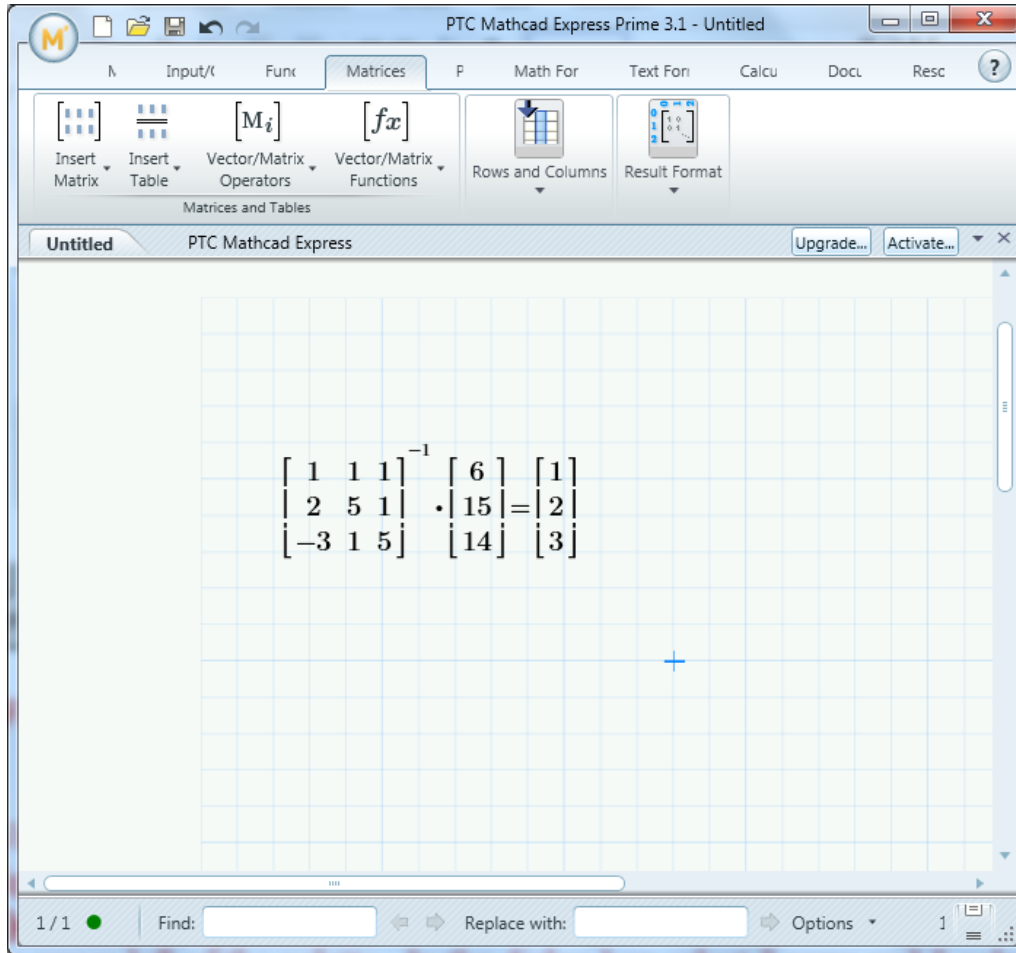

Figure 4. Using the Mathcad to perform matrix arithmetic.

11. There is actually a quick and accurate way to solve simultaneous equations by using matrix algebra. The first step involves rewriting the system of equations in standard form. In standard form, all variables are to the left of the equal sign, only constants are on the right. In addition, the variables occur in the same order on the left side of each equation. For example, these equations define a system involving x_1, x_2, and x_3:

$$1x_1 + 1x_2 + 1x_3 = 6$$
$$2x_1 + 5x_2 + 1x_3 = 15$$
$$-3x_1 + 1x_2 + 5x_3 = 14$$

These equations are written in standard form. The variables x_1, x_2, and x_3 appear, in the same order, in the left side of each and every equation. The right side of each equation contains only constants. The matrix equation shown in Figure 5 calculates x_1, x_2, and x_3. Note that the square matrix is composed of the coefficients of x_1, x_2, and x_3. The column matrix is just the values on the right-hand side of the equations. The result tells us that x_1 is 1, x_2 is 2, and x_3 is 3.

$$\begin{bmatrix} 1 & 1 & 1 \\ 2 & 5 & 1 \\ -3 & 1 & 5 \end{bmatrix}^{-1} \cdot \begin{bmatrix} 6 \\ 15 \\ 14 \end{bmatrix} = \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$$

Figure 5. Using matrix algebra to solve for a set of simultaneous equations.

12. Mathcad can be used to generate plots (for example, in ECET 2300 Electronics I and ECET 2310 Electronics II, you will be plotting experimental data from your laboratory exercises). First the concept of ranging variables and functions must be introduced. In Figure 6 the variable V starts at 0 and goes to 30 in steps of 5. This is created in Mathcad by entering the variable name V, selecting **Shift :**, entering the first value of V (0), entering a comma, entering the second value of V (5), the range symbol (..) is created automatically, and finally enter the last value of V (30).
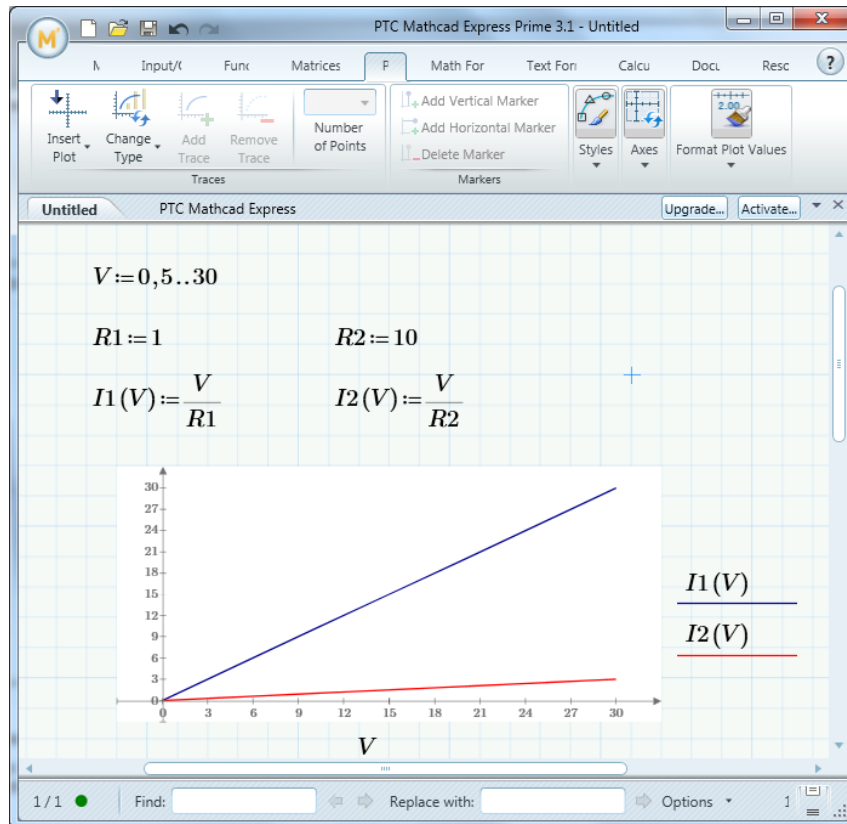
Figure 6. Generating a simple plot using Mathcad.

13. Next R_1 and R_2 are declared as 1 and 10. The function $I_1(V)$ is created as V / R_1. $I_2(V)$ is created in a similar manner. To generate the plot, click below the declarations of $I_1(V)$ and $I_2(V)$. Click on the **Plots** tab. Click on **Insert Plot** and select **XY Plot** from the drop down to generate a plot. Enter V along the x-axis and $I_1(V)$ along the y-axis. Hit the enter button and the plot will be displayed. To add $I_2(V)$ to the plot click on **Add Trace**.

14. Finally, a few more plots will be generated using Mathcad. In Figure 7 the variable t starts at 0 and goes to 2 in steps of 0.001. Again, this is created in Mathcad by entering the variable name t, selecting **Shift :**, entering the first value of t (0), entering a comma, entering the second value of t (0.001), and finally entering the last value of t (2).
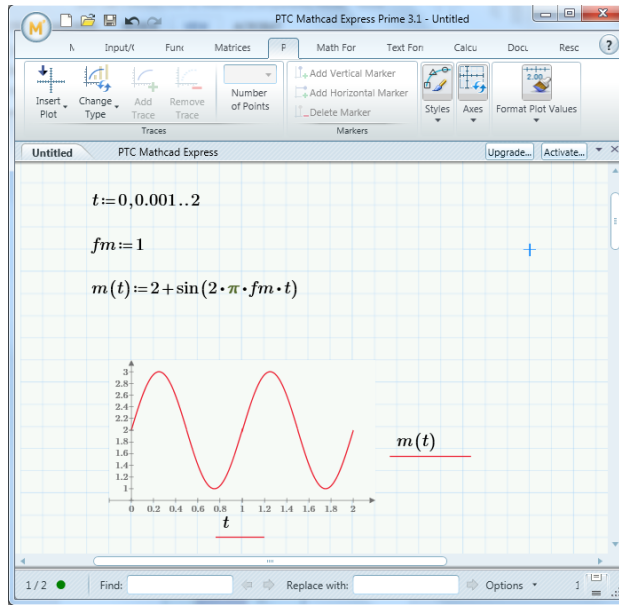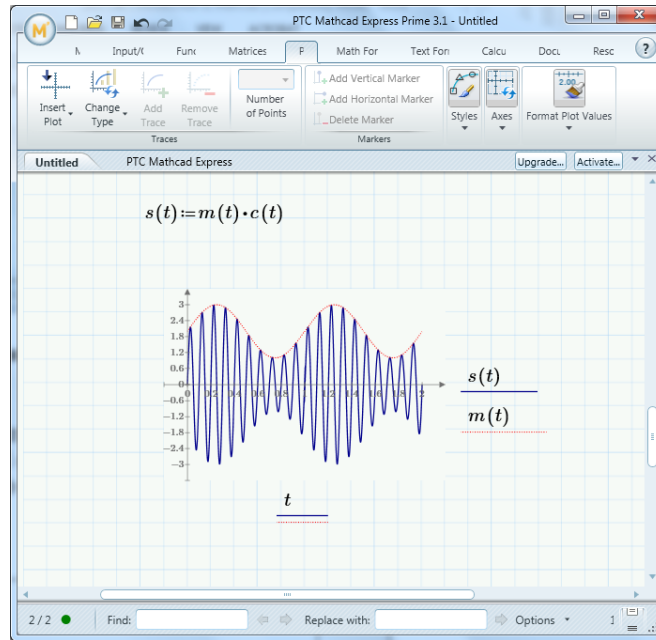
Figure 7. Plotting a simple signal using Mathcad.

15. Next the function *m(t)* is created as the $2 + \sin(2\pi f_m t)$ where f_m is a frequency of 1 Hertz. To generate the plot, click below the declarations of f_m and *m(t)*. Select **Insert Plot** to generate a plot. Enter *t* along the x-axis and *m(t)* along the y-axis. Hit the enter button and the plot will be displayed. Mathcad automatically scales the plots. See if you can change the color of the plot trace (Trace 1) to red.

16. Now repeat steps 14 and 15 to create and plot the carrier *c(t)* $\sin(2\pi f_c t)$ where f_c is a frequency of 10 Hertz. The result should look like Figure 8.
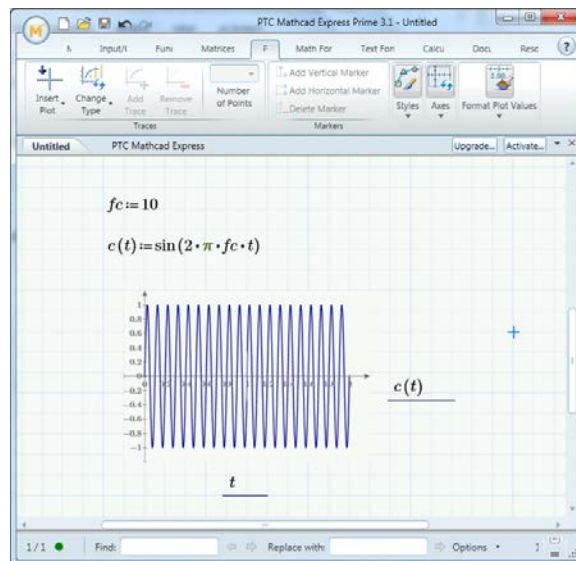
Figure 8. Plotting a carrier signal using Mathcad.

17. Finally, let's see what an amplitude modulated (AM) carrier looks like (you will learn about amplitude and other forms of modulation in ECET 3400 Data Communications). Again, *c(t)* will be the carrier signal and *m(t)* will be the modulating signal. For example, *m(t)* might be the voice signal of a radio announcer and *c(t)* would be the AM station operating frequency such as 640 KHz. Amplitude modulation is accomplished by multiplying the carrier signal by the modulating signal, *s(t) = m(t) * c(t)*. *s(t)* is declared as shown in Figure 9 and a final plot is generated. To display both the modulated carrier *s(t)* and the modulating signal *m(t)* for the y-axis first enter *s(t)*. Then add a trace for *m(t)*. Pressing the enter button at this point generates a plot with two traces. Try to change the line style for *m(t)* to dotted.

Figure 9. Plotting an amplitude modulated carrier signal using Mathcad.

18. Have your instructor review your Mathcad work. Make any required corrections. Once done and demonstrated to your instructor, have your instructor sign, date, and collect these lab worksheets.

Instructor Signature:		Date:	