math xpander

user's guide

Introduction

Math Xpander is an interactive tool for exploring various topics in high school mathematics (in particular, graphing and geometry). Students can explore topics at their own pace, following their own paths of exploration.

Each exploration is automatically recorded in a workbook so that students can return to it at any time. They might, for example, want to repeat a particular exploration, or use one exploration as the starting point for another exploration.

Teachers can use Math Xpander to devise illustrative mathematical experiments which their students can recreate in the classroom. Teachers can also take advantage of built-in teaching aids, such as a catalog of common relations: linear, quadratic, exponential, etc. These relations can be easily customized and plotted, helping students to learn how to identify the type of relation that generates a particular graphical form.

Math Xpander has been designed for handheld devices running the Microsoft® Windows® CE operating system.

e-Lessons

A companion product is a Math Xpander e-Lesson. An e-Lesson is a self-paced tutorial covering one or more important mathematical concepts. It can also be used by teachers to demonstrate a particular mathematical concept or problem.

Math Xpander Components

Math Xpander has five components. These are:

- **scientific calculator**

  You can use Math Xpander as you would any other scientific calculator. You can, for example, make algebraic, trigonometric, relational, probability, and calculus calculations (see chapter 3).

- **Table Xpander**

  Table Xpander enables you to create and statistically analyze samples of data.

  Table Xpander is discussed in chapter 4.

- **Graph Xpander**

  You plot graphs using Graph Xpander. You can transform a graph and watch the equation for the graph continuously update. You can also add various objects to the viewing window, display measurements, and make calculations based on those measurements.

  Graph Xpander is discussed in chapter 5.

- **Geometry Xpander**

  Geometry Xpander enables you to create various geometric objects—such as points, segments, rays, lines, and circles—transform these objects, set various constraints, take measurements, and make calculations based on the attributes of objects.

  Geometry Xpander is discussed in chapter 6.

- **Note Recorder**

  You can use two on-screen keyboards to type notes. Your notes could be reminders, lists of books to read, homework topics, and so on.

  Notes are discussed on page 16.

Every operation you undertake, regardless of the component used, is recorded in a workbook. A workbook is like a diary of your calculations and explorations. You can go back to an entry in that diary—for example, a graph you plotted, a geometric object you constructed, or a table of data you analyzed—and repeat that exploration. The notes you enter are also recorded in a workbook.

Launching Math Xpander

When Math Xpander is launched initially, a blank workbook is displayed.

The workbook window keeps a record of all the explorations and calculations you've undertaken while this particular workbook was open. Up to 9 items can be displayed at one time. You can scroll vertically to display further explorations, and horizontally to reveal more of a particular exploration.

See "Workbooks and Notes" on page 7 for further information.

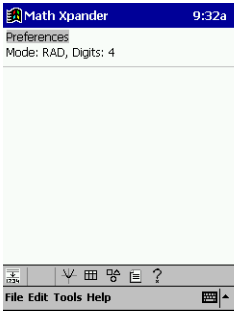


Figure 1-1: A blank workbook.

Input and Selection

Stylus

The stylus is the principal tool for entering information, making selections, and drawing and manipulating objects.

You enter information—such as mathematical expressions, notes, and workbook names—by using the stylus to tap on characters from on-screen keyboards. Similarly, you select an option—a menu item, an OK button, a check box, and so on—by tapping on it with the stylus.

Information that can be edited or copied—such as a mathematical expression, the result of a calculation, a name of a file, and so on—can be selected using the stylus. In some cases you can just tap once on the information to select it—a workbook item, for example—while in other cases you must drag the stylus over the characters you want to select.

You will also need the stylus to draw objects in Math Xpander—such as points, segments, and circles—and to manipulate them.

Keyboards

For most input, you will make use of two on-screen keyboards:

- math keyboard, and
- standard keyboard.

The math keyboard has numerous palettes of mathematical functions and operators. You choose a function or operator by displaying the appropriate palette and tapping on the button that represents that function or operator. The math keyboard is described in detail in chapter 3.

The standard keyboard contains the QWERTY characters you find on a standard PC keyboard. You use the standard keyboard to enter text and to give names to the variables and files that you create.

- To display the currently selected keyboard, tap on the keyboard icon.

  The keyboard icon is  if the standard keyboard is selected, or  if the math keyboard is selected.

- To hide the keyboard, tap on the keyboard icon.
- To select a keyboard, tap on .

  The keyboard list is displayed.

  Select either **Math Keyboard** or **Standard Keyboard**.

  The selected keyboard is displayed.

Menus

You use the stylus to display and select menu options.

Math Xpander online help

To display online help, select **Help** from the **Start** menu. If a dialog box is open at the time, the online help displayed provides information about that box; otherwise a list of online help topics relevant to the environment in which you are working is displayed. For example, if you select **Help** from the **Start** menu when the graph window is open, a list of help topics relevant to graphing is displayed.

You can display a complete list of Math Xpander help topics by selecting **Contents** from the **Help** menu when a workbook is open. This list covers all the Math Xpander environments: workbooks, notes, tables, math, graphing, and geometry.

Workbooks and Notes

A workbook is the hub of your Math Xpander activities. You perform calculations from a workbook, and it is from a workbook that you access the other components that make up Math Xpander: tables, graphing, geometry, and note recording.

Everything you do with Math Xpander—all your graphic, geometric, and tabular explorations, your notes, and all your calculations—are recorded sequentially in a workbook. You can always go back to a previous activity and repeat it. You can also copy a previous calculation to a new line in the workbook.

You can create any number of workbooks. You could, for example, create one workbook for classwork, one workbook for homework, and another for a class project.

Only one workbook can be open at a time.

The Workbook Window

When you open Math Xpander, a workbook window is displayed.

When Math Xpander is opened for the first time, the workbook window is blank (as in Figure 2-1). A blank workbook window is also displayed:

- when you create a new workbook, or
- when you return to Math Xpander after exiting a workbook (that is, after selecting **Exit** from the **File** menu).

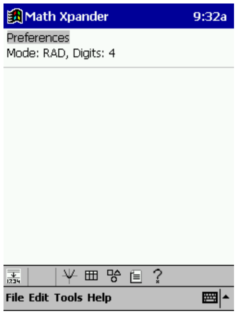


Figure 2-1: Blank workbook

In other cases, you can return to Math Xpander and find the workbook window is as it was when you left it, with all your explorations and calculations still listed.

The workbook window displays all the explorations and calculations you've undertaken while this particular workbook was open (see Figure 2-2 below). Up to 9 items can be displayed in the workbook history at one time. You can scroll vertically to display further explorations, and horizontally to reveal more of a particular exploration.

Input line

The input line is the next free line on the workbook window (see Figure 2-2 below). It is where you can enter calculations.

To enter a calculation, the input line must be active (that is, the cursor must be on the line). To make the input line active:

- tap on the button, or
- tap on the input line.

To record what you enter on the input line, tap on **ENTER** on the math keyboard (see page 20). To cancel an entry, thereby preventing it from being recorded, tap on **ESC**.

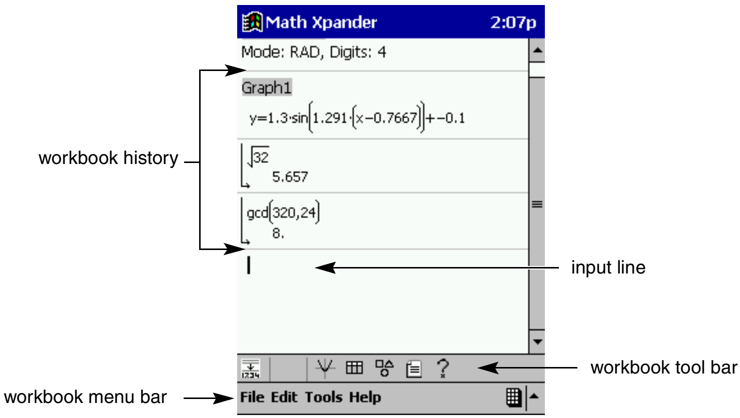


Figure 2-2: Workbook window with items

Workbook menu map

- File
  - New
  - Open...
  - Save as...
  - Create
    - Graph
    - Table
    - Construction
    - Note
  - Exit
- Edit
  - Copy
  - Paste
  - Duplicate
  - Delete
  - Preferences...
- Tools
  - Numeric Root...
- Help
  - Contents...
  - About...

Figure 2-3: Workbook menu map

Workbook tool bar buttons

The workbook window tool bar buttons provide you with workbook tools and with access to Math Xpander's components.

Button	Name	Description
	**Input line**	Moves the cursor to the input line.
	**Graph**	Opens Graph Xpander.
	**Table**	Opens Table Xpander.
	**Geometry**	Opens Geometry Xpander.
	**Note Recorder**	Opens the Note Recorder.
	Help	Opens online help.

Table 2-1: Workbook window tool bar buttons

Workbook items

Graph, geometry, and table workbook items are labeled and show a summary of the exploration. The label uniquely identifies each workbook item: Graph1, Graph2, Graph3, and so on. Notes are also labeled. The entire contents of a note appears in the workbook.

Horizontal lines separate each item.

You can add a comment to a workbook item (see “Adding a comment to workbook item” on page 12). The comment is displayed to the right of the workbook item label. You can later edit the comment.

Returning to a previous exploration

You can return to a previous exploration by selecting it from the workbook history. You might want to review an exploration, or use it as the starting point for another exploration. The original workbook item cannot be modified, unless it is the last item in the workbook.

To return to a previous exploration:

1. Tap on the label of the workbook item you want to re-explore.

   A label menu is displayed.

2. Select **Explore** to open the workbook item, or, in the case of a note, select **Edit**.

   Note that only table, graph, geometry, and note items can be re-explored in this way. To repeat a calculation, you need to copy it to the input line (as explained in the next section).

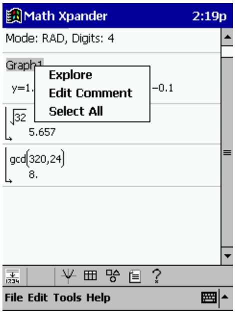


Figure 2-4: Workbook label menu

Selecting a previous expression or result

To select an expression or result in history, tap once on it. The expression or result is highlighted to indicate that it is selected.

To select a subexpression or part of a result:

1. Tap once on the expression or result that contains the character(s) you want to select.

   The expression or result is highlighted to indicate it is selected.

2. Drag the stylus across the character(s) you want to select.

   The character(s) are highlighted to indicate that they are selected. The remaining characters are no longer highlighted.

Duplicating a previous expression or result

Once you have selected a previous calculation, subexpression, result, or subresult, you can copy your selection straight to the input line using the **Duplicate** function:

1. Select the expression, subexpression, result, or subresult.
2. Open the **Edit** menu.
3. Select **Duplicate**.

   The expression, subexpression, result, or subresult you selected is copied to the input line.

Reusing the result of the last calculation

You can copy the result of the last calculation straight to the input line. Make sure nothing is selected and:

1. Open the **Edit** menu.
2. Select **Duplicate**.

   The result of the last calculation is copied to the input line.

Copying a previous expression or result

Once you have selected a previous calculation, subexpression, result, or subresult, you can copy your selection and paste it on the input line:

1. Select the expression, subexpression, result, or subresult that you want to copy (as explained above).
2. Open the **Edit** menu.
3. Select **Copy**.
4. Make the input line active (see "Input line" on page 8).
5. Open the **Edit** menu.
6. Select **Paste**.

   The characters you copied are pasted on the input line.

This procedure is useful if you want to repeat a calculation with greater precision (as explained in chapter 3).

Deleting workbook items

You can only delete the last workbook item.

1. Tap on the label of the workbook item.

   The label menu is displayed (see Figure 2-4 above).

2. Tap on **Select All**.
3. Open the **Edit** menu.
4. Select **Delete**.

   If you are deleting a calculation, the calculation is immediately deleted and you can ignore the rest of this procedure.

5. If you are deleting an item other than a calculation, a warning message is displayed asking you to confirm that you want to delete the workbook item. Tap on **Yes**.

   The workbook item is deleted.

   You cannot undo the deletion of an item.

> You can also delete a calculation. Tap in the space in front of the result of the calculation, and then tap on **Select All** from the pop-up label menu. Then follow the above procedure from step 3.

Adding a comment to workbook item

1. Tap on the label of the item that you want to add a comment to.

   The label menu is displayed (see Figure 2-4).

2. Tap on **Edit Comment**.
3. Type the comment using keys from the standard keyboard (see "Keyboards" on page 5 for further information).

   The comment is displayed to the right of the workbook item label.

You can later edit the comment by repeating the above procedure.

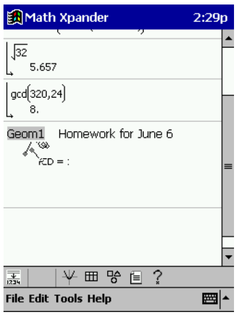


Figure 2-5: Comment added to an item

Setting Preferences

By default, Math Xpander interprets angle measurements in radians and displays numbers only to four significant digits. These default preferences are shown as the first item in every workbook. You cannot delete this item from the workbook history.

You can change these preferences at any time. A record of the change is automatically added to the workbook history and subsequent calculations and explorations use these new preferences.

To change workbook preferences:

1. Open the **Edit** menu.
2. Select **Preferences…**

   The **Preferences** dialog box is displayed.

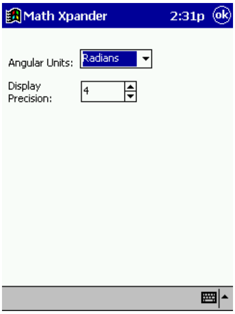


Figure 2-6: Preferences dialog box

3. If required, change the unit of angle measure:
   a. Tap on the **Angular Units** arrow to display the list of options.
   b. Select a unit of angle measure. You have the choice of radians or degrees.
4. If required, change the numeric display precision. You do this by tapping in the **Display Precision** box and:
   - tapping on the **Display Precision** arrows, or
   - entering numbers from the hard keyboard.

   You can enter a number between 1 and 12. This number determines how many digits are displayed in floating-point numbers.
5. Tap on **OK**.

Note that you can set the angular units setting in Geometry Xpander, but this setting applies only to geometry.

Workbook Management

You can create any number of workbooks, although only one can be open at a time. A workbook file always has the extension **.mwb**.

Creating a workbook

To create a new workbook:

1. Open the **File** menu.
2. Select **New**.

   A message is displayed asking if you want to save your current workbook.
3. You can create a new workbook without saving changes, or save the changes to the workbook.
   - If you want to save the current workbook, tap on **Yes**.

     If you have previously saved the current workbook, it is saved again and a new blank workbook is displayed.

     If the current workbook has not been previously saved, you must now give it a name and specify a location for it. See “Saving a workbook” on page 14 for further information.
   - If you don’t want to save the workbook, tap on **No**.

     Any changes you made to the current workbook are discarded, and a new blank workbook is displayed.
4. If you want to cancel the process and return to the current workbook, tap on **Cancel**.

Saving a workbook

You can save a workbook using a different name and, if required, to a different file location.

1. Open the **File** menu.
2. Select **Save As…**

   The **Save As** dialog box is displayed.
3. If you want to save your workbook in some other folder, open that folder.
4. Tap in the **Name** box.

5. Display the standard keyboard (see “Keyboards” on page 5).
6. Enter a name for the workbook.
7. Tap on **OK**.

   The workbook is saved in the specified location.

   Note that the **Type** box contains default settings. Do not change these settings.

Opening a workbook

1. Open the **File** menu.
2. Select **Open**…

   The **Open** dialog box is displayed.

3. If the workbook you want to open is in another folder, open that folder.
4. In the **Type** box, select **Workbooks (*.mwb)**.

   Workbooks are listed by name.

5. Double-tap on the workbook you want to open.

Exiting a workbook

When you exit a workbook, you also close Math Xpander.

1. Open the **File** menu.
2. Select **Exit**.

   A message is displayed asking if you want to save your current workbook.

3. To save the workbook, tap on **Yes**.
   - If you have previously saved the current workbook, the workbook is saved and Math Xpander closes.
   - If the current workbook has not been previously saved, you must now give it a name and specify a location for it. See “Saving a workbook” on page 14 for further information. After saving the workbook, Math Xpander closes.
4. To exit without saving the workbook, tap on **No**.

Notes

You can use the Note Recorder to enter a description, comment, or annotation regarding a particular exploration. You could also record a note to describe the contents of the entire workbook.

Creating a note

1. With a workbook open:
   - tap on the Note Recorder button on the tool bar: , or
   - open the **File** menu, select **Create**, and then select **Note**.

   The **Notes** dialog box is displayed.
2. Open the standard keyboard (see “Keyboards” on page 5).
3. In the **Heading** box, enter a heading for the note.
4. In the **Notes** box, enter your note.
5. Tap on **OK**.

   The note is added to the workbook history.

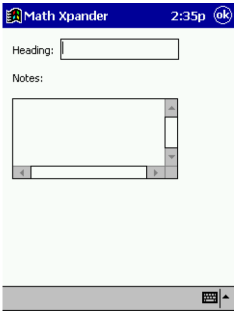


Figure 2-7: Recording notes

Editing a note

1. Tap on the label of the note in the workbook history. The note label menu is displayed.
2. To edit just the heading of the note, select **Edit Comment** from the note label menu and go to step 4.
3. To edit the body of the note, select **Edit** from the note label menu.

   The **Notes** dialog box is displayed, showing the note’s contents.
4. Open the standard keyboard (see “Keyboards” on page 5).
5. Make your changes.

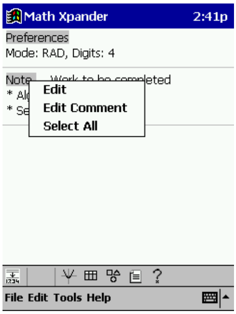


Figure 2-8: Note label menu

6. If you are editing the **Notes** dialog box, tap on **OK** to save your changes; otherwise tap elsewhere to complete the changes to the note heading.

Chapter 3

Math

Math Xpander provides you with tools for performing many types of calculations. Use the special on-screen math keyboard for calculations.

The math keyboard can also be used to:

- construct expressions
- assign values to variables, and
- define functions.

There is also a special tool to help you find the root(s) of an equation.

To perform calculations, you need to have a workbook window displayed (see “The Workbook Window” on page 7).

Math Keyboard

The on-screen math keyboard provides access to a wide range of mathematical operators and functions that you can use to construct expressions.

To display the math keyboard

Tap on the keyboard button on the task bar. The appearance of this button is determined by what keyboard is currently selected:

if the standard keyboard is selected, or if the math keyboard is selected.

If the standard keyboard is displayed instead of the math keyboard:

1. tap on the keyboard switch on the task bar— ▲ —and
2. select **Math Keyboard** from the keyboard list.

To hide the math keyboard

Tap on the keyboard button on the task bar.

Math keyboard functions and operators

The math keyboard comprises three groups of keypads; a left keypad group, a center keypad group, and a right keypad group. Within each keypad group you can display various palettes of symbols, functions, and operators.

LEFT KEYPAD	CENTER KEYPAD	RIGHT KEYPAD
Palettes:	Palettes:	Palette:
– numeric	– main menu	– commands
– variables	– algebra	
	– trigonometric	
	– test	
	– number	
	– advanced	
	– edit	

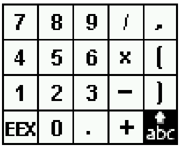
Figure 3-1: Math keyboard groupings

When the math keyboard is displayed for the first time, the numeric and algebra palettes are displayed. If you hide the math keyboard, and then display it again, you will find it as it was when you left it. For example, suppose you displayed the math keyboard and selected functions and operators from the trigonometric and variables palettes to construct an expression. You then hid the math keyboard. When you display the math keyboard again, the trigonometric and variables palettes are displayed.

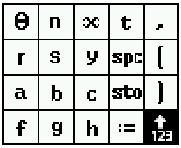
Left keypad group

The left keypad group displays one of two palettes:

- numeric palette, containing numerals and arithmetic operators
- variables palette, containing commonly used variable names, and operators to create variables and define functions.



numeric



variables

Figure 3-2: Left keypad palettes

When the numeric palette is displayed, tap on [icon] to display the variables palette.

When the variables palette is displayed, tap on [icon] to display the numeric palette.

Center keypad group

The center keypad group contains five palettes of mathematical functions and one palette of edit and navigation commands.

The palettes of functions are:

- algebra
- trigonometric
- test
- number
- advanced

Figure 3-3 shows the functions that can be selected from each palette.

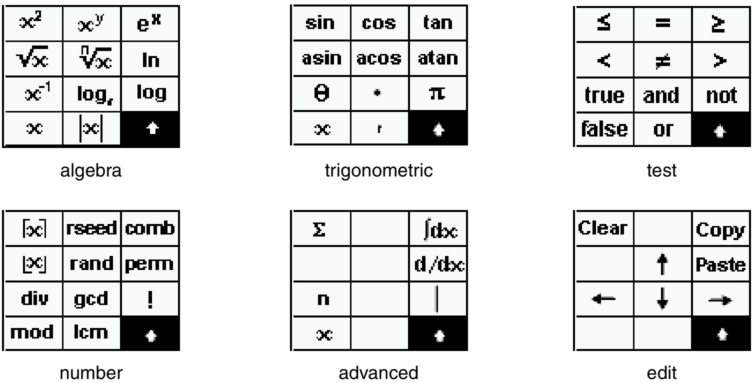


Figure 3-3: Center keypad palettes

To display the center keypad group's main menu, tap on [icon] on any function palette. Tap on a menu option to display the corresponding palette.

For example, to display the trigonometric palette:

1. Tap on to display the center keypad group's main menu.

   The center keypad group's main menu is displayed (see Figure 3-4).

2. Tap on **Trig**.

   The trigonometric palette is displayed.

3. To select a trigonometric function, tap on the corresponding button.

A complete list of functions—including syntax and examples—can be found in Appendix E.

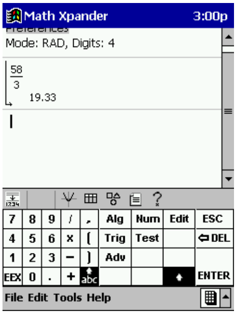


Figure 3-4: Center keypad group's main menu

Right keypad group

The right keypad group does not contain further palettes. It contains buttons for the commonly used commands: **ESC**, ⇦**DEL**, and **ENTER**.

Special constants

In addition to mathematical functions and operators, the on-screen keyboards give you access to the special constants π and *e*.

Constant	Select from…	Approximation used
π	trigonometric palette of math keyboard.	3.14159265358979
e	standard keyboard (standard lower-case letter). See “Keyboards” on page 5 for instructions on accessing the standard keyboard.	2.71828182845905

Table 3-1: Special constants

Calculations using the Math Keyboard

You can perform calculations by constructing expressions using the symbols, functions, and operators on the various palettes of the on-screen keyboards. Numbers and basic arithmetic operators can also be entered from the hard keyboard.

You construct an expression in the same left-to-right order that you use when writing out an expression on paper.

In some cases you need to explicitly indicate an operator's scope. For example, to enter $10^3 + 4$ rather than 10^{3+4}, you need to indicate that the addition is to apply to the entire entry rather than just to the exponent. You indicate this by tapping the right arrow key of the math keyboard after entering the exponent. Similarly, to indicate that you want to calculate $\sqrt{5} + 2$ rather than $\sqrt{5+2}$, you must tap on → after entering 5.

Five sample calculations are provided over the next few pages. The first example illustrates how to construct basic mathematical expressions.

The second example illustrates how you can construct an expression by taking building blocks from more than one palette of the math keyboard. It also illustrates the use of the standard keyboard in constructing expressions containing *e*.

Examples three and four illustrate the general method for specifying functions that take more than one argument.

The final example illustrates how to use an expression from an earlier workbook item as a building block in creating a new expression.

Each example illustrates how the right arrow key can be used to ensure that operators are applied to their correct operands. Note that in many cases, you can use the stylus to position the cursor instead of the right arrow key. Using the stylus may be easier in cases where you would need to tap on → twice to correctly position the cursor for the next entry (as in example 2 below).

The results in examples 1, 2, and 4 are approximations based on the default numeric display precision of 4. To get the most precise answer possible, you should set the numeric display precision to 12. See "Setting Preferences" on page 13 for instructions on changing the numeric display precision.

Example 1

To enter and evaluate $\sqrt{6^3 - 7^2}$:

1. If the cursor is not displayed on the input line:
   - tap on the button, or
   - tap on the input line.
2. Display the math keyboard (see “To display the math keyboard” on page 19).
3. Enter the expression by:
   a. tapping on $\sqrt{x}$
   b. tapping on **6**
   c. tapping on **x^y^**
   d. tapping on **3**
   e. tapping on **→** or tapping to the immediate right of the last entry
   f. tapping on **–**
   g. tapping on **7**
   h. tapping on **x²**
4. Evaluate the expression by tapping on **ENTER**.

   The result, `12.92`, is displayed on the line below the expression. This result assumes a numeric display precision of 4.

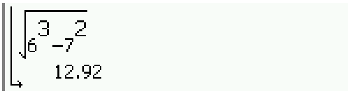


Figure 3-5: Sample expression and result

Example 2

To enter and evaluate sin(3π/4)–log(e):

1. If the cursor is not displayed on the input line:
   - tap on the button, or
   - tap on the input line.
2. Display the math keyboard (see “To display the math keyboard” on page 19).
3. Display the trigonometric palette (see “Math keyboard functions and operators” on page 20).

4. Enter the expression by:
   a. tapping on **sin**
   b. tapping on **3**
   c. tapping on **x** (multiplication sign, not the variable *x*)
   d. tapping on π
   e. tapping on **/**
   f. tapping on **4**
   g. tapping on **→** or tapping to the immediate right of the last entry
   h. tapping on **–**
   i. displaying the algebra palette
   j. tapping on **log**
   k. displaying the standard keyboard (see “Keyboards” on page 5), and
   l. tapping on **e**
5. Evaluate the expression by tapping on **ENTER**.

   The result, `0.2728`, is displayed on the line below the expression.

Figure 3-6: Sample expression and result

   This result assumes a numeric display precision of 4 and that the mode is set to radians.

Example 3

To calculate the greatest common divisor of 124 and 32:

1. If the cursor is not displayed on the input line:
   - tap on the button, or
   - tap on the input line.
2. Display the math keyboard (see “To display the math keyboard” on page 19).
3. Display the number palette (see “Math keyboard functions and operators” on page 20).
4. Enter the expression by:
   a. tapping on **gcd**
   b. tapping on **1**
   c. tapping on **2**
   d. tapping on **4**
   e. tapping on **→** or tapping to the immediate right of the comma
   f. tapping on **3**
   g. tapping on **2**
5. Evaluate the expression by tapping **ENTER**.

   The result, `4`, is displayed on the line below the expression.

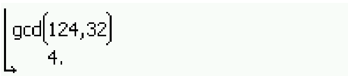


Figure 3-7: Sample expression and result

Example 4

To integrate $3x^4$ with respect to x over the range 1–5:

1. If the cursor is not displayed on the input line:

   - tap on the button, or
   - tap on the input line.

2. Display the math keyboard (see “To display the math keyboard” on page 19).
3. Display the advanced palette (see “Math keyboard functions and operators” on page 20).
4. Enter the expression by:

   a. tapping on **∫dx**

   b. tapping on **l**

   c. tapping on **→** or tapping on the upper limit

   d. tapping on **5**

   e. tapping on **→** or tapping on the integrand

   f. tapping on **3**

   g. tapping on **x** (the multiplication sign, not the variable x)

   h. tapping on **x** (the variable x, not the multiplication sign)

   i. displaying the algebra palette

   j. tapping on **x^y**

   k. tapping on 4

   l. tapping on **→** or tapping on the right of the “d”

   m. tapping on **x** (the variable x, not the multiplication sign).

5. Evaluate the expression by tapping on **ENTER**.

   The result, `1874`, is displayed on the line below the expression.

   This result assumes a numeric display precision of 4.

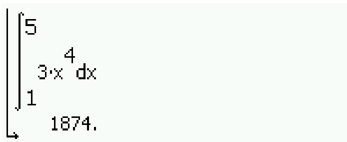


Figure 3-8: Sample expression and result

Example 5

To differentiate cos(2·x) with respect to x:

1. If the cursor is not displayed on the input line:
   - tap on the  button, or
   - tap on the input line.
2. Display the math keyboard (see “To display the math keyboard” on page 19).
3. Display the advanced palette (see “Math keyboard functions and operators” on page 20).
4. Enter the expression by:

   a. tapping on **d/dx**

   b. tapping on **x** (the variable x, not the multiplication sign)

   c. tapping between the parentheses

   d. displaying the trigonometric palette

   e. tapping on **cos**

   f. displaying the numeric palette

   g. tapping on **2**

   h. tapping on **x** (the multiplication sign, not the variable x)

   i. displaying the variable palette

   j. tapping on **x** (the variable x, not the multiplication sign).
5. Evaluate the expression by tapping on **ENTER**.

   The result is displayed on the line below the expression.

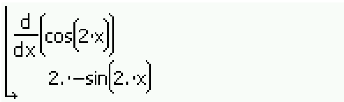


Figure 3-9: Sample expression and result

Example 6

You can use copy and paste tools to reuse a previous expression or result.

Suppose the expression, $x^2 + 2 \cdot x + 1$ appears in history—as in Figure 3-10—and you want to modify it by applying the sine function to the subexpression, $2 \cdot x$.

1. Select the expression, $x^2 + 2 \cdot x + 1$ from history. See “Copying a previous expression or result” on page 11 for instructions on selecting entries in the workbook.

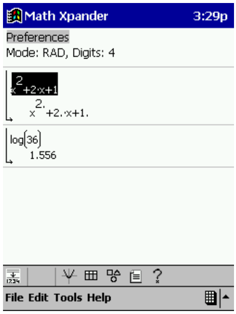


Figure 3-10: Item selected from history

2. Open the **Edit** menu.
3. Select **Copy**.
4. Tap on .

   The cursor is displayed on the input line.

5. Open the **Edit** menu.
6. Select **Paste**.

   The expression is pasted on the input line.

   Any selected character or sequence of characters on the input line is replaced when you paste to the input line.

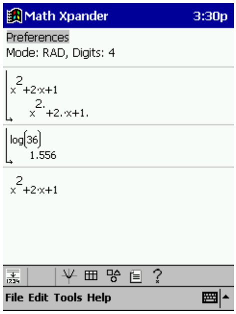


Figure 3-11: Item copied to input line

7. Drag the stylus across $2 \cdot x$ to highlight the subexpression (as in Figure 3-12).
8. Display the math keyboard (see “To display the math keyboard” on page 19).
9. Display the trigonometric palette (see “Center keypad group” on page 21).

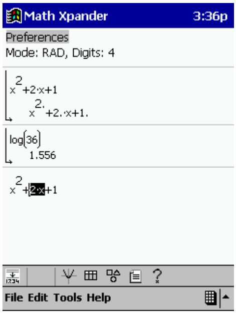


Figure 3-12: Selected a subexpression

10. Select **sin**.

    The expression becomes $x^2 + \sin(2 \cdot x) + 1$. Note that parentheses are inserted automatically.

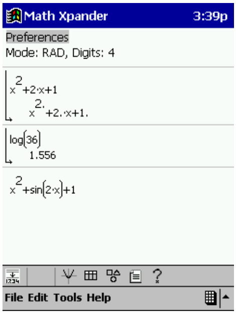


Figure 3-13: Function applied to a subexpression

The copy-and-paste technique illustrated in example 5 above is useful if you want to repeat a calculation at a higher numeric display precision (that is, to obtain a more precise answer). After increasing the numeric display precision, select the earlier expression or result, and select Duplicate from the Edit menu to copy it to the input line, and tap on **ENTER**.

Clearing the contents of the input line

You can clear the contents of the input line by selecting the contents on the input line and tapping on ⇦DEL in the right keypad group in the math keyboard.

Parentheses

Math Xpander automatically inserts parentheses to enclose arguments for functions, such as `cos(45)`. If a function requires more than one argument, a comma is displayed inside the parentheses. The cursor is located in the first argument position. Enter the first argument, tap on → or to the right of the comma, and enter the second argument.

Parentheses are important in specifying the order of operation. Without parentheses, Math Xpander calculates according to the order of *algebraic precedence* (see “Order of operation” on 31).

Order of operation

Functions and operators within an expression are evaluated in the following order. Functions and operators with the same precedence are evaluated in order from left to right (with the exception of consecutive powers, which are evaluated from right to left).

1. Expressions in parentheses (from inner to outer).
2. Prefix functions (for example, sin, ln) and functions where the arguments are graphically enclosed: square root, nth root, division, absolute value, integral, etc.
3. The factorial operator:!
4. Power
5. Unary – (negation), unary +
6. Multiplication
7. Binary + and –
8. =, ≠, <, >, ≤, ≥
9. not
10. and
11. or
12. »(definition of variable)
13. := (definition of function)

Scientific notation

If the result of a calculation is too small or too large to be accurately displayed using the currently set numeric display precision, the number is displayed in scientific notation. For example, if the numeric display precision is 4, the result of calculating 5^6 is displayed as 1.563E+004 (which is equivalent to1.563 $\times 10^4$).

You can enter very large or very small numbers using the **EEX** operator. This operator can be selected from the numeric palette of the math keyboard (see page 20).

Example

To calculate $(5 \times 10^{16}) \times (8 \times 10^{26})$:

1. Display the math keyboard (see “To display the math keyboard” on page 19).
2. If the cursor is not displayed on the input line:
   - tap on the button, or
   - tap on the input line.
3. Enter the expression by:
   a. tapping on **5**
   b. tapping on **EEX**
   c. tapping on **1**
   d. tapping on **6**
   e. tapping on **x** (the multiplication sign, not the variable *x*)
   f. tapping on **8**
   g. tapping on **EEX**
   h. tapping on **2**
   i. tapping on **6**
4. Evaluate the expression by tapping on **ENTER**.

   The result, `4E+043` (that is 4×10^{43}) is displayed under the expression.

Figure 3-14: Sample expression and result

Largest and smallest numbers

The largest number Math Xpander can represent is 1.79769313486E+308. Any larger result is displayed as `Overflow`. The smallest positive number Math Xpander can represent is 2.22507385851E–308. Any smaller result is displayed as zero.

Explicit multiplication

All multiplication must be explicit. You must enter a multiplication sign in an expression where multiplication is to occur. For example, $2x$ must be entered as $2 \times x$. It is displayed as $2 \cdot x$.

Assigning a Value or Expression to a Variable

You can create your own variables and assign a real number or expression to each one.

You give a variable a name. The name can consist of:

- a single alphabetical character other than *e* or π, or
- a string of alphanumeric characters that begins with an alphabetical character.

Variable names are case-sensitive.

In general, the process to assign a value or expression to a variable is to specify the value or expression, select the **sto** command from the math keyboard, specify a name for the variable, and tap on **ENTER**.

Example

To assign the value of the expression $5 - 2^3$ to the variable named *a*:

1. If the cursor is not displayed on the input line:
   - tap on the  button, or
   - tap on the input line.
2. Display the math keyboard (see “To display the math keyboard” on page 19).

3. Enter the expression by:
   a. tapping on **5**
   b. tapping on **–**
   c. tapping on **2**
   d. tapping on **x^y**
   e. tapping on **3**
   f. tapping on **→** or tapping to the immediate right of the last entry
4. Open the variables palette (see “Left keypad group” on page 20).
5. Tap on **sto**
6. Specify the name for the variable by tapping on **a**
7. Tap on **ENTER**.

   The result of the evaluated expression, `-3`, is stored in the variable named *a*.

Figure 3-15: Assigning an expression to the variable named *a*.

In this example, the name for the variable was chosen from the variables palette. However, you are not restricted to the variables on the variables palette in naming your variables. You can, for example, use the standard keyboard to give your variable any name you choose (as long as it begins with an alphabetical character); for example, *length* or *slope*.

Recalling a variable

You recall the number or expression assigned to a variable by entering the variable's name.

Example

This example recalls the variable, *a*, used in the example above to evaluate the expression $4a \times 2$.

1. If the cursor is not displayed on the input line:

   - tap on the button, or
   - tap on the input line.

2. If the math keyboard is not already open, open it (see "To display the math keyboard" on page 19).
3. If the variable palette is not displayed, tap on .

   If you had named your variable using characters only available from the standard keyboard, you would have to open the standard keyboard at this step, not the variables palette of the math keyboard.

4. Enter the expression by:

   a. tapping on **4**

   b. tapping on **x** (the multiplication sign, not the variable *x*)

   c. tapping on **a**

   d. tapping on **x** (the multiplication sign, not the variable *x*)

   e. tapping on **2**

5. Tap on **ENTER**.

   Because –3 had been assigned to *a* (see previous section), the expression $4a \times 2$ evaluates to `-24`.

Figure 3-16: Recalling the variable named *a*.

Defining and Evaluating a Function

You can define a function in terms of one, two or three variables. The syntax to use is:

> *function name* (*variable*$_1$, *variable*$_2$, …) := *definition*

Examples: $h(x) := 9x + 7$ and $m(x, y) := x^2 + y^2$

Once a function is defined, you can evaluate it for a particular value of the independent variable by specifying that value as the argument of the function; for example, h(9).

Example

In this example the function, $h(x) := 9x + 7$ is first defined and then evaluated when $x = 9$.

Define the function

1. Place the cursor on the input line (see page 8).
2. Display the math keyboard (see “To display the math keyboard” on page 19).
3. If the variable palette is not displayed, tap on  .
4. Specify the function by:
   a. tapping on **h**
   b. tapping on **(**
   c. tapping on **x** (the variable *x*, not the multiplication sign)
   d. tapping on **→** or tapping to the right of the *x*
   e. tapping on **:=**
5. Enter the expression by:
   a. tapping on **9**
   b. tapping on **x** (the multiplication sign, not the variable *x*)
   c. tapping on **x** (the variable *x*, not the multiplication sign)
   d. tapping on **+**
   e. tapping on **7**
6. Define the function by tapping on **ENTER**.

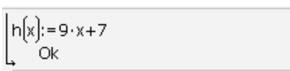


Figure 3-17: Define the function

Evaluate the function when x=9

1. If the cursor is not displayed on the input line:
   - tap on the  button, or
   - tap on the input line.
2. Tap on **h**
3. Tap on **(**
4. Tap on **9**
5. Evaluate the function by tapping on **ENTER**.

   The result, `88`, is obtained by substituting 9 for x in the expression you assigned to the function h(x).

Figure 3-18: Evaluate the function when x=9

Finding a Numeric Root

Math Xpander provides you with a tool—the numeric root finder—for finding the numeric value of a variable for which a particular expression evaluates to zero or an equation is satisfied. The expression or equation must evaluate to a real number.

The expression or equation may contain more than one variable, in which case you must not only specify the variable to solve for, but also have stored values in the other variables.

You can construct your expression or equation in the numeric root finder, or copy it into the numeric root finder from the workbook history.

The numeric root finder is accessible from a workbook.

To find the numeric root of an expression:

1. Open the **Tools** menu.
2. Select **Numeric Root**.

   The Numeric Root dialog box is displayed.

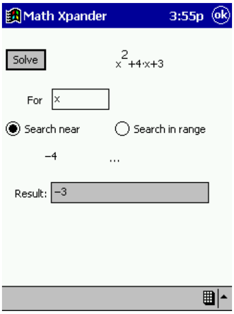


Figure 3-19: Numeric root solution near a value

3. In the Solve box, enter the expression you want to solve.

   Enter the expression by constructing it from the various palettes of the math keyboard.
4. In the **For** box, enter the variable that you want to solve for.

   Even if your expression is in one variable, you still need to enter the variable in the **For** box.
5. To indicate that the root you want to find is near a particular value, tap on the **Search near** button and enter the value in the box below the button.

   Typically this value is an estimate of the root based on your analysis of the graph of the expression.
6. To indicate that the root you want to find lies between two values:

   a. Tap on the **Search in range** button.

   b. Tap in the left box below the buttons and enter a value for the lower bound of the search range.

   c. Tap in the right box below the buttons and enter a value for the upper bound of the search range.

   The search range value could be based on your analysis of the graph of the expression.

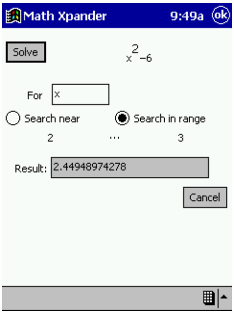


Figure 3-20: Numeric root solution within a range

7. Tap on **Solve**.

   The result is displayed in the **Result** box.

Exploring Tables

Table Xpander is where you can record data and statistically analyze it.

Accessing Table Xpander

You access Table Xpander from a workbook (see “The Workbook Window” on page 7 for information). Once a workbook is open, you can:

- tap on the Table button on the toolbar:  , or
- open the **File** menu, select **Create**, then select **Table**, or
- tap on a table label in the workbook history and select **Explore** from the menu.

If you tap on the **Table** button or choose **Table** from the **Create** submenu, Table Xpander opens with a blank table; if you tap **Explore** after tapping on a table label in history, Table Xpander opens and displays details of the table associated with that workbook item.

The Table Window

The table window consists of the table pane, sash, and statistics pane.

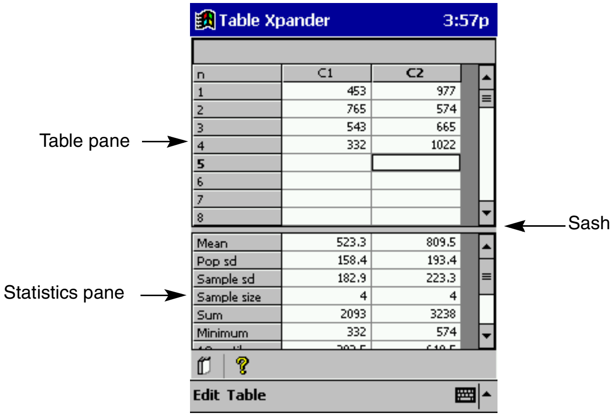


Figure 4-1: Table window

Scrolling vertically. Use the vertical scroll box to scroll through rows of data.

Scrolling horizontally. Use the horizontal scroll box to scroll through columns of data.

Table pane

The table pane is where you create a table. You create one table at a time. If you are beginning a new table exploration, the table pane displays a three-column table. The first column is headed **n** and displays the row numbers. The other two columns are empty and are headed **C1** and **C2**. If you are revisiting a table exploration, the table pane displays the columns and data of the particular exploration.

Statistics pane

The statistics pane displays statistics based on the data in the table pane. The statistics are displayed only if you have selected **Statistics** from the **Table** menu (see page 45).

Statistics are automatically updated to reflect changes you make to the values in the table pane.

Sash

The sash is the shaded boundary between the table pane and the statistics pane. The sash enables you to increase or decrease the size of a pane:

1. Place the stylus on a sash.
2. Drag the stylus up or down.

Dragging the sash up reveals more of the statistics pane; dragging the sash down reveals more of the table pane.

Table window menu map

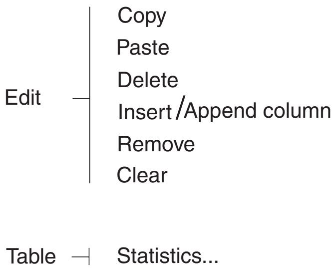


Figure 4-2: Table window menu map

Table window buttons

Button	Name	Description
	Workbook	Returns you to the current workbook.
	Help	Display the contents of the online help.

Table 4-1: Table window buttons

Adding Values

You can add an unlimited number of columns, and an unlimited number of values, to a table.

To add a value:

1. Tap on an empty cell.

   The cell is highlighted to indicate it is selected. If the cursor is not displayed, tap on the cell again.

2. Enter a number or an expression that evaluates to a real number; for example, 6 or $9^2 \times 6^3$.

3. Repeat steps 1 and 2 to enter further values.

Editing Tables

You can edit a table by:

- inserting rows and columns
- appending a column to a table
- changing the width of a column
- clearing values in a specified column
- removing columns and rows
- changing the value in a cell.

Inserting an empty row

1. Select a row. You can do this by:

   - tapping on the row number, or
   - dragging the stylus through the entire row.

   The row is highlighted to indicate it is selected.

2. Open the **Edit** menu.

3. Select **Insert row**.

   An empty row is inserted directly above the selected row.

Inserting an empty column

You can insert an empty column in a table. The empty column is inserted to the left of the selected column.

1. Select a column. You can do this by:
   - tapping on the column heading, or
   - dragging the stylus through the entire column.

   The column is highlighted to indicate it is selected.
2. Open the **Edit** menu.
3. Select **Insert column**.

   An empty column is inserted directly left of the selected column.

Appending an empty column

You can append an empty column to the end of a table. Make sure no column is selected and:

1. Open the **Edit** menu.
2. Select **Append column**.

   An empty column is added after the last column in the table.

Changing the width of a column

You can increase or decrease the width of a column.

1. Select the right border of the heading of the column you want to change the width of.
2. Change the column width by either:
   - dragging the stylus to the left to decrease the column width, or
   - dragging the stylus to the right to increase the column width.
3. Lift the stylus from the heading.

Clearing values in a column

To clear the values in a column:

1. Select the column. You can do this by:
   - tapping on the column heading, or
   - dragging the stylus through the entire column.

   The column is highlighted to indicate it is selected.
2. Open the **Edit** menu.
3. Select **Clear column**.

   The data is removed and a blank column remains.

Removing a column

To remove a column:.

1. Select the column that you want to remove.

   The column is highlighted to indicate that it is selected.
2. Open the **Edit** menu.
3. Select **Remove column**.

   The column is removed from the table. The numbers of the remaining columns are adjusted.

Removing a row

To remove a row:

1. Select the row that you want to remove.

   The row is highlighted to indicate that it is selected.
2. Open the **Edit** menu.
3. Select **Remove row**.

   The row is removed from the table. The numbers of the remaining rows are adjusted.

Changing the value in a cell

To change a value in a cell:

1. Tap on the cell that contains the value you want to change.

   The cell is highlighted to indicate it is selected.

2. Enter a number or expression that evaluates to a real number.
3. Tap in a blank cell or on **ENTER**.

Calculating Statistics

You can statistically analyze the values in a table. Only one-variable analysis is possible. The frequency of each value in a column is taken as 1.

The statistics that can be calculated are shown in Table 4-2.

1. Open the **Table** menu.
2. Select **Statistics…**

   The **1-Var Statistics** dialog box is displayed.

3. Select the one-variable statistics to calculate by tapping on the corresponding check boxes.
4. Tap on **OK**.

   The statistics for each column of data are displayed in the statistics pane.

Figure 4-3: 1-Var Statistics dialog box

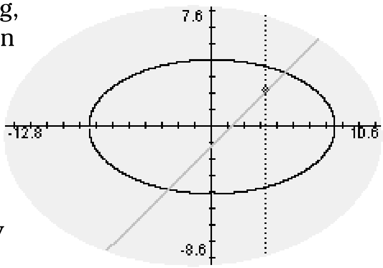
Statistic	Description
Mean	Mean of values
Population Std Dev	Population standard deviation
Sample Std Dev	Sample standard deviation
Sample size	Number of values
Sum	Sum of the values
Minimum	Minimum value
1st quartile	Median of the lower half of the values
Median	Median of the values
3rd quartile	Median of the upper half of the values
Maximum	Maximum data value

Table 4-2: One-variable statistics.

Chapter 5

Exploring Graphs

Graph Xpander provides an interactive and dynamic tool for creating, manipulating, and exploring graphs. It is interactive in that you can directly transform certain graphs with the stylus; and it is dynamic: when you transform a graph, its equation is continuously updated on the screen.



You can create a graph by first roughly sketching it with the stylus and then choosing a type of relation that you want the sketch to represent. Your sketch is then redrawn so that it becomes a mathematically precise instance of the type of relation you chose. You can also create a graph by choosing its type from a list and specifying the constants.

x	p11	p12	q1
0.00	4.07	-4.07	-1.10
0.10	4.07	-4.07	-1.00
0.20	4.07	-4.07	-0.90
0.30	4.06	-4.06	-0.80
0.40	4.06	-4.06	-0.70

For each graph you create, you can choose to display a table of the coordinates of plotted points. You can modify this table in various ways, and use it to determine the value(s) of a dependent variable for a specified value of the independent variable.

You can add various objects to a graph and to the viewing window, trace a graph, translate and dilate a graph, and zoom in or out on the viewing window.

You can also take measurements of the geometric objects you add to the viewing window. These measurements are continuously updated as you move the underlying objects.

Accessing Graph Xpander

You access Graph Xpander from a workbook. Once a workbook is open, you can:

- tap on the Graph button on the tool bar: ❶
- open the **File** menu, select **Create** and then select **Graph**: ❷, or
- tap on a graph label in the workbook history, ❸, and select **Explore** from the label menu.

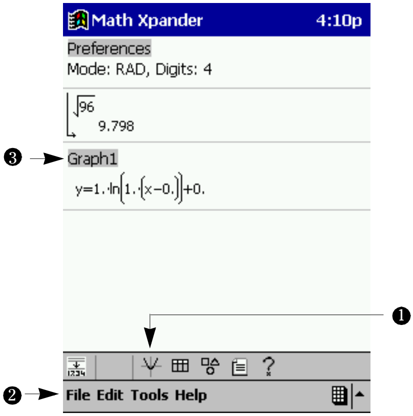


Figure 5-1: Accessing Graph Xpander

If you tap on the Graph button (or choose **Graph** from the **Create** submenu), Graph Xpander opens with a blank window; if you choose **Explore** after tapping on a graph label in history, Graph Xpander opens and displays details of the graph(s) associated with that graph label (that is, the graph(s) defined by the equation(s) below the label). In the latter case, you could, for example, draw a new graph over the existing graph(s).

Unless the graph you display by selecting **Explore** is the last item in the workbook, any change you make to it—such as adding a point or modifying a component equation—will not be saved in the workbook. Only changes made to the last workbook item are saved.

Graph Window

The graph window is the window displayed when you open Graph Expander. It is divided into three panes: the symbolic pane, graph pane, and table pane. Each pane is separated from an adjacent pane by a sash.

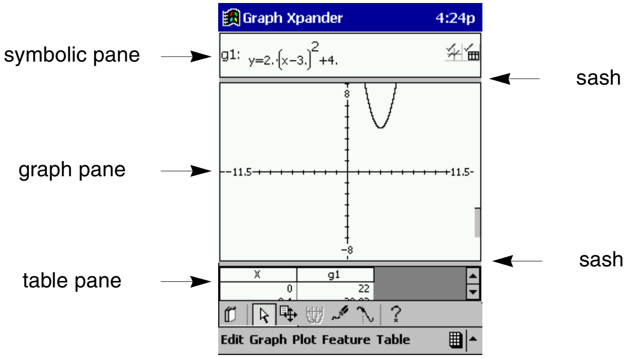


Figure 5-2: Graph Xpander window

Sashes

A sash is the shaded boundary between two panes (see Figure 5-2 on page 49). A sash enables you to increase or decrease the size of a pane:

1. Place the stylus on a sash.
2. Drag the stylus up or down.

Dragging the sash up reveals more of the pane below the sash; dragging the sash down reveals more of the pane above the sash.

Symbolic pane

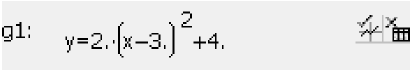


Figure 5-3: Symbolic pane

The symbolic pane displays the equation of each graph. You can edit the constants in an equation—2, 3, and 4 in the example in Figure 5-3—by tapping on them and entering new values (see “Changing the equation of a graph” on page 65). You can also change an equation by directly changing the corresponding graph (see “Directly manipulating a graph” on page 65).

There is an equation for each graph displayed. If the equation you want to see is hidden, tap on the scroll bar at the right of the symbolic pane. (Scroll bars only appear if there is more information displayed in the symbolic pane than can fit in its current size.)

Near the right edge of the symbolic pane are two small buttons. One button——represents a graph you have plotted, and the other button——represents the associated dependent variable column(s) in the table pane. You can hide and redisplay a graph, or the dependent variable column(s), by tapping on the corresponding button. A checkmark to the left of the button indicates that the graph or dependent variable column(s) are displayed; a cross indicates that they have been hidden. In the example in Figure 5-3, the graph is displayed, but the dependent variable column is hidden.

Graph pane

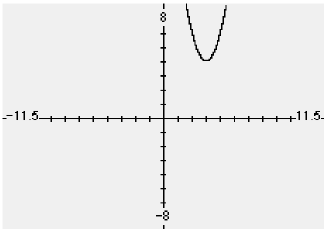


Figure 5-4: Graph pane

The graph pane is where graphs are drawn.

The boundary values of the graph pane are centered along the edges of the graph pane. In the example in Figure 5-4, these values indicate that the graph pane extends from $x = -11.5$ to $x = 11.5$, and from $y = -8$ to $y = 8$.

You can directly manipulate certain graphs with the stylus (see “Directly manipulating a graph” on page 65). You can also:

- change the boundaries of the viewing window (see “Modifying the Viewing Window” on page 67)
- add objects—such as points and segments—to the viewing window (see “Adding Elements to the Graph Pane” on page 79)
- take measurements (see “Measurements” on page 82)

Hiding and redisplaying axes

By default, axes are drawn on the graph pane. To hide the axes:

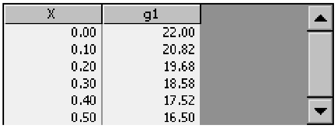
1. Open the **Graph** menu.
2. Select **Show**.
3. Select **Axes**.

The axes and the boundaries of the graph pane are hidden.

To redisplay hidden axes, follow the same procedure.

Table pane

The table pane displays a table of coordinate values for points on a graph. The leftmost column lists values of the independent variable. The remaining columns list corresponding values for the dependent variable for each graph plotted.



X	g1
0.00	22.00
0.10	20.82
0.20	19.68
0.30	18.58
0.40	17.52
0.50	16.50

Figure 5-5: Table pane showing coordinate values

By default, only a single row of values is visible in the table pane. You need to drag the sash between the graph pane and the table pane upward to see more rows of the table pane, as in Figure 5-5.

Where you have plotted many graphs, the columns for each graph may not be visible. You can display more columns either by using the scroll bar or by reducing the width of one or more columns.

The values of the coordinates listed in the table pane are determined by your table settings (see “Changing table settings” on page 74). The vertical scroll bar to the right of the table pane enables you to scroll through the values in that range.

Graph window menu map

- Edit
  - Copy
  - Paste
  - Delete
- Graph
  - Show
    - Axes
  - Tracer
  - Select
  - Zoom
    - In
    - Out
    - Into Box
    - Integer
    - Decimal
    - Trig
  - Pan
  - Translate
  - Dilate
  - Settings...
- Plot
  - Function...
  - Conic...
  - Fit Sketch
    - Linear
    - Quadratic
    - Exponential
    - Logarithmic
    - Sine
    - Cosine
    - Power
  - Fit Conic
    - Circle
    - Ellipse
    - Horizontal Hyperbola
    - Vertical Hyperbola
    - Horizontal Parabola
    - Vertical Parabola
- Feature
  - Function
    - Point on curve
    - First derivative
  - Geometric
    - Point
    - Segment
    - Measurement...
    - Delete Measurement
    - Attributes...
    - Point Trail
  - Sketch
- Table
  - Zoom In
  - Zoom Out
  - Settings...

Figure 5-6: Graph window menu map

Graph window buttons

	Button	Name	Description
		**Workbook**	Returns you to the workbook, adding a workbook item summarizing the graph(s) you have drawn.
		**Select**	Makes the stylus a select tool. Crosshairs are displayed at the stylus tip when the stylus becomes a select tool. An object subsequently tapped becomes selected. You can also select an object by using the stylus to place the center of the crosshairs on the object, and then lifting the stylus. Note that you can select only one object at a time with the select tool in Graph Xpander.
group		**Pan**	Makes the stylus a pan tool. You can now drag the stylus through the graph pane to modify the boundary values (see page 70).
		**Zoom**	Makes the stylus a Zoom Into Box tool (see page 71). A rectangle drawn on the screen becomes the region zoomed in on.
group		**Translate**	Makes the stylus a translation tool. You can now translate—that is, move—a selected object (see page 65). The translation tool is only active if an object is selected.
		**Dilate**	Makes the stylus a dilation tool. You can now dilate—that is, stretch or shrink—a selected graph (see page 66). The dilation tool is only active if an object is selected.
group		**Sketch**	Makes the stylus a sketch tool. You can now draw freehand objects in the graph pane (see page 63).
		**Point**	Makes the stylus a point-creation tool (see page 79).
		**Segment**	Makes the stylus a segment-creation tool (see page 80).

Table 5-1: Graph window buttons

Button	Name	Description
	**Trace**	Activates the trace tool (see page 76). A vertical trace line is drawn on the screen and a trace point appears at the intersection of the trace line and the selected graph.
	**Help**	Displays the contents of the online help.

Table 5-1: Graph window buttons (Cont.)

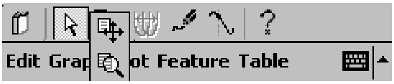


Figure 5-7: Pan and Zoom button group

The **Pan** and **Zoom** buttons form a button group, as do the **Translate** and **Dilate** buttons, and the **Sketch**, **Point**, and **Segment** buttons. In a button group, only one button is displayed at one time. To display the other button(s) in the group, hold your stylus on the button. The other button(s) appear directly below the first button (as in Figure 5-7).

When a second or third button is displayed, it can be selected by tapping on it. A button you select in this way then becomes the button displayed for the group.

Plotting Graphs

The types of graphs you can plot are:

- function, and
- conic section

There are three ways you can plot a graph:

- by specifying the equation for the graph (except for conic sections))
- by selecting a type of graph from a list, or
- by roughly sketching the graph with the stylus and converting the sketch to a mathematically defined graph.

You can draw multiple graphs in the one viewing window, that is, superimpose one or more graphs over another. However, a maximum of 10 graphs can be plotted in the one viewing window.

Functions

A function plot is a plot of an equation that returns a unique value for each value of x. Examples of such equations are $y = x^2 + 2x + 3$ and $y = \sin x$.

You can plot a function by:

- specifying the equation of the function
- selecting a predefined equation from a menu of common functions, or
- drawing a sketch and converting it to the graph of a function.

To specify an equation, you choose **User-Defined** as the type of function to plot. To plot a predefined equation, you must first select one of seven categories of equations (see next section). If you want to convert a sketch to the graph of a function, see "Creating a graph by sketching" on page 63.

Predefined equations

The functions for which predefined equations are available for selection are:

- linear
- quadratic
- exponential
- logarithmic
- sine
- cosine, and
- power.

The predefined equations are listed in Table 5-2 below.

Function Type	Predefined Equation
linear	$y = m(x-h)+k$
quadratic	$y = a(x-h)^2+k$
exponential ■ general ■ natural	 $y = ba^x+k$ $y = be^{ax}+k$
logarithmic	$y = b \cdot \ln(a(x-h))+k$
sine	$y = b \cdot \sin(a(x-h))+k$
cosine	$y = b \cdot \cos(a(x-h))+k$
power	$y = a(x-h)^r+k$

Table 5-2: Equations of predefined functions

When you choose a predefined function, default values are provided for the constants *a*, *b*, *m*, *h*, *k, and r.* You can change these values, both before plotting and after plotting.

If you choose to plot a function based on one of the predefined equations listed in Table 5-2, you can also superimpose the plot of the first derivative of the equation. See “Adding the first derivative of a function” on page 81 for detailed instructions.

Plotting a function

1. If Graph Xpander is not open, open it. (See “Accessing Graph Xpander” on page 48 for instructions.)
2. Open the **Plot** menu.
3. Select **Function…**

   The **Function Plot** dialog box is displayed. The default function type is **User-Defined**.

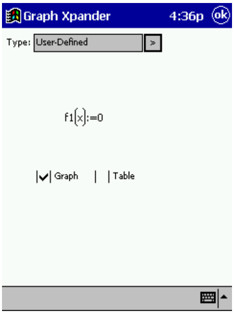


Figure 5-8: Function Plot dialog box

4. If you want to graph a user-defined function:
   a. Enter the function, using the math keyboard to assemble the components. See page 19 for instructions on using the math keyboard.

      Note that you can define a function in terms of another function by referring to its label; for example, $x \cdot f3(x + 2)$.

   b. continue from step 8.
5. If you want to graph one of the predefined equations, tap on the functions menu button to the right of the **Type** field:
6. Choose the type of function from the function menu (see Figure 5-9).

   If you chose exponential, a submenu of equations is displayed. Tap on the equation you want to plot.

   The equation you chose now appears in the text box (see Figure 5-10).

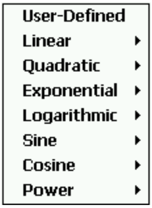


Figure 5-9: Functions menu

7. To change a constant, select the constant and type a new value.

   You select a constant by dragging the stylus over it.

8. You can choose whether or not to display the graph of the equation you have specified or selected. You might, for instance, only be interested in the coordinates of points on the graph (which are displayed in the table pane).

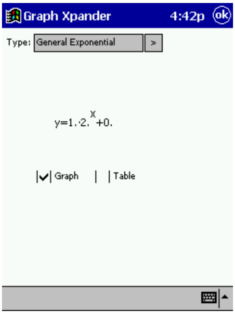


Figure 5-10: Pre-defined function

   By default, the graph is displayed. To suppress the display, clear the **Graph** check box by tapping on it.

9. You can also choose whether or not to display a dependent variable column in the table pane. (See “Table pane” on page 51.) The range and spread of values displayed is determined by your table settings (see page 74).

   By default, the dependent variable column is not displayed. To display the column, select the **Table** check box by tapping on it.

10. Tap on **OK**.

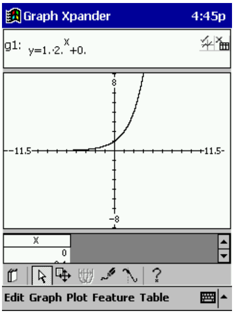


Figure 5-11: Sample function Plot

   The equation of your graph appears in the symbolic pane, the plot is drawn in the graph pane (if the **Graph** check box is selected), and a dependent variable column is displayed in the table pane (if the **Table** check box is selected).

   User-defined functions are labeled **f1**, **f2**, **f3**, … **f10** in the symbolic and table panes, while those based on a predefined equation are labeled **g1**, **g2**, **g3**, … **g10**.

   You can display the graph even if you earlier chose to suppress it (see step 8). You do this by tapping on the graph button at the right-hand side of the symbolic pane. Similarly, you can display a suppressed dependent variable column by tapping on the table button, also at the right-hand side of the symbolic pane. The graph and table buttons will also hide a graph or dependent variable column if it is displayed. (The graph and table buttons are illustrated on page 50.)

11. If you have displayed the graph, it will be automatically selected. (This enables you to immediately transform the graph, or display the trace point.) To deselect the graph, tap on it.

12. If you want to plot another function in the same viewing window, repeat the procedure from step 2. If you want to plot a conic section in the same viewing window, follow the procedure in “Conic section plots” on page 60.

Related topics. Once you have plotted a function, you can:

- change the boundaries of the viewing window (see “Modifying the Viewing Window” on page 67)
- trace a point along the graph (see “Trace Tool” on page 76)
- transform the plot, providing it is based on one of the predefined equations (see “Directly manipulating a graph” on page 65)
- add graphic objects to the graph pane (see “Adding Elements to the Graph Pane” on page 79)
- add the first derivative (see “Adding the first derivative of a function” on page 81).

Conic section plots

The equation for a conic section plot is a polynomial of second degree or less in both x and y. An example is $x^2 + y^2 = 8$. You plot a conic section by first selecting a predefined type of conic section from a menu of common types. The predefined types and the associated equations are listed in Table 5-3 below.

Type	Predefined Equations
circle	$(x-h)^2 + (y-k)^2 = r^2$
ellipse	$\frac{(x-h)^2}{a^2} + \frac{(y-k)^2}{b^2} = 1$
hyperbola	$\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$ $\frac{(y-k)^2}{b^2} - \frac{(x-h)^2}{a^2} = 1$
parabola	$(x-h)^2 = 4a(y-k)$ $(y-k)^2 = 4a(x-h)$

Table 5-3: Predefined conic section equations

When you choose a conic section equation, Graph Explorer provides default values for the constants a, b, h, k, and r. You can change these values, both before and after plotting.

Plotting a conic section

1. If Graph Xpander is not open, open it. (See “Accessing Graph Xpander” on page 48 for instructions.)
2. Open the **Plot** menu.
3. Select **Conic...**

   The **Conic Section Plot** dialog box is displayed enabling you to select your conic section equation.

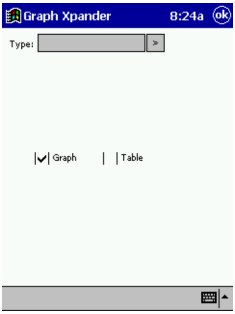


Figure 5-12: Conic Section Plot dialog box

4. Tap on the conic section menu button to the right of the **Type** field: [>]
5. The conic section menu gives you the choice of six conic section equations. Tap on the type of equation you want to plot.

   The equation you chose now appears in the text box (see Figure 5-13). The constants have their default values.

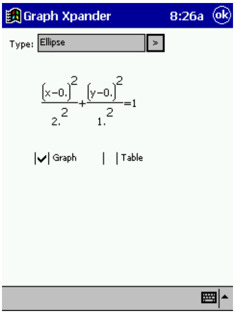


Figure 5-13: Pre-defined conic section

6. To change a default constant, select the constant and type a new value.

   You select a constant by dragging the stylus over it.
7. You can choose whether or not to display the graph of the equation you have specified. You might, for instance, only be interested in the coordinates of points on the graph (which are displayed in the table pane).

   By default, the graph is displayed. To suppress the display, clear the **Graph** check box by tapping on it.
8. You can also choose whether or not to display columns for *y* values. (These are displayed in the table pane, as described in “Graph Window” on page 49.) The range of values, and the interval between them, is determined by your table settings (see page 74). Note that because there are two *y* values for each *x* value in the case of circles and ellipses, two columns of *y* values are listed in the table pane.

By default, the *y* value columns are not displayed. To display the columns, select the **Table** check box by tapping on it.

9. Tap on **OK**.

   The definition of your plot appears in the symbolic pane, the plot is drawn in the graph pane (if you chose to display the graph), and *y* values are listed in the table pane (if you chose to display the *y* values).

   Note that conic section equations are labeled **p1**, **p2**, **p3**,...**p10** in the symbolic pane. Each equation has two corresponding columns in the table pane, **pn1** and **pn2**, where *n* is the number of the equation in the symbolic pane.

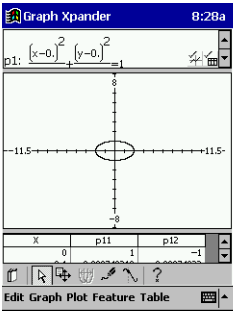


Figure 5-14: Sample conic plot

   You can display the graph even if you earlier chose to suppress it (see step 8). You do this by tapping on the graph button at the right-hand side of the symbolic pane. Similarly, you can display suppressed *y* value columns by tapping on the table button, also at the right-hand side of the symbolic pane. The graph and table buttons will also hide a graph or *y* value columns if they are displayed. (The graph and table buttons are illustrated on page 50.)

10. If you have displayed the graph, it will be automatically selected. (This enables you to immediately transform the graph, or display the trace point.) To deselect the graph, tap on it.

11. If you want to plot another conic section in the same viewing window, repeat the procedure from step 2. If you want to plot a function in the same viewing window, follow the procedure in "Functions" on page 55.

Related topics. Once you have plotted a conic section, you can:

- change the boundaries of the viewing window (see "Modifying the Viewing Window" on page 67)
- trace a point along the graph (see "Trace Tool" on page 76)
- transform the plot (see "Directly manipulating a graph" on page 65)
- add graphic objects to the graph pane (see "Adding Elements to the Graph Pane" on page 79)

Creating a graph by sketching

You can create a graph by sketching it with the stylus and then converting the sketch to a mathematically defined graph.

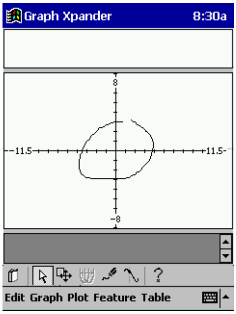


Figure 5-15: Sketch for an ellipse

1. Tap on the **Sketch** button:

   You can now draw with the stylus.

   Selecting **Sketch** from the **Feature** menu also configures the stylus for drawing.
2. Draw a sketch of the graph you want to create. Keep the stylus in contact with the screen while you are sketching.
3. Open the **Plot** menu.
4. To fit your sketch to a function, tap on **Fit Function**.

   A menu is displayed listing the functions available to convert your sketch to a mathematically precise graph.
5. To fit your sketch to a conic section, tap on **Fit Conic**.

   A menu is displayed listing the conic sections available to convert your sketch to a mathematically precise graph.

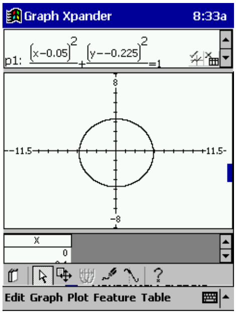


Figure 5-16: Sketch converted to an ellipse

6. Tap on an equation type.

   The sketch is now replaced by a graph of the type you selected.

Selecting and Deselecting a Graph

You can select a graph by:

- tapping on the graph label in the symbolic pane, or
- tapping on the **Select** button, placing the center of the crosshairs on the graph you want to select, and then lifting the stylus, or
- tapping on the heading of the column for an associated dependent variable in the table pane.

  The graph changes to light gray to indicate it is selected. The graph label and column heading are highlighted to indicate the graph is selected.

Follow the same procedure to deselect a graph. The graph changes to black to indicate it is deselected, and the graph label and column heading are no longer highlighted.

Transforming a Graph

You can transform a graph by way of:

- translation or
- dilation.

In translation, a plot undergoes vertical shift, horizontal shift, or a combination of the two. Both the size and shape of the plot are retained.

In dilation, a plot is shrunk or stretched.

You can transform a graph by changing its equation in the symbolic pane. You can also transform certain graphs by directly manipulating them.

Changing the equation of a graph

After drawing a graph, you can transform it by directly changing the graph's equation in the symbolic pane.

1. If the graph you want to modify is not selected, tap on it or on its equation in the symbolic pane.
2. Tap on the constant that you want to change.
3. Change the value.
4. Tap **ENTER** on the math keyboard (see page 20).

   The graph is redrawn to match your changes. The values of the dependent variable in the table pane are also updated. (You will not see this occur if you chose to suppress the display of the dependent variable column.)

Note that if you change the constants in a user-defined function, the result may not be equivalent to translation or dilation.

Directly manipulating a graph

If a graph is based on a predefined equation, you can transform it with the stylus.

Translating a graph

1. If the graph you want to translate is not selected, select it. (See "Selecting and Deselecting a Graph" on page 64.)
2. Tap on the **Translate** button: 

   The **Translate** button is one of two buttons in the **Transform** button group. (Button groups are explained on page 54.) The other button is the **Dilate** button: . If the **Dilate** button is currently displayed, hold your stylus on the button for about a second and then tap on the **Translate** button.

   You can also choose the translate tool by selecting **Translate** from the **Graph** menu.

3. Drag the stylus across the screen. The selected graph moves in the direction of the stylus.

   A copy of the graph remains at its original position until you lift the stylus from the screen.

   As you move the graph, its equation in the symbolic pane continuously updates to reflect the graph's new position.

4. Lift the stylus from the screen when the graph is where you want it to be.
5. Deselect the graph.

   You do this by tapping on the **Select** button and then on the graph.

Dilating a graph

In dilation, a graph is shrunk or stretched. Each graph is dilated with respect to its center of dilation. Table 5-4 below gives the center of dilation for various graph types.

Graph Type	Center of Dilation
exponential	$(0, k)$
others	(h, k)

Table 5-4: Center of dilation for various graph types

If the graph you wish to dilate is a circle—and was created as a circle—dilation will always be uniform; that is, the circle will expand or shrink vertically by the same factor as it shrinks or expands horizontally. With other graph types—including an ellipse that has become a circle as a result of an earlier dilation—the degree of expansion or shrinking in a particular direction depends on how far you move the stylus in that direction.

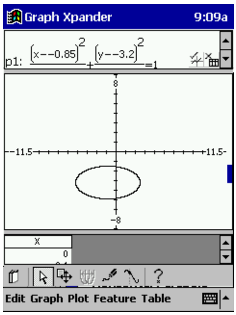


Figure 5-17: Before dilation

1. If the graph you want to dilate is not selected, tap on the **Select** button and then on the graph.
2. Tap on the **Dilate** button: 

   The **Dilate** button is one of two buttons in the **Transform** button group. (Button groups are explained on page 53.) The other button is the **Translate** button: . If the **Translate** button is currently displayed, hold your stylus on the button and then tap on the **Dilate** button.

   You can also choose the dilate tool by selecting **Dilate** from the **Graph** menu.

3. Drag the stylus across the screen. Depending on the direction in which you move the stylus, the selected graph expands or shrinks. If you move the stylus away from the center of dilation, the graph expands; if you move the stylus towards the center of dilation, the graph shrinks.

   The distance you move the stylus determines the extent of the dilation.

   As you dilate the graph, its equation continuously updates to reflect the new graph.

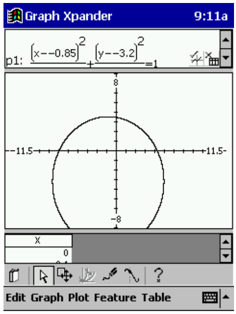


Figure 5-18: After dilation

   A copy of the graph remains at its original position until you lift the stylus from the screen.

4. Deselect the plot.

   You do this by tapping on the **Select** button and then on the graph.

Modifying the Viewing Window

The viewing window is the section of the coordinate plane that is displayed in the graph pane.

There are four ways to change the boundaries of the viewing window:

- changing Graph Xpander settings
- directly changing the displayed boundaries
- panning
- zooming.

Changing graph settings

1. Open the **Graph** menu.
2. Select **Settings…**

   The **Graph Settings** dialog box is displayed.

   The settings that determine the boundaries of the viewing window are:

   - **Horiz Min**
   - **Horiz Max**
   - **Vert Min**
   - **Vert max**

Figure 5-19: Graph settings

3. To change the lower boundary of the *x* axis, select the value in the **Horiz Min** field and change it.
4. To change the upper boundary of the *x* axis, select the value in the **Horiz Max** field and change it.
5. To change the lower boundary of the *y* axis, select the value in the **Vert Min** field and change it.
6. To change the upper boundary of the *y* axis, select the value in the **Vert Max** field and change it.
7. Tap on **OK** to save your changes.

   The viewing window changes to match the values you specified in the **Settings** dialog box. The limits of the viewing window displayed on the screen change accordingly.

The **Graph Settings** dialog box also has fields for the **Horiz Tick** value and **Vert Tick** value (see Figure 5-19). These values—together with the boundaries of the viewing window—determine how many ticks appear on each axis. For example, with the viewing window extending horizontally from $x = -10$ to $x = 10$, and a **Horiz Tick** value of 1, there will be 21 ticks along the *x* axis: 10 to the left of the origin, 10 to the right, and one at the origin (visible only if the axes are off screen).

Therefore, changing the horizontal extent of the viewing window also changes the spacing between the ticks on the *x* axes. For example, if you change the **Horiz Min** to -23 and **Horiz Max** to 23, and keep the **Horiz Tick** value at 1, there will now be 46 ticks along the *x* axis.

The **Horiz Tick** or **Vert Tick** value is automatically changed to prevent a clutter of ticks in the viewing window. For example, if you specify a **Horiz Min** value of –46 and a **Horiz Max** value of 46, the **Horiz Tick** value is automatically set to 10, yielding just 9 tick marks, four on either side of the origin and one at the origin.

The **Graph Settings** dialog box contains a field—Zoom—that enables you to set the factors by which you zoom in or zoom out. The default zoom factor values are 4. Zooming is described in detail in “Zooming” on page 70.

Changing the boundaries

The boundary values of the viewing window are displayed in the graph pane, one centered at each edge of the pane (see Figure 5-4). The value displayed at the far right of the graph pane is the current value for **Horiz Max**. Similarly, the value displayed at the bottom of the graph pane is the current value of **Vert Min**.

The boundary values can be directly changed:

1. Tap on the boundary value.

   The value is highlighted to indicate that it is selected.

2. Enter a new value for the boundary, or an expression for the boundary that evaluates to a real number.

3. Tap on **ENTER**.

   - The new value is displayed on the graph pane.
   - The axes are redrawn to reflect the new viewing window.
   - All displayed graphs and graphic objects are redrawn.
   - If the new viewing window excludes the *x* or *y* axis, a dotted line appears along the edge of the screen closest to that axis. The line will have tick marks spaced according to the value in the **Horiz Tick** or **Vert Tick** field. In Figure 5-20, the *x* axis is excluded by *y* boundary values of 10 and 20. Although not visible, the *x* axis is closer to the bottom edge of the graph pane than to the top edge; therefore a dotted line with tick marks is drawn along the bottom edge of the pane.

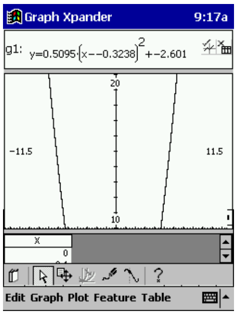


Figure 5-20: X axis indicated by dotted line

Panning

Panning is similar to scrolling, but you use the stylus rather than scroll bars.

1. Tap on the **Pan** button: 

   The **Pan** button is one of two buttons in a button group. (Button groups are explained on page 54.) The other button is the **Zoom Into Box** button:  . The **Zoom Into Box** button is currently displayed, hold the stylus on the button until the **Pan** button is displayed, and then tap on the **Pan** button.

   You can also choose **Pan** from the **Graph** menu.

   The cursor is now the pan tool.

2. Drag the stylus across the screen.

   - The graph plane moves in the direction in which you drag the stylus.
   - The boundary values are continuously updated as you drag the stylus.

3. Tap on another button to deactivate the pan tool.

Zooming

You can also change the viewing window by zooming. You can:

- zoom in or zoom out by specified factors
- specify an area of the current viewing window to zoom in on, or
- choose from a number of preset zoom options.

Zooming in and zooming out

The zoom in function enables you to look at a particular region of the plot in more detail. The zoom out function enables you to look at more of the plot than is currently displayed. The factors by which you zoom in or zoom out are set in the **Graph Settings** dialog box.

Zooming in divides the horizontal scale by the **Horiz Zoom** value and the vertical scale by the **Vert Zoom** value specified in the **Graph Settings** dialog box.

The center of the graph viewing window remains fixed.

To zoom in:

1. Open the **Graph** menu.
2. Select **Zoom**.

   The **Zoom** submenu is displayed.
3. Select **In**.

Zooming out multiplies the horizontal scale by the **Horiz Zoom** value and the vertical scale by the **Vert Zoom** value specified in the **Graph Settings** dialog box.

To zoom out:

1. Open the **Graph** menu.
2. Select **Zoom**.

   The **Zoom** submenu is displayed.
3. Select **Out**.

Specifying a zoom area

1. Tap on the **Zoom Into Box** button: 

   The **Zoom Into Box** button is one of two buttons in a button group. (Button groups are explained on page 54.) The other button is the **Pan** button:  . If the **Pan** button is currently displayed, hold your stylus on the button for about a second and then tap on the **Zoom Into Box** button.

   You can also choose **Zoom Into Box** from the **Zoom** submenu accessible from the **Graph** menu.
2. Place the stylus at one corner of the region that you want to zoom in on.
3. Drag the stylus to the diagonally opposite corner of the region that you want to zoom in on.

   A temporary rectangle is drawn on the screen to indicate the region you want to zoom in on. This is the zoom box.

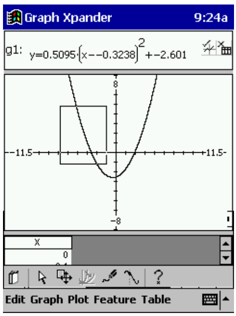


Figure 5-21: Creating a zoom box

4. Lift the stylus from the screen.

   The region bounded by the zoom box now fills the entire viewing window, and the boundary values are updated to indicate the dimensions of the new viewing window.

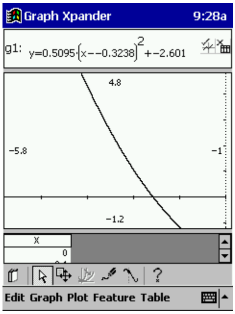


Figure 5-22: After zooming in

Choosing a preset zoom

There are three preset zoom options. To choose a preset zoom:

1. Open the **Graph** menu.
2. Select **Zoom**.

   The **Zoom** submenu appears. There are three preset options on the submenu. The options, and their effect on the viewing window, are listed in the following table:

Zoom option	New Horizontal Boundaries
Integer	[–115, 115]
Decimal	[–11.5, 11.5]
Trig	[–115π/48, 115π/48] (with radians set) [–431.25, 431.25] (with degrees set)

Table 5-5: Preset zoom options

3. Select a zoom option.

   The viewing window changes to the limits set by the zoom option you chose. All graphs are redrawn accordingly.

When you choose a **Trigonometric**, **Integer**, or **Decimal** zoom, the **Horiz Tick** and **Vert Tick** values are set as follows:

Zoom option	Horiz Tick value	Vert Tick value
Integer	10	10
Decimal	1	1
Trig (in radians)	$\pi/2$	1
Trig (in degrees)	90	1

Table 5-6: Tick mark units after zooming

For example, after a **Trig** zoom, each tick mark on the *x* axis represents $\pi/2$ units and each tick mark on the *y* axis represents one unit, and after an **Integer** zoom, each tick mark—on both axes—represents 10 units. A **Decimal** zoom returns the viewing window to its default settings.

Modifying the Table View

You can change the values displayed in the table pane by:

- scrolling
- changing Graph Xpander settings
- directly changing a value in the independent variable column
- zooming.

You can also change the width of a column in the table pane.

Scrolling through the table

To see lesser or greater values in the table, tap on the vertical scroll bar or scroll arrows, or drag the scroll box in the vertical scroll bar.

To see values in columns not currently visible, tap on the horizontal scroll bar or scroll arrows, or drag the scroll box in the horizontal scroll bar.

Changing table settings

The values listed in the table pane are determined by two settings.

To change these settings:

1. Open the **Table** menu.
2. Select **Settings…**

   The **Table Settings** dialog is displayed.

   The fields that determine the values in the table pane are:

   - **Independent Variable Start** (default = 0)
   - **Independent Variable Step** (default = 0.1).

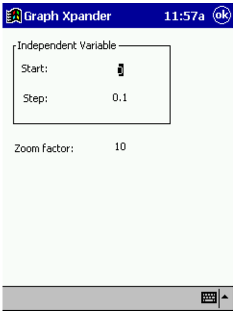


Figure 5-23: Table Settings

3. To change the first value in the independent variable column, change the value in the **Independent Variable Start** field.
4. To change the difference between consecutive values in the independent variable column, change the value in the **Independent Variable Step** field.
5. Tap on **OK** to save your changes.

For example, changing these settings to 3 and 0.5 respectively changes the default values in the independent variable column from 0, 0.1, 0.2, 0.3, … to 3, 3.5, 4, 4.5, …

The Table Settings dialog also enables you to set the table zoom factor. (See “Table zooming” on page 75 for detailed information.)

Directly changing table values

1. Tap on a cell in the independent variable column of the table pane.
2. Enter a real number or an expression that evaluates to a real number.
3. Tap on **ENTER**.

   The value in the cell changes to the number you entered, or to the number generated by the expression you entered, and:

   - all the other values in the independent variable column change so that the difference between consecutive values remains equal to the **Independent Variable Step** value
   - all the values in the dependent variable column(s) are updated.

Table zooming

You can display more detail, or less detail, in the table by zooming in, or zooming out, on a selected table row. When you zoom in, the **Independent Variable Step** value is divided by the table zoom factor (see “Changing table settings” on page 74). With the default table zoom factor of 10, zooming in once decreases the default **Independent Variable Step** value from 0.1 to 0.01; zooming in again reduces the value to 0.001, and so on.

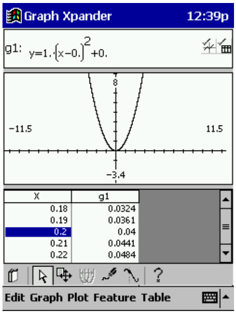


Figure 5-24: Zooming in

Conversely, when you zoom out, the **Independent variable step** value is multiplied by the table zoom factor. With the default table zoom factor of 10, zooming out increases the default **Independent Variable Step** value from 0.1 to 1.

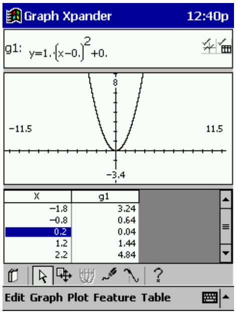


Figure 5-25: Zooming out

To zoom in or out:

1. Tap on a cell in the *x* column.
2. Open the **Table** menu.
3. Select **Zoom In** or **Zoom Out**.

   The value in the highlighted cell is retained while the remaining values in the independent variable column are updated to reflect the new **Independent Variable Step** value. The values in the dependent variable columns are also updated.

Changing column width

To change the width of a column:

1. Hold the stylus on the right edge of the column’s heading.
2. Drag to the left to decrease the column’s width, or to the right to increase the column’s width.

Trace Tool

The trace tool enables you to step through plotted points one by one and have the coordinates of each point visited displayed in the graph pane. It does this by marking a movable trace point on the plot.

Displaying the trace point

To display the trace point:

1. Select the graph you want to trace.

   The graph is highlighted to indicate that it is selected.

   If you don't select a graph before activating the trace tool, the trace point will appear on the *x* axis and will move only along the *x* axis.

2. Tap on the **Trace** button: 

   Alternatively, you can select **Tracer** from the **Graph** menu.

   A dotted vertical line is displayed. This is the **trace line**.

   The point where the trace line intersects the graph is marked (as in Figure 5-26). This point is called the **trace point**.

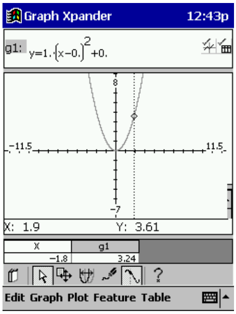


Figure 5-26: Trace point on a function plot

For graphs with two *y* values for each *x* value—for example, circles and ellipses—the trace point appears on the upper part of the curve (as in Figure 5-27).

The coordinates of the trace point are displayed at the bottom of the graph pane. In Figure 5-27, the coordinates are (1.7, 4.873).

Note that for some graphs, the trace point will initially be beyond the boundaries of the viewing window, and therefore not visible. In such cases, the coordinates of the trace point are still displayed at the bottom of the graph pane.

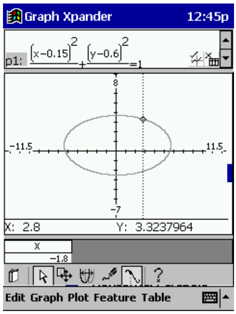


Figure 5-27: Trace point on an ellipse

Where there is no plotted *y* value for the *x* value of the trace line, **Undef** is displayed as the *y* value at the bottom of the graph pane.

Related topics. Once you have displayed the trace point, you can:

- remove the trace point (see page 77)
- move the trace point along a graph (see page 77)
- move the trace point from one graph to another (see page 78).

Removing the trace point

Tap on the **Trace** button: 

Alternatively, select **Tracer** from the **Graph** menu.

Moving the trace point along a plot

You can move the trace point (and trace line) by:

- dragging the trace line
- specifying a position for it
- tapping on the arrow keys on the math keyboard.

Regardless of how you move the trace point, the trace line always remains perpendicular to the *x* axis.

Note that no trace point appears if you move the trace line to a position where there is no *y* value for the corresponding *x* value.

Dragging the trace point

1. Tap on the **Select** button: 
2. Place the stylus on the trace line.
3. Drag the line to the desired location.

   The trace point and trace line move to match the *x* coordinate of the stylus.

   The trace point information at the bottom of the graph pane is continuously updated to match the coordinates of the trace point.

Specifying the position of the trace point

The coordinates of the trace point are displayed in an information box at the bottom of the graph pane. You can move the trace point by directly changing the value of the independent variable in this box (that is, the value labelled **X:**).

1. Tap on the independent variable value in the information box.

   The value is highlighted to indicate that it is selected.

2. Enter a new value for the independent variable.

   The value you enter can be beyond the boundaries of the viewing window; but in this case the trace line will not be visible.

3. Tap on **ENTER**.

   The trace line moves to the specified location. In addition, the trace point information box displays the new location of the trace point.

> You can use this method to calculate the value of the dependent variable for a specified value of the independent variable.

Using the arrow keys to move the trace point

Tapping on ← or → on the math keyboard moves the trace line one pixel left or one pixel right respectively. The trace point moves accordingly, and the trace point information box is updated with each tap.

Moving the trace point to another plot

The trace point appears on whatever graph you selected before choosing the **Trace** tool. To move the trace point to another graph:

1. Tap on the **Select** button:
2. Select the graph.

The trace point moves to the intersection of the selected graph and the vertical trace line. The old coordinate display is replaced by the coordinates of the new trace point.

You can also move the trace point to another graph by tapping on ↑ or ↓ on the math keyboard. The trace point moves to the next, or previous, graph in the order in which graphs are listed in the symbolic pane.

If the trace point is on a branch of a conic section, tapping on ↑ or ↓ moves the trace point to the other branch in the direction of the arrow.

Adding Elements to the Graph Pane

Adding points

You can add points to a graph. You can also add points to the viewing window that are not on a graph.

Points are either analytic or geometric. **Analytic points** are points that you attach to a graph and are transformed with the graph when the graph is transformed. **Geometric points** are points that are independent of a graph. You can place a geometric point on a graph, but if you transform the graph, the point remains at its position. Geometric points can be placed anywhere within the viewing window.

Adding an analytic point

1. If a trace point is not displayed, display it.
2. Move the trace point to the position where you want to attach the point.
3. Open the **Feature** menu.
4. Select **Function**.
5. Select **Point on curve**.

An analytic point is added to the graph. The point will be selected.

Initially, the trace point and analytic point coincide; but if you move the trace point, the analytic point remains at the location at which it was created.

Adding a geometric point

A geometric point is a point that is independent of a graph. Unlike an analytic point, a geometric point does not move if a graph is transformed. Conversely, you can move a geometric point without necessarily moving a graph.

To add a geometric point:

1. Open the **Feature** menu.
2. Select **Geometric**.

   The **Geometric** submenu is displayed.
3. Select **Point**.
4. Tap the stylus on the graph pane where you want the point to be. The point will be selected.

Each geometric point you create is labeled: A, B, C, and so on.

You can move a geometric point by selecting it and using the translate tool (see "Translating a graph" on page 65).

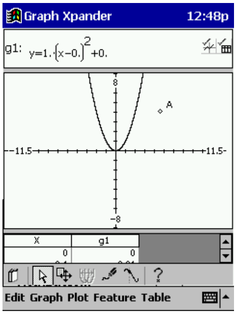


Figure 5-28: Adding a geometric point

Adding segments

1. Open the **Feature** menu.
2. Select **Geometric**.

   The **Geometric** submenu is displayed.
3. Select **Segment**.
4. Drag the stylus across the pane.

   As you drag, a segment is created along the trail of the stylus.
5. To complete the segment, lift the stylus from the screen.

   A point is created at each end of the segment. The points are labeled.

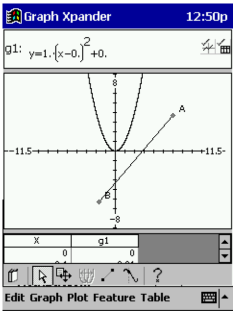


Figure 5-29: Drawing a segment

You can add a segment between existing points. Select the segment tool and start dragging from one point to another. The points become the endpoints of the segment and will move with the segment if the segment is moved. Note that you do not need to start, or end, precisely on a point.

As long as you are close to a point, the point will be converted to the endpoint of the segment.

You can also add a segment by dragging the stylus to, or from, an existing point. For example, you can add a segment that begins or ends on the trace point. In this case, the segment will move as you move the trace point. (To disengage the segment from the trace point, you could add an analytic point to the graph at the position of the trace point. The analytic point becomes the end point of the segment and will not move as the trace point moves. See “Adding an analytic point” on page 79.)

Adding the first derivative of a function

If you base a plotted function on one of the predefined equations listed in Table 5-2, you can also plot the first derivative of the function. The graph of the first derivative is superimposed over the graph of the function.

1. If the graph whose first derivative you want to plot is not selected, tap on the **Select** button and then on the graph.
2. Open the **Feature** menu.
3. Open the **Function** submenu.
4. Select **First derivative**.

   The graph of the first derivative is drawn in the graph pane and its equation appears in the symbolic pane. The equation is labeled **dgn**, where *n* is the number of the function on which the first derivative is based.

   By tapping on the table button to the right of the equation in the symbolic pane, you can display a column of coordinate points for the first derivative in the table pane.

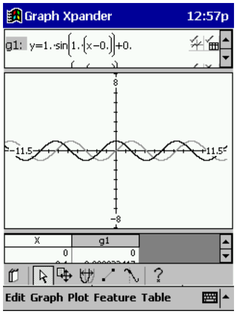


Figure 5-30: Adding the first derivative of $y = \sin x$

The graph of the first derivative is transformed if the graph on which it is based is transformed. It also changes to reflect any changes you directly make to the equation of the function on which it is based.

Note that if you delete the graph on which the first derivative is based, the graph of the first derivative is also deleted. However, you can delete the graph of the first derivative without deleting the graph on which it is based.

Adding freehand objects

You can add freehand objects to the graph pane. You could, for example, draw arrows or circle particular features.

1. Tap on the **Sketch** button:

   The stylus is now a sketch tool.

2. With the stylus, draw an object. The object you create will be selected.

   If you lift the stylus from the window, you will need to tap on the **Sketch** button again to add further freehand objects.

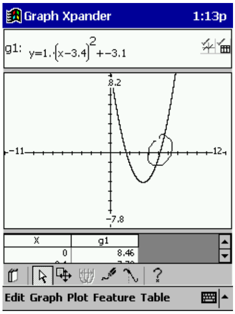


Figure 5-31: Sample freehand object

Measurements

You can measure various properties of the objects you create in the graph pane. These measurements are the slope, angle of inclination, and length of a segment, and the *x* and *y* coordinates of a point.

To display a measurement:

1. Select a point or segment in the graph pane.

   The object is highlighted to indicate that it is selected.

2. Open the **Feature** menu.

3. Select **Geometric**.

   The **Geometric** submenu is displayed.

4. Select **Measurement**.

   A pop-up menu is displayed listing the measurement options available.

5. Select an option (see Table 5-7 below).

   The measurement is displayed on the screen.

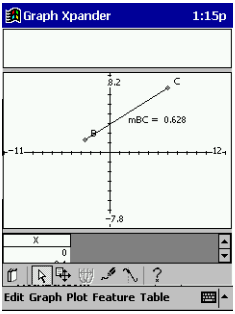


Figure 5-32: Measuring the slope of a segment

The measurement options available depend on the type of object selected. The possibilities are set out in the following table. Each measurement is labeled on the screen. In the following table, the labels refer to a point A and to segment AB.

Object selected	Measurements available	Label
geometric point	■ *x* coordinate ■ *y* coordinate	■ xA ■ yA
segment	■ angle of inclination ■ length ■ slope	■ iAB ■ lAB ■ mAB

Table 5-7: Measurements of object properties

Deleting a measurement

To delete all measurements of an object:

1. Select the object.
2. Open the **Feature** menu.
3. Select **Geometric**.

   The **Geometric** submenu is displayed.
4. Select **Delete Measurement**.

Attributes

You can also view a point's coordinates—or a segment's length and angle of inclination—by displaying it's **attributes**. In this case, the values of the measurements are displayed in a dialog box, not on the window. The values in the dialog box can be changed, and the underlying object changes accordingly.

To display the attributes of a point or segment:

1. Select the point or segment.
2. Open the **Feature** menu.
3. Select **Geometric**.

   The **Geometric** submenu is displayed.
4. Select **Attributes**.

   A dialog box is displayed showing the attributes of the point or segment you selected.
5. To change an attribute, select the current value and enter a new value.
6. To constrain the point to have the coordinates specified, select the **Constraint** check box.
7. To save your changes, tap on **OK**.

   The selected object changes to match the value of the attribute(s) you changed.

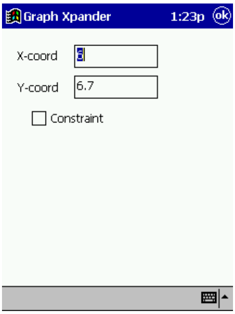


Figure 5-33: Point attributes

Point Trail

You can choose to draw the path of a point as the point moves. The path is known as a **point trail**. You can draw the trail of both analytic and geometric points.

1. Select the point.
2. Open the **Feature** menu.
3. Select **Geometric**.

   The **Geometric** submenu is displayed.
4. Select **Point Trail**.

   As the point moves, a trail is left on the screen to indicate its previous positions.

Deleting an Object

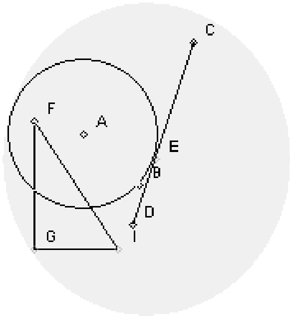
To delete a graph, point, or segment:

1. Select the object you want to delete.
2. Open the **Edit** menu.
3. Select **Delete**.

You can also delete a selected object by tapping on the **⇦DEL** key on the math keyboard.

Exploring Geometry

Geometry Xpander provides a tool for creating, manipulating, and exploring geometric constructions. You can create a variety of geometric objects, enforce attribute and object constraints, take measurements, make calculations based on attributes, and sketch freehand objects.



Accessing Geometry Xpander

You access Geometry Xpander from a workbook. Once a workbook is open, you can:

- tap on the Geometry button on the tool bar: ❶
- open the **File** menu, select **Create** and then select **Construction**: ❷, or
- tap on a geometry label in the workbook history and select **Explore** from the label menu: ❸.

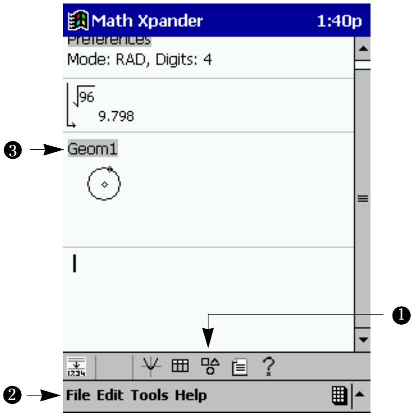


Figure 6-1: Accessing Geometry Xpander

If you tap on the Geometry button (or choose **Construction** from the **Create** submenu), Geometry Xpander opens with a blank window; if you choose **Explore** after tapping on a geometry label in history, Geometry Xpander opens and displays details of the geometric construction associated with that label.

Geometry Window

The geometry window is divided into three panes: construction pane, message pane, and formula pane. Each pane is separated from an adjacent pane by a sash.

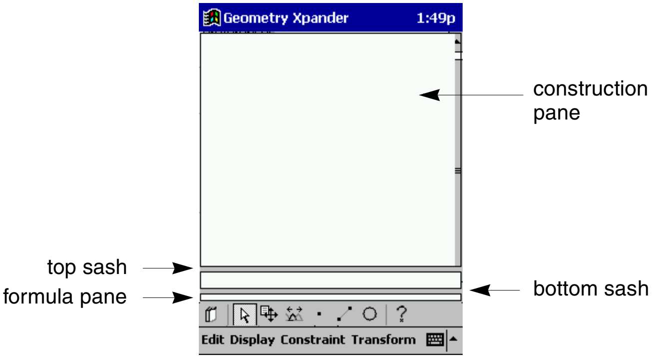


Figure 6-2: Default geometry window

Panes

The **construction pane** is where you create and manipulate geometric objects.

The **message pane** provides messages to help you complete certain tasks (such as transformations).

The **formula pane** lists the dynamic attribute definitions and calculations you create, and provides a way for you to edit or delete them. Initially, the formula pane is hidden. It becomes visible once you create a dynamic attribute or calculation. You can also make it visible, and increase its size, by dragging the top sash upward.

Sashes

A sash is the shaded boundary between two panes. The top sash enables you to increase or decrease the size of the construction pane and formula pane:

1. Place the stylus on the top sash.
2. Drag the stylus up or down.

Dragging the sash up reveals more of the formula pane; dragging the sash down reveals more of the construction pane. In both instances, the message pane remains the same size.

Displaying and hiding axes

By default, the construction pane does not display axes and boundary values.

To display the axes and boundary values:

1. Open the **Display** menu.
2. Select **Axes**.

Repeat the procedure to hide the axes and boundary values.

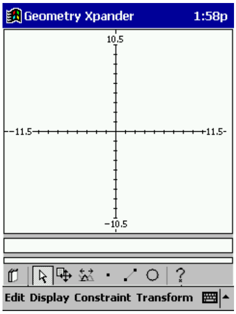


Figure 6-3: Geometry window with axes and boundary values

Settings

To change the boundary values, tick mark spacing, angle unit setting, or timer speed:

1. Open the **Display** menu.
2. Select **Settings**

   The **Geometry Settings** dialog box is displayed.

   The settings that determine the boundaries of the viewing window are:

   - **Horizontal Min**
   - **Horizontal Max**
   - **Vertical Min**
   - **Vertical Max**

   Only the first three of these four settings can be changed.

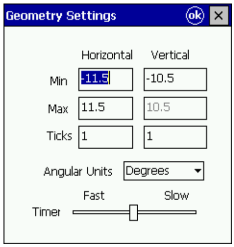


Figure 6-4: Geometry Settings dialog box

3. To change the lower boundary of the *x* axis, select the value in the **Horizontal Min** field and change it.

4. To change the upper boundary of the *x* axis, select the value in the **Horizontal Max** field and change it.
5. To change the lower boundary of the *y* axis, select the value in the **Vertical Min** field and change it.
6. Tap on **OK** to save your changes.

   The viewing window changes to match the values you specified in the **Geometry Settings** dialog box. The limits of the viewing window displayed on the screen change accordingly.

The **Geometry Settings** dialog box also has fields for the **Horizontal Tick** value and **Vertical Tick** value. These values—together with the boundaries of the viewing window—determine how many ticks appear on each axis if you choose to display the axes.

The **Geometry Settings** dialog box also enables you to:

- specify the units in which angle measurements will be interpreted: degrees or radians, and
- alter the timer speed (which has the effect of speeding up, or slowing down, geometric animations: see page 109).

Note: unlike in Graph Xpander, you cannot directly change a boundary value on the construction pane by tapping on it and entering a new value.

Geometry window menu map

- Edit
  - Copy
  - Paste
  - Delete
  - Undo
  - Select All
  - Deselect All
  - Start/Stop timer
- Display
  - Axes
  - Attributes...
  - Dynamic attribute
  - Measurement...
  - Delete Measurement
  - Calculation...
  - Settings...
  - Point Trail
- Constraint
  - Points
    - Point on Object
    - Intersection Point
    - Midpoint
  - Perpendicular
  - Tangent
  - Congruent
  - Remove Contraint
- Transform
  - Dilate
  - Translate
  - Rotate
  - Reflect

Figure 6-5: Geometry window menu map

Geometry window buttons

Button	Name	Description
	**Workbook**	Returns you to the workbook, adding a workbook item that represents your construction.
	**Select**	Makes the stylus a select tool. Objects subsequently tapped become selected. Note that you can select any number of objects with the select tool in Geometry Xpander.
	**Pan**	Makes the stylus a pan tool. You can now drag the stylus to view other regions of the geometry window.
	**Move**	For moving selected objects.
group 	**Point**	For adding a point.
	**Sketch**	For drawing objects freehand.
	**Angle**	For creating an angle from three points.
group 	**Segment**	For adding a segment.
	**Ray**	For adding a ray.
	**Line**	For adding a line.
group 	**Circle**	For adding a circle.
	**Polygon**	For adding a polygon.

Table 6-1: Geometry window buttons

Many buttons—for example, the point, sketch, and angle buttons—form a button group. In a button group, only one button is displayed at one time. To display the other button(s) in the group, hold your stylus on the button. The other button(s) appear directly below the first button (as in Figure 6-6).

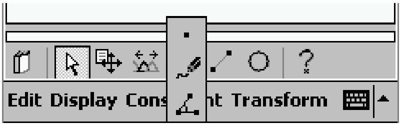


Figure 6-6: Point, sketch, and angle button group

When a second or third button is displayed, you can select it by tapping on the button. A button you select in this way then becomes the button displayed for the group.

Creating Objects

Geometry Xpander provides special tools for creating seven basic objects:

- point tool
- angle tool
- segment tool
- ray tool
- line tool
- circle tool
- polygon tool

To create an object, first tap on the corresponding button (see page 92).

Once activated, an object tool remains active only while you are drawing one object; that is, if you want to draw, say, two circles, you will need to activate the circle tool twice.

When you create an object, the object is automatically selected. Objects that were selected at the time you created the new object are automatically deselected.

Creating a point

1. Tap on the **Point** button:

   The **Point** button is part of a button group (see “Geometry window buttons” on page 92).

2. Tap on the construction pane where you want the point to be created.

   A point is created. It is labeled with a letter of the alphabet: A, B, C, D, and so on.

3. To deselect the point, tap on it or on its label.

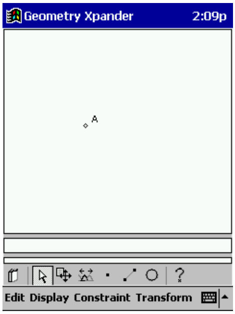


Figure 6-7: New point and label

Creating an angle

You can create an angle from three existing points.

1. Tap on the **Angle** button:

   The **Angle** button is part of a button group (see “Geometry window buttons” on page 92).

2. Select a point on the first defining side other than the vertex.

3. Select the point that is to be the vertex.

4. Select a point on the second defining side.

5. To deselect the angle, tap on it.

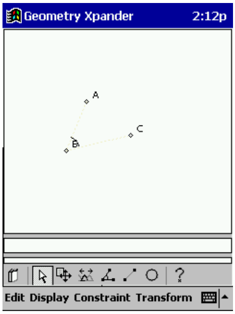


Figure 6-8: New angle and labels

Creating a segment

1. Tap on the **Segment** button: 

   The **Segment** button is part of a button group (see “Geometry window buttons” on page 92).

2. Place the stylus on the window where you want the segment to begin and drag to where you want the segment to end.

   A segment is drawn from the starting point to the tip of the stylus as you drag the stylus.

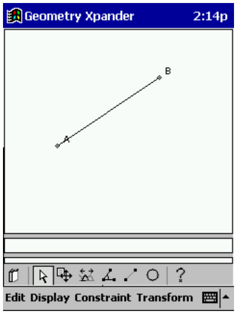


Figure 6-9: New segment and labels

3. Lift the stylus where you want the segment to end.

   A labeled point is added to each end of the segment.

   Note that if the starting location or ending location is close to an existing point, the existing point is used as an endpoint of the segment.

4. To deselect the segment, tap on it.

Creating a ray

1. Tap on the **Ray** button: 

   The **Ray** button is part of a button group (see “Geometry window buttons” on page 92).

2. Place the stylus on the window where you want the ray to begin and drag to another location that will be on the ray you are about to create.

3. Lift the stylus.

   Labeled points are created at the start and end location, and a ray is drawn from the starting point through the end point.

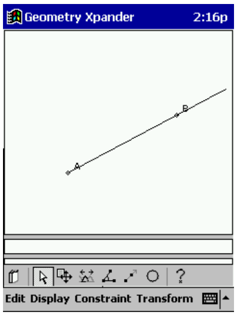


Figure 6-10: New ray and labels

Note that if the starting location or ending location is close to an existing point, the existing point is used as a defining point of the ray.

4. To deselect the ray, tap on it.

Creating a line

1. Tap on the **Line** button: 

   The **Line** button is part of a button group (see “Geometry window buttons” on page 92).

2. Place the stylus on the window at a location that will be on the line you want to create and drag to another location that will be on the line.

3. Lift the stylus.

   Labeled points are created at the start and end location and a line is drawn through these points.

   Note that if the starting location or ending location is close to an existing point, the existing point is used as a defining point of the line.

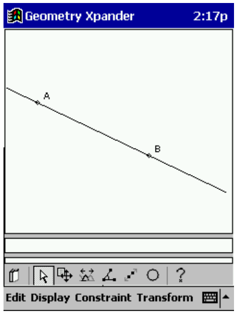


Figure 6-11: New line and labels

4. To deselect the line, tap on it.

Creating a circle

1. Tap on the **Circle** button: 
2. Place the stylus on the window where you want the center of the circle to be.
3. Drag the stylus to a location that is to be on the circumference of the circle you want to draw.
4. Lift the stylus.

   A circle, centered on the first location and passing through the second location, is created. In addition, labeled points are created at the two locations.

   Note that if the starting location or ending location is close to an existing point, the existing point is used as a defining point of the circle.

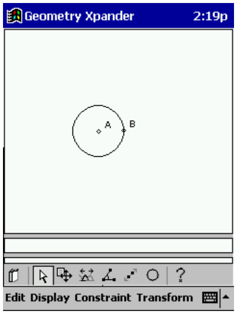


Figure 6-12: New circle and labels

5. To deselect the circle, tap on it.

Creating a polygon

1. Tap on the **Polygon** button:

   The **Polygon** button is part of a button group (see “Geometry window buttons” on page 92).

2. Place the stylus on the construction pane where you want the first segment to begin and drag to where you want the first segment to end.

   A segment is drawn from the starting point to the tip of the stylus as you drag the stylus.

3. Lift the stylus where you want the first segment to end.

   A labeled point is added to each end of the segment.

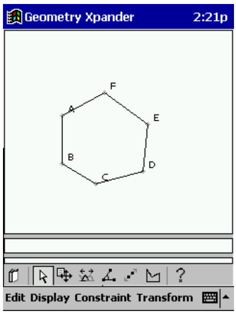


Figure 6-13: New segment

4. Tap on the construction pane where you want the next segment to end.

   Another segment is drawn. The starting point is the endpoint of the previously created segment.

5. Repeat step 4 to create as many additional segments as required.
6. Complete the polygon by tapping on the starting point of the first segment.
7. To deselect the polygon, tap on it.

   Note that if any side of the polygon begins or ends close to an existing point, the existing point is used as a defining point of the segment. An existing segment can also be used as a side of a polygon.

Adding freehand objects

You can add freehand objects to the geometry window. You could, for example, draw arrows or circle particular features.

1. Tap on the **Sketch** button: 

   The **Sketch** button is part of a button group (see “Geometry window buttons” on page 92).

   The stylus is now a sketch tool.

2. With the stylus, draw an object.

   If you lift the stylus from the window, you will need to tap on the **Sketch** button again to add further freehand objects.

3. To deselect the object, tap on it.

Selecting and Deselecting Objects

Selecting

You can select an object by tapping on the **Select** button, and then:

- tapping on the object with the stylus, or
- using the stylus to place the center of the crosshairs on the object you want to select, and then lifting the stylus, or
- in the case of a point, tapping on its label.

The object changes to light gray to indicate it is selected.

To quickly select all objects, choose **Select All** from the **Edit** menu.

If you want to select an object that is close to another object, hold the stylus near the objects. A pop-up menu is displayed listing all the objects in the vicinity of the stylus point (as in Figure 6-14). You can select an object by choosing it from the pop-up menu. (If an object is currently selected, it has a check mark beside it, as is the case of point B in Figure 6-14.)

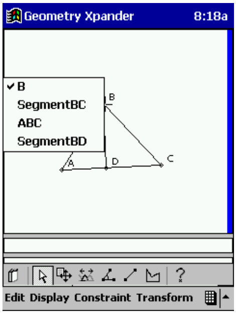


Figure 6-14: Selection pop-up menu

Note that an object is automatically selected when you create it.

Deselecting

To deselect an object, tap on it (or, in the case of a point, on its label). To quickly deselect all selected objects, choose **Deselect All** from the **Edit** menu.

Transforming an object

You can transform one or more objects by:

- translation
- dilation
- rotation
- reflection

These options are available from the **Transform** menu.

When you apply a transformation option chosen from the **Transform** menu, the objects you select are retained in their original position and an image of them is created based on the type of transformation selected. The objects and their image remain linked. If you change the object, the image is changed so that the transformation relation between the two is retained. Similarly, if you change the image, the object on which it is based changes so as to retain their transformation relation.

There is one form of transformation that does not generate an image of the object but acts directly on the object. This is translation using the stylus, which has the effect simply of moving a selected object without creating an image of it. This form of translation is applied using the **Move** button (see page 92) and is not available from the **Transform** menu.

Translation

In translation, selected objects undergo vertical shift, horizontal shift, or a combination of both. Both the size and the shape of each object is retained.

There are two ways to translate an object:

- by dragging the object to a new position with the stylus, or
- by specifying a new position for the object.

If you specify a new position for the object, a copy of the object remains in its original position.

Method 1: translation using the stylus

1. Select the object(s) you want to translate.
2. Tap on the **Move** button:  .
3. Drag the stylus across the screen. The selected objects move in the direction of the stylus.

   A copy of each selected object remains at its original position until you lift the stylus from the screen.

   As you move the objects, any measurements or calculations based on the objects are continuously updated.
4. Lift the stylus from the screen when the objects are where you want them to be.
5. Deselect the objects.

   You do this by tapping on the **Select** button and then on the objects, or by selecting **Deselect All** from the **Edit** menu.

Method 2: translation by specification

If you translate objects using the stylus—see method 1 above—a copy of each object remains at its original position only until you lift the stylus from the screen. If you translate objects by specification, each selected object remains at its original position after translation. In effect, translation by specification creates an image of each selected object, with the image offset by a horizontal and a vertical distance that you specify.

1. Open the **Transform** menu.
2. Select **Translate**.
3. Select the object(s) you want to translate.
4. Tap on **Next**.

   The **Define Translation** dialog box is displayed.
5. In the **Dx** box, enter the horizontal distance from each selected object to where you want the image of each object placed.
6. In the **Dy** box, enter the vertical distance from each selected object to where you want the image of each object placed.

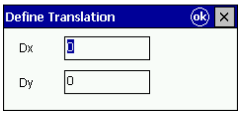


Figure 6-15: Define Translation dialog box

7. Tap on **OK**.
8. Tap on **Next**.

   An image of each selected object is placed at the position indicated by the values you entered in the **Dx** and **Dy** fields. The original objects remain at their pre-translated position. They retain their original labels, while the labels of the images are given numeric suffixes (such as A1, B1, C1, and so on, as in Figure 6-16).

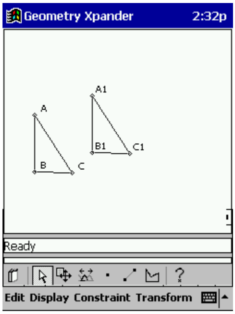


Figure 6-16: Translation

Dilation

In dilation, a shrunk or stretched image of an object is created. The image is positioned relative to a specified center of dilation.

1. Open the **Transform** menu.
2. Select **Dilate**.
3. Select the object(s) you want to create a dilated image of.
4. Tap on **Next**.

   The **Define Dilation** dialog box is displayed.
5. In the **Scale** box, enter a value for the scale factor.

   The scale factor can be any positive real number. For example, a scale factor of 0.5 creates an image that is half the size of the selected object, while a scale factor of 2 creates an image that is twice the size of the selected object.
6. Tap on **OK**.
7. Select a point to be the center of the dilation.
8. Tap on **Next**.

   An image of each selected object is created, with a size and position determined by the scale factor and center of dilation you specified.

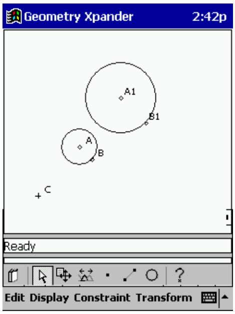


Figure 6-17: Dilation

Rotation

In rotation, a image of each selected object is created at a specified angle to the object on which it is based. The size and the shape of each image matches the object.

1. Open the **Transform** menu.
2. Select **Rotate**.
3. Select the object(s) you want to create a rotated image of.
4. Tap on **Next**.

   The **Define Rotation** dialog box is displayed.

5. In the **Angle** box, enter the angle by which you want the images placed relative to each object's original position.

   A positive value rotates the selected objects clockwise, while negative values rotate the objects counterclockwise.

6. Tap on **OK**.
7. Select a point to be the center of the rotation.
8. Tap on **Next**.

   An image of each selected object is created at an angle and position determined by the angle and center of rotation you specified.

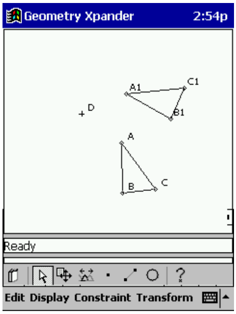


Figure 6-18: Rotation

Reflection

In reflection, a mirror image of each selected object is created over a specified line of reflection. The size and the shape of each image matches the object on which it is based.

1. Open the **Transform** menu.
2. Select **Reflect**.
3. Select the object(s) you want to create a mirror image of.
4. Tap on **Next**.
5. Select a line to be the line of reflection.
6. Tap on **Next**.

   A mirror image of each selected object is created across the line of reflection.

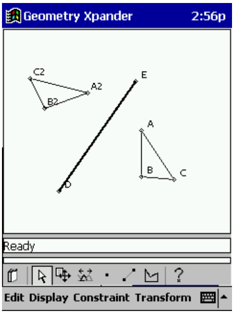


Figure 6-19: Reflection

Viewing and Changing an Object's Attributes

With the exception of polygons, you can display various attributes of the objects you create. These attributes can be directly changed, thereby changing the associated objects. You can also change an attribute indirectly by making its value dependent on the values of other attributes (as explained in "Dynamic Attributes" on page 108).

Object	Attribute
point	■ *x* and *y* coordinates
angle	■ angle
segment	■ length ■ angle of inclination
ray	■ angle of inclination
line	■ angle of inclination
circle	■ radius

Table 6-2: Attributes that can be directly changed

To view and directly change an object's attribute:

1. Select the object.
2. Open the **Display** menu.
3. Tap on **Attributes…**.

   A dialog box is displayed listing the object's attributes.

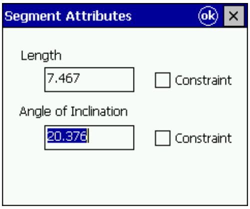


Figure 6-20: Attribute listing for a segment

4. Select the value that you want to change.
5. Change the attribute's value.
6. To constrain the attribute to the set value, tap on the **Constraint** check box.
7. If another attribute is displayed and you want to change its value, repeat from step 5.
8. Tap on **OK**.

   The object is redrawn to match each attribute value you set.

Taking Measurements

In addition to determining the various attributes of objects (see “Viewing and Changing an Object’s Attributes” on page 105), you can also measure various features of objects or groups of objects. Unlike attributes, measurements are displayed on the screen rather than in a dialog box.

The measurement options available depend on the type of object selected. The possibilities are set out in the following table. Each measurement is labeled on the screen. In the following table, the labels refer to a point P, segment PQ, ray PQ, line PQ, circle PQ, polygon PQRS, and angle PQR.

Object selected	Measurements available	Label
point	■ *x* coordinate ■ *y* coordinate	■ xP ■ yP
segment	■ angle of inclination ■ length ■ slope	■ iPQ ■ lPQ ■ mPQ
ray or line	■ angle of inclination ■ slope	■ iPQ ■ mPQ
circle	■ area ■ circumference ■ radius	■ aPQ ■ cPQ ■ rPQ
polygon	■ area ■ perimeter	■ aPQRS ■ pPQRS
angle	■ angle	■ mvPQR

Table 6-3: Measurements of objects

The value of a measurement is automatically updated if an object on which the measurement is based is transformed in a way that changes that measurement.

To take a measurement of an object:

1. Deselect any other object that is selected.
2. Select the object you want to measure.

   Only one object can be measured at a time.
3. Open the **Display** menu.
4. Select **Measurement...**.

   A menu of measurements available for the selected object is displayed (as in Figure 6-21).
5. Select the measurement you want to take.

   The measurement is displayed on the screen (see Figure 6-22) along with a label that identifies the measurement (see Table 6-3 above).

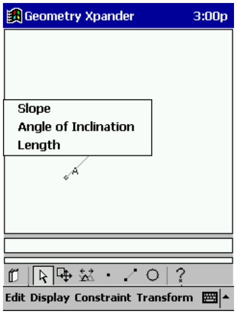


Figure 6-21: Available segment measurements

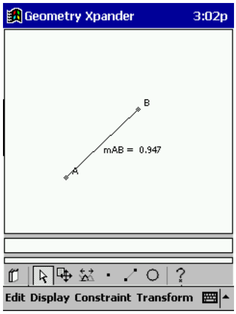


Figure 6-22: Segment slope

Deleting measurements

To delete measurements:

1. Select the associated object.
2. Open the **Display** menu.
3. Select **Delete Measurement**.

All the measurements associated with the selected object are deleted, but the object remains.

Dynamic Attributes

As well as directly changing the value of an attribute, you can make the value of an attribute dependent on the value of some other attribute. You can also make the value of an attribute dependent on a special variable, *t*, which represents ticks of the timer. This variable enables you to animate objects (see page 109).

To make an attribute dynamic—that is, dependent on the value of one or more other attributes:

1. Select the object with the attribute you want to make dynamic.
2. Open the **Display** menu.
3. Select **Dynamic Attribute**.

   The **Define Calculation** dialog box is displayed.

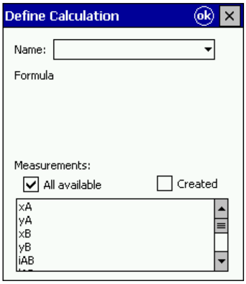


Figure 6-23: Dynamic Attribute dialog box

4. From the **Name** drop-down list, select the attribute that you want to make dynamic.

   Only the available attributes of the object you selected—as set out in Table 6-2 on page 105—are available from the **Name** drop-down list.

5. Tap in the **Formula** box and enter the expression that is to determine the value of the chosen attribute.

   You can build your expression from a list of measurements, combining them if necessary with the operators available on the math keyboard. (See Table 6-3 on page 106 for the meaning of each measurement suffix.) To select a measurement, tap on it in the **Measurements** list.

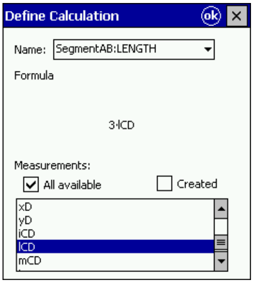


Figure 6-24: Sample formula

   In the example in Figure 6-24, the dynamic attribute is the length of segment AB, and it has been made equal to 3 times the length of segment CD. Now whenever the length of CD changes, the length of AB will change to preserve the relationship specified in the formula.

By default, all possible measurements of all objects in the geometry window are displayed in the **Measurements** list. If you want to see listed only those measurements you have taken yourself, tap on the **Created** checkbox.

6. When you have finished constructing your expression, tap on **OK**.

   The object with the dynamic attribute you have created is redrawn to match the expression you entered. In addition, the expression is evaluated and the result displayed in the formula pane near the bottom of the geometry window (as in Figure 6-25).

   The object is now constrained by the values of the attributes on which its dynamic iterate is based.

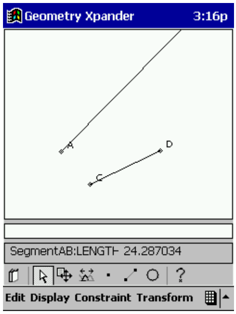


Figure 6-25: Effect of making the length of AB dynamic

Animation

If you have all measurements listed in the **Measurements** list on the **Dynamic Attribute** dialog box, the very last item in the list is the special variable *t*. This measurement—which represents the number of ticks per second of the timer—can be included in an expression that defines a dynamic attribute.

For example, if you make a segment's angle of inclination equal to *t*, you can force the segment to rotate by one angle unit—that is, one degree or one radian, depending on your angle setting—with every tick of the timer. Similarly, if you make the segment's angle of inclination equal to 5·*t*, you can force the segment to rotate by five angle units with every tick of the timer.

To create an animation:

1. Create one or more dynamic attributes each of which is based on the special variable *t*.

   See "Dynamic Attributes" on page 108 for instructions.

2. Open the **Edit** menu.
3. Select **Start Timer**.

   You can make an animation proceed slower or faster by adjusting the timer speed on the Geometry Settings dialog (see "Settings" on page 89). For example, increasing the timer speed increases the number of timer ticks per second.

To stop an animation:

1. Open the **Edit** menu.
2. Select **Stop Timer**.

Editing and deleting dynamic attributes

The formula for each dynamic attribute you create is listed in the formula pane near the bottom of the geometry window. If you want to edit or delete a formula, you need to first tap on it in this pane.

Initially, there is room to display only one formula in the formula pane. If there are formulas, you can display them by either:

- tapping on the scroll arrows to the right of the displayed formula to scroll through the list of formulas, or
- dragging the sash at the bottom of the construction pane upward to reveal more formulas.

Editing

1. In the formula pane, tap on the formula you want to edit.

   A pop-up menu is displayed, with two options: **Edit** and **Delete**.

2. Tap on **Edit**.

   The **Dynamic Attribute** dialog box is displayed (see page 108).

3. Modify the expression in the **Calculation** box.
4. Tap on **OK**.

Deleting

1. In the formula pane, tap on the formula you want to delete.

   A pop-up menu is displayed, with two options: **Edit** and **Delete**.

2. Tap on **Delete**.

Calculations

You can perform calculations based on the values of attributes. This is similar to creating a dynamic attribute (see page 108), but in this case you are simply evaluating an expression rather than constraining an attribute to the result of an expression.

1. Open the **Display** menu.
2. Select **Calculation…**

   The **Define Calculation** dialog box is displayed.

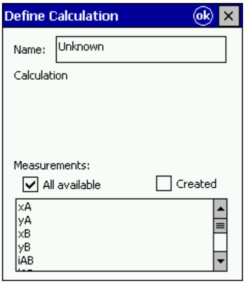


Figure 6-26: Calculation dialog box

3. In the **Name** box, enter a name for the calculation.

   There are no restrictions on the names you can give your calculations.

4. Tap in the **Calculation** box and enter the components of your calculation.

   You can build your calculation from the list of measurements at the bottom of the dialog box, combining them if necessary with the operators available on the math keyboard. (See Table 6-3 on page 106 for the meaning of each measurement suffix.) To select a measurement, tap on it in the **Measurements** list.

   By default, all possible measurements of all objects in the geometry window are displayed in the **Measurements** list. If you want to see listed just those measurements you have taken yourself, tap on the **Created** checkbox.

5. When you have finished constructing your calculation, tap on **OK**.

   The expression is evaluated and the result displayed in the formula pane, together with any dynamic attribute formulas you have created.

Editing and deleting calculations

Editing

1. In the formula pane, tap on the calculation you want to edit.

   A pop-up menu is displayed, with two options: **Edit** and **Delete**.

2. Tap on **Edit**.

   The **Calculation** dialog box is displayed (see page 108).

3. Modify the expression in the **Calculation** box.
4. Tap on **OK**.

Deleting

1. In the formula pane, tap on the calculation you want to delete.

   A pop-up menu is displayed, with two options: **Edit** and **Delete**.

2. Tap on **Delete**.

Creating Object Constraints

As well as constraining the attributes of an object to specified values, you can constrain multiple objects to particular configurations.

Creating a point on an object

To create a constrained point on an object—that is, a point that remains on the object if you move the object—the object and a point must already exist.

1. Select the object on which you want to add a point.
2. Select the point that you want to constrain to the object.
3. Open the **Constraint** menu.
4. Select **Points**.
5. Select **Point on Object**.

The point moves to the object and is constrained to remain on the object.

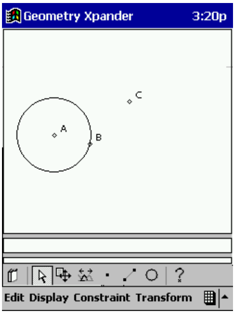


Figure 6-27: Object and point before constraint

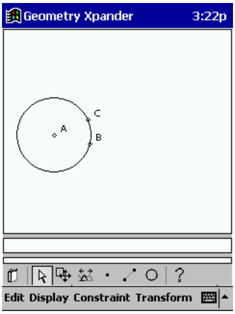


Figure 6-28: Object and point after constraint

Creating a point at an intersection

1. Select two intersecting objects.
2. Open the **Constraint** menu.
3. Select **Points**.
4. Select **Intersection Point**.

   A point is created at each intersection of the objects.

   The two objects are constrained to always intersect. If you move one or both objects, there will always be as many points of intersection as there were when you created the intersection points.

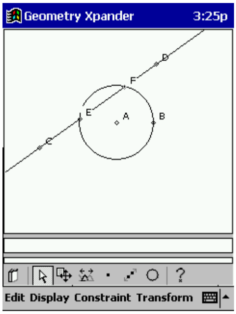


Figure 6-29: Point marking intersection

Creating a midpoint on a segment

To create a point constrained to be midway along a segment, the object and a point must already exist. The point does not need to be on the segment before beginning this procedure.

The midpoint of a segment is constrained by the length of the segment. If you change the length of the segment, the midpoint will move so that it remains at the center of the segment.

1. Select the segment.
2. Select a point.
3. Open the **Constraint** menu.
4. Select **Points**.
5. Select **Midpoint**.

   The point moves to a position midway along the length of the segment.

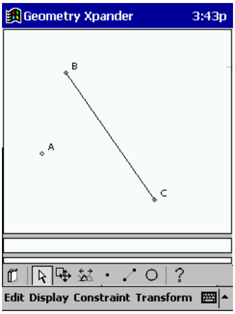


Figure 6-30: Segment and point before constraint

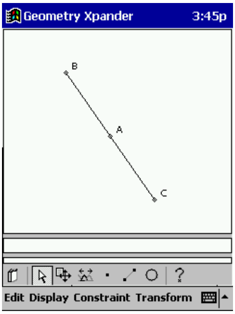


Figure 6-31: Segment and point after constraint

Creating congruent segments

You can constrain two segments so that they always have the same length. If you change the length of one segment, the length of the other segment automatically changes to match it.

After you apply the constraint, the two segments take on the length of the segment you created first.

1. Select the two segments.
2. Select **Constraint**.
3. Select **Congruent**.

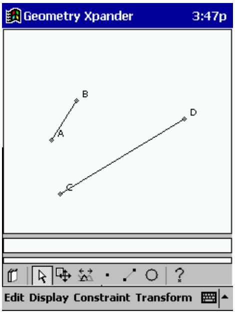


Figure 6-32: Segments before constraint

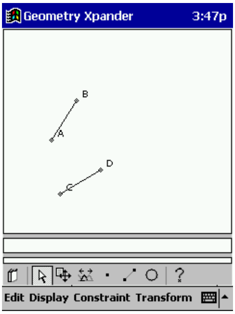


Figure 6-33: Segments after constraint

Creating congruent angles

You can constrain two angles so that they are always equal in angular measure. If you change the angle of one, the angle of the other automatically changes to match it.

After you apply the constraint, the two angles have the measure of the the angle you created first.

1. Select the two angles.
2. Select **Constraint**.
3. Select **Congruent**.

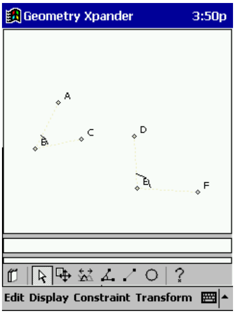


Figure 6-34: Angles before constraint

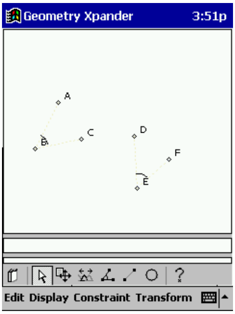


Figure 6-35: Angles after constraint

Creating a perpendicular line

To make a segment, ray, or line perpendicular to another segment, ray, or line, both objects must already exist.

After you apply the constraint, the more recently created object is made perpendicular to the earlier created object.

1. Select a segment, ray, or line.
2. Select another segment, ray, or line.
3. Open the **Constraint** menu.
4. Tap on **Perpendicular**.

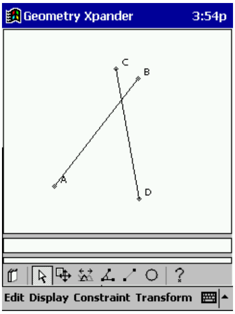


Figure 6-36: Two segments

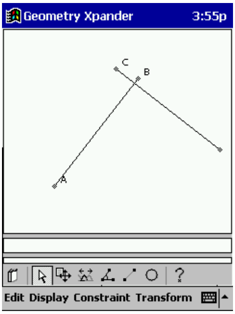


Figure 6-37: Segments made perpendicular

Creating a tangent

You can make a segment, ray, or line, tangent to a circle. You must already have created the segment, ray, or line, and the circle.

1. Select the circle.
2. Select the segment, ray, or line.
3. Open the **Constraint** menu.
4. Select **Tangent**.

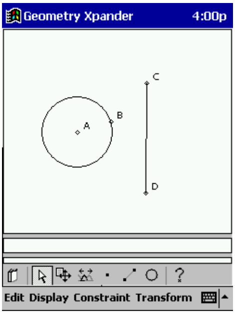


Figure 6-38: Circle and segment

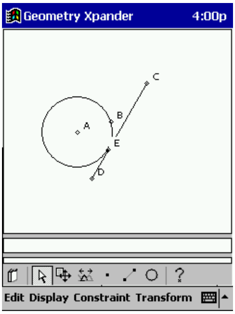


Figure 6-39: Circle and tangent line

Removing Constraints

You can remove a constraint between two objects.

1. Select the object which has a constraint you want to remove.
2. Open the **Constraint** menu.
3. Select **Remove Constraints**.

   A list of the object's constraints is displayed.
4. Tap on a constraint that you want to remove.
5. Tap on **Remove**.

   The constraints list closes and the selected constraint is removed.

You can also remove an attribute constraint:

1. Select the object with the attribute constraint you want to remove.
2. Open the **Display** menu.
3. Select **Attributes...**

   The attributes dialog box is displayed.
4. Uncheck the appropriate **Constraint** check box.
5. Tap on **OK**.

   The attributes dialog box closes and the attribute constraint is removed.

Point Trails

You can choose to draw the path of a point as the point moves. The path is known as a **point trail**. You can create a point trail by manually moving a point, or by activating an animation.

1. Select the point.
2. Open the **Display** menu.
3. Select **Point Trail**.

   Anything you subsequently do to the construction that moves the point will leave a trail of that point.

   When you stop moving the point, the point trail is converted to a sketch. You can select a point trail sketch just as you can a geometric object. (You could, for example, copy the sketch to Graph Xpander and apply a fit model to it.)

The following examples illustrate some of the many constructions you can create using point trails.

Example 1: Parabola. To create a point that traces a parabola:

1. Create a segment AB and constrain its angle of inclination to 0.

   See "Viewing and Changing an Object's Attributes" on page 105 for instructions on constraining attributes.
2. Select point A and constrain its *x* coordinate to –10 and its *y* coordinate to 0.
3. Create a point C and constrain its *x* coordinate to 0 and its *y* coordinate to 4.

4. Create a point D and constrain it to segment AB.

   See "Creating a point on an object" on page 112 for instructions.

5. Create a segment DE and another segment CE.
6. Constrain segments DE and CE to be congruent.

   See "Creating congruent segments" on page 115 for instructions.

7. Constrain segment DE to be perpendicular to segment AB.

   See "Creating a perpendicular line" on page 117 for instructions.

   Your construction should look similar to that in Figure 6-40.

8. Select point E and choose to display its point trail.
9. Deselect all objects and then select point D.
10. Translate point D.

    As point D moves, point E traces the path of a parabola (as in Figure 6-41).

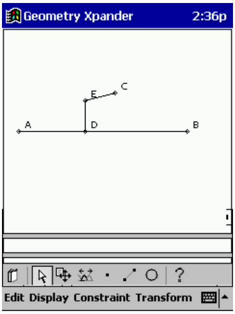


Figure 6-40: Preparing to trace a parabola

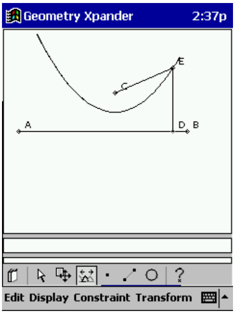


Figure 6-41: Point trail traces a parabola

Example 2: Surprising Limacon. To create a point that traces a limacon:

1. Create two segments: AB and AC.
2. Constrain the coordinates of point A to (0, 0).
3. Constrain the length of AB to 5.
4. Make the angle of inclination of segment AC a dynamic attribute by making its value twice the angle of inclination of segment AB.

   See "Dynamic Attributes" on page 108 for instructions.

5. Create a segment BC.
6. Create point D and constrain it to be the midpoint of BC.

   See “Creating a midpoint on a segment” on page 114 for instructions.

   Your construction should look similar to that in Figure 6-42.
7. Select point D and choose to display its point trail.
8. Deselect all objects and then select point B.
9. Slowly translate point B.

   As point B moves, point D traces the path of a limacon (as in Figure 6-43).

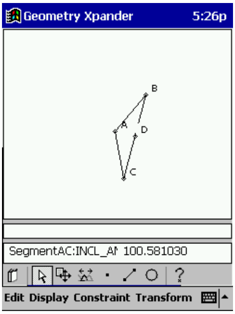


Figure 6-42: Preparing to trace a limacon

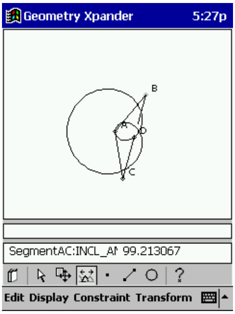


Figure 6-43: Point trail traces a limacon

Example 3: Solar System. To create a point that traces the path of a satellite orbiting a planet that is revolving around a star:

1. Make sure that the angle unit setting is radians.
2. Create a point A and constrain its coordinates to (0,0).
3. Create point B.
4. Make the x coordinate of point B a dynamic attribute by making its value equal to $5 \cdot \cos(t/40)$.
5. Similarly make the y coordinate of point B equal to $5 \cdot \sin(t/40)$.
6. Create point C.
7. Make the x coordinate of point C a dynamic attribute by making its value equal to $xB + 2 \cdot \cos(t/10)$.
8. Similarly make the y coordinate of point C equal to $yB + 2 \cdot \sin(t/10)$.

Your construction should look similar to that in Figure 6-44.

9. Select point C and choose to display its point trail.

10. Select **Start Timer** from the **Edit** menu.

    Point C traces the path of a satellite orbiting a planet—point B—that is revolving around a star—point A—as in Figure 6-45.

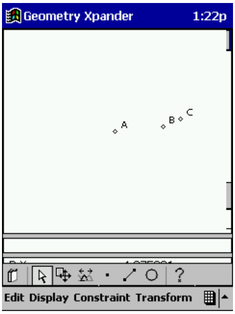


Figure 6-44: Preparing to trace a solar system

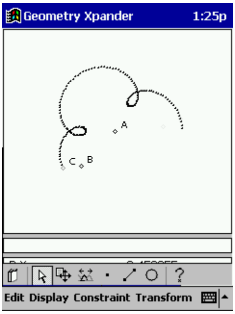


Figure 6-45: Point trail traces a solar system

Deleting an Object

1. Select the object(s) you want to delete.
2. Open the **Edit** menu.
3. Select **Delete**.

Functions and Operators

This appendix lists the mathematical functions and operators that can be selected from the on-screen keyboards. They are grouped according to the palette on which they appear. See “Math Keyboard” on page 19 for a description of each palette.

Numeric palette

Key	Description
EEX	Used to enter numbers in scientific notation. **Syntax** *mantissa* **EEX** *exponent* **Example** 8 **EEX** 26 is displayed as `8E26` and returns `8E+026` (which is equal to 8×10^{26})
+, –, /, ×	Addition, subtraction, division, and multiplication operators. **Syntax** *value* operator *value* **Example** 8×26 is displayed as `8·26` and returns `208`

Table A-1: Numeric palette operators

Algebra palette

Key	Description
x^2	Square. **Syntax** *value* x^2 **Example** 1 7 x^2 is displayed as `17`^{2} and returns `289`
$\sqrt{x}$	Square root. **Syntax** $\sqrt{x}$ *value* **Example** $\sqrt{x}$ 16 is displayed as $\sqrt{16}$ and returns `4`
x^{-1}	Reciprocal. **Syntax** *value* x^{-1} **Example** 5 x^{-1} is displayed as `5`$^{-1}$ and returns `0.2`
x^y	Power (x raised to y). **Syntax** *value* x^y *power* **Example** 5 x^y 6 is displayed as `5`^{6} and returns `1.563E+004`

Table A-2: Algebra functions and operators

Key	Description (Cont.)
$\sqrt[n]{x}$	Represents the n^{th} root of a number. Tapping this key opens a template of the form $\sqrt[n]{x}$ where *n* is the index of the root and *x* is the number. The cursor appears in the *n* field. **Syntax** $\sqrt[n]{x}$ *index*, *number* **Example** $\sqrt[n]{x}$ 4 →16 is displayed as $\sqrt[4]{16}$ and returns `2`
e^x	Natural exponential. **Syntax** e^x *value* **Example** e^x 4 is displayed as e^4 and returns `54.6`
ln	Natural logarithm. **Syntax** ln (*value*) **Example** ln 4 is displayed as `ln(4)` and returns `1.386`

Table A-2: Algebra functions and operators

Key	Description (Cont.)
log	Common logarithm. **Syntax** log(*value*) **Example** log 1000 is displayed as `log(1000)` and returns `3`
$\log_r$	Logarithm to arbitrary base. **Syntax** $\log_{base}$ (*value*) **Example** $\log_r 2 \longrightarrow 64$ is displayed as $\texttt{log}_2\texttt{(64)}$ and returns `6`
$\mid x \mid$	Absolute value. **Syntax** $\mid value \mid$ **Example** $\mid x \mid - 5$ is displayed as `|-5|` and returns `5`

Table A-2: Algebra functions and operators

Number palette

Key	Description
$\lceil x \rceil$	Ceiling function. Smallest integer greater than or equal to *value*. **Syntax** $\lceil value \rceil$ **Example** $\lceil x \rceil$ 7 . 2 is displayed as $\lceil$`7.2`$\rceil$ and returns `8`
$\lfloor x \rfloor$	Floor function. Greatest integer less than or equal to value. **Syntax** $\lfloor value \rfloor$ **Example** $\lfloor x \rfloor$ 7 8.6 is displayed as $\lfloor$`78.6`$\rfloor$ and returns `78`
div	Integer division. The quotient when *value1* is divided by *value2*. **Syntax** *value1* div *value2* **Example** 3 5 div 8 is displayed as `35 div 8` and returns `4`

Table A-3: Number functions and operators

Key	Description (Cont.)
mod	Modulo. The remainder when *value1* is divided by *value2*. **Syntax** *value1* mod *value2* **Example** 3 5 mod 8 is displayed as `35 mod 8` and returns `3`
gcd	Greatest common divisor. Returns the greatest common divisor of two integers. **Syntax** gcd(*argument1*, *argument2)* **Example** gcd 124 →12 is displayed as `gcd(124,12)` and returns `4`
lcm	Least common multiple. Returns the least common multiple of two integers. **Syntax** lcm(*argument1*, *argument2)* **Example** lcm 124 → 12 is displayed as `lcm(124,12)` and returns `372`

Table A-3: Number functions and operators

Key	Description (Cont.)
rseed	Seed for random number generator. The algorithm used in the **rand** function uses a seed number to begin its sequence. To ensure that two calculations produce different random sequences, use the **rseed** function to seed different starting values before using **rand** to produce the numbers. **Syntax** rseed *value* **Example** rseed 1 2 3 4 5 6 7 8 9 is displayed as `rseed(123456789)` and returns `Ok`.

Table A-3: Number functions and operators

Key	Description (Cont.)
rand	Uniformly distributed random number in [0,1) The algorithm used in the **rand** function uses a seed number to begin its sequence. See "rseed" on page 129 (above) for further information. **Syntax** rand **Example** rand is displayed as `rand` and returns `0.908` Note that this result assumes that the last workbook calculation was the rseed operation illustrated in the previous section.
comb	Number of combinations of *n* things taken *r* at a time, with $r \le n$. **Syntax** comb(*n*,*r*) **Example** comb 5 $\longrightarrow$ 2 is displayed as `comb(5,2)` and returns `10`

Table A-3: Number functions and operators

Key	Description (Cont.)
perm	Number of permutations of *n* things taken *r* at a time, with $r \leq n$. **Syntax** perm(*n*,*r*) **Example** perm 5 $\longrightarrow$ 2 is displayed as `perm(5,2)` and returns `20`
!	Factorial of a non-negative integer. **Syntax** *value* ! **Example** 5 ! is displayed as `5!` and returns `120`

Table A-3: Number functions and operators

Trigonometric palette

Key	Description
sin	Sine. Inputs and outputs depend on the current angle mode. **Syntax** sin(*value*) **Example** sin $\frac{\pi}{2}$ is displayed as `sin`$\left(\frac{\pi}{2}\right)$ and returns `1` (in radians mode)

Table A-4: Trigonometric functions and operators

Key	Description
cos	Cosine. Inputs and outputs depend on the current angle mode. **Syntax** cos(*value)* **Example** cos 2 0 is displayed as `cos(20)` and returns `0.9397` (in degrees mode)
tan	Tangent. Inputs and outputs depend on the current angle mode. **Syntax** tan(*value)* **Example** tan $\frac{\pi}{4}$ is displayed as `tan`$\left(\frac{\pi}{4}\right)$ and returns `1` (in radians mode)
asin	Arc sine. Inverse trigonometric sine function. Output range is from –90° to 90° or –π/2 to π/2. Inputs and outputs depend on the current angle mode. **Syntax** asin(*value*) **Example** asin 1 is displayed as `asin(1)` and returns `1.571` (in radians mode)

Table A-4: Trigonometric functions and operators

Key	Description
acos	Arc cosine. Inverse trigonometric cosine function. Output range is from 0° to 180° or 0 to π. Inputs and outputs depend on the current angle mode. **Syntax** acos(*value*) **Example** acos 1 is displayed as `acos(1)` and returns `0` (in either mode)
atan	Arc tangent. Inverse trigonometric tangent function. Output range is from –90° to 90° or –π/2 to π/2. Inputs and outputs depend on the current angle mode. **Syntax** atan(*value*) **Example** atan 1 is displayed as `atan(1)` and returns `45` (in degrees mode)
°	Degrees unit of measure. This operator can be used to override the current angle mode. **Syntax** *value*° **Example** sin 30° is displayed as `sin(30°)` and returns `0.5` (in either degrees or radians mode)

Table A-4: Trigonometric functions and operators

Key	Description
r	Radians unit of measure. This operator can be used to override the current angle mode. **Syntax** *value*^{r} **Example** sin 1.5 ^{r} is displayed as `sin(1.5`^{r}`)` and returns `0.9975` (in either degrees or radians mode)
π	3.14159265358979

Table A-4: Trigonometric functions and operators

Test palette

Key	Description
=	Equals. A logical test for equality. Returns true or false. **Syntax** *value1* = *value2* **Example** 2 = 8 is displayed as `2 = 8` and returns `False`
≠	Not equal to. **Syntax** *value1* ≠ *value2* **Example** 1 ≠ 5 is displayed as `1 ≠5` and returns `True`

Table A-5: Test functions and operators

Key	Description
<	Less than. **Syntax** *value1* < *value2* **Example** 1 < 0 is displayed as `1 < 0` and returns `False`
≤	Less than or equal to. **Syntax** *value1* ≤ *value2* **Example** 2 ≤ 4 is displayed as `2 ≤ 4` and returns `True`
>	Greater than. **Syntax** *value1* > *value2* **Example** 7 > 6 is displayed as `7>6` and returns `True`
≥	Greater than or equal to. **Syntax** *value1* ≥ *value2* **Example** 1 ≥ 2 is displayed as `1 ≥2` and returns `False`

Table A-5: Test functions and operators

Key	Description
and	Returns true if *value1* and *value2* are both true, otherwise returns false. **Syntax** *value1* and *value2* **Example** 2 < 3 and 5 ≥ 7 is displayed as `2 < 3 and 5 ≥ 7` and returns `False`
not	Returns true if *value* is false, otherwise returns false. **Syntax** not *value* **Example** not 8 ≤ 9 is displayed as `not 8 ≤ 9` and returns `False`
or	Returns true if either *value1* or *value2* is true or both are true, otherwise returns false. **Syntax** *value1* or *value2* **Example** 4 > 6 or 5 ≠ 7 is displayed as `4 > 6 or 5 ≠ 7` and returns `True`
true	Logical constant
false	Logical constant

Table A-5: Test functions and operators

Advanced palette

Key	Description
Σ	Summation. Tapping on this key opens a template of the form $$\sum_{variable\,=\,initialvalue}^{finalvalue}(expression)$$ which finds the sum of *expression* with respect to *variable* from *initialvalue* to *finalvalue*. **Template** $$\sum_{variable\,=\,initialvalue}^{finalvalue}(expression)$$ **Example** Σ x → 4 → 8 → x + 3 is displayed as $\sum_{x=4}^{8}(x+3)$ and returns `45`
|	Substitutes a value for a variable. Tapping this key opens a template of the form $(expr_1)\,\vert\,var_1 = expr_2$, where $expr_1$ is an expression containing the variable var_1, and $expr_2$ is the value intended to replace var_1 in $expr_1$. **Template** $$(expr_1)\,\vert\,var_1 = expr_2$$ **Example** |5 + 3 – x → x → 2 is displayed as `(5 + 3 - x)|x = 2` and returns `6`

Table A-6: Advanced functions and operators

Key	Description
$\int dx$	Definite integral. The numerical integral of an expression between two numerical limits. Tapping this key opens a template of the form $\int_{expr_2}^{expr_1}(expr_3)dv$ where $expr_1$ and $expr_2$ are expressions that evaluate to real numbers, v is a variable, and $expr_3$ is an expression in the variable v. **Template** $\int_{expr_2}^{expr_1}(expr_3)dv$ **Example** $\int 1 \rightarrow 2 \rightarrow x$ **x**^{2} + 3 **x** $x \rightarrow x$ is displayed as $\int_1^2 (x^2 + 3 \cdot x)dx$ and returns `6.833`

Table A-6: Advanced functions and operators

Key	Description
$\frac{d}{dx}$	Derivative. The symbolic first derivative of an expression with respect to a specified variable. Tapping this key opens a template of the form $\frac{d}{d(var_1)}(expr_1)$ where var_1 is a variable, and $expr_1$ is an expression containing var_1. **Template** $\frac{d}{d(var_1)}(expr_1)$ **Example** d/dx $x \rightarrow x \times \sin 2 \times x$ is displayed as $\frac{d}{dx}(x \cdot \sin(2 \cdot x))$ and returns $x \cdot 2 \cdot \cos(2 \cdot x) + \sin(2 \cdot x)$

Table A-6: Advanced functions and operators

Index

A

B

C

U

V

W

X

Z