

Northfield Mount Hermon

Using the
**Texas Instruments
Nspire CAS handheld
in High School Mathematics**

June 21, 2011

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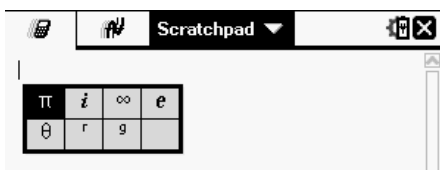
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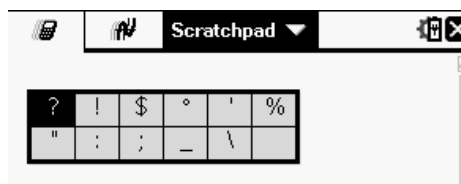
Some helpful shortcut keys:

- ctrl ÷ produces a nice division template
- the key below the esc key toggles between the Calculate and Graph scratchpad
- ctrl-g toggles the function entry window

The π key is located at the bottom left. It provides quick access to some helpful values, like π , e, i.



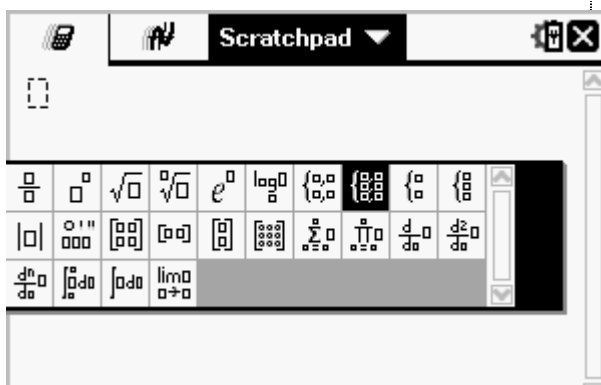
The ? key is at the bottom right. It also has some important keys, like ! and °.



Two very important keys are the Expressions Template and the catalog key, found on the left and right of the two-sided key immediately below the **del** key.

Note that the catalog has 6 windows which can be accessed by typing the appropriate number. Catalog Page 5 is the list of templates. Pressing ctrl-catalog brings up the list of symbols, which is the same as catalog, page 4.

the Expressions Template



the catalog



Introduction

This manual was originally created by members of the Northfield Mount Hermon School mathematics department in June of 2001. The purpose was to help students develop proficiency with the TI-89, which has been used to supplement the instruction of mathematics in the high school mathematics curriculum at Northfield Mount Hermon School.

The manual has been updated in the spring of 2011 to serve as a similar guide for the Nspire CAS handheld calculator, running OS 3.0.

The Nspire CAS handheld represents a significant upgrade over the TI-89. It has a robust file management system, which is very similar to the operating system present in computers. Although these features of the Nspire will not be addressed in this manual, it should be useful to note that the Nspire handheld is "document-based and menu-driven". This means that everything you do must be done in a *document*, much like on a computer, and the tools for every application can be found in its *menu*.

NOTE WELL: Many of the examples in this manual are done within the calculate or graph *scratchpad*. This is a quick and easy way to access these applications. Work done in the scratchpad is not saved.

There are times when it is preferable to work within a *document*. While working in a document you will notice 1.1, 1.2, etc. in the tab marks at the top of the screen. Each document can have several *pages*, some of which have functions not available in the scratchpad, such as Lists & Spreadsheets and Data & Statistics. Documents can be saved (press doc) permanently, just as you save documents on a computer. To open a new document, press the home key. To open a new page in a document, press ctrl-doc.

The purpose of this document is to provide simple instruction, with appropriate screenshots, on how to perform the basic operations expected in high school Algebra 2, Precalculus and Calculus courses. While the Nspire provides a powerful and helpful tool for a course in statistics, and also a platform for work similar to The Geometer's Sketchpad™, those applications are not addressed in this manual.

CHAPTER 1 - OPERATIONS

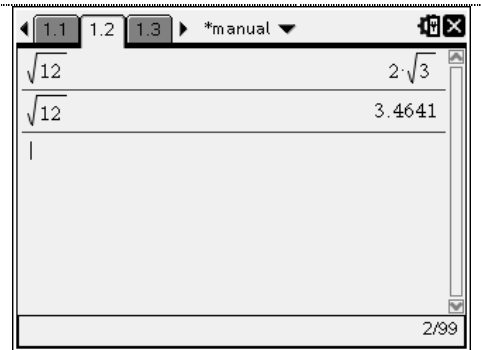
1. Preliminaries

The work we will do in these first few sections will require the calculator window. When you turn on the Nspire, select Scratchpad, A: Calculate.

learning the four basic arithmetic operations and other functions:

The **Nspire CAS** uses the standard keys for addition, multiplication, subtraction, division, exponentiation and grouping..

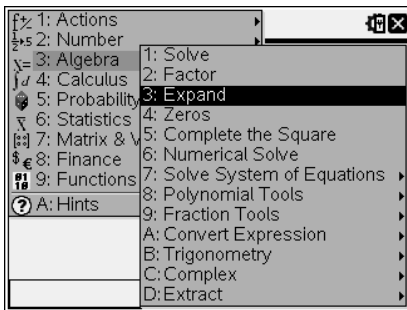
If the Nspire returns a result in exact form, you can get a decimal approximation by pressing **ctrl-enter**.



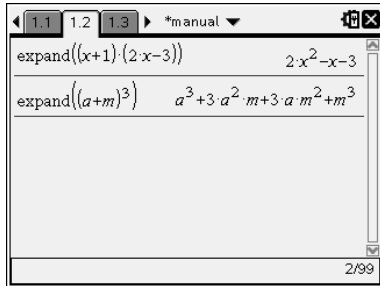
pull-down menus

Just like a computer, the Nspire makes use of pull-down menus.

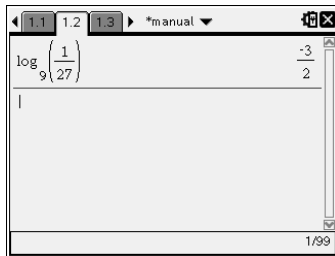
As an example, the **expand** command can be found by pressing menu, Algebra, Expand, as shown below.



To type a variable name like a or b, simply type the key from the keypad. The following shows the *expand* operation available under Algebra menu



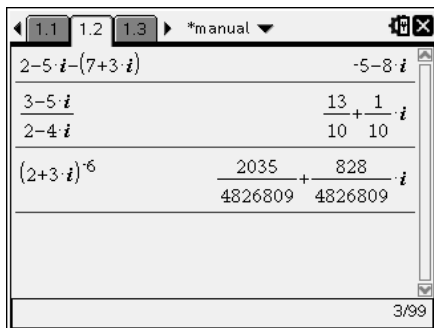
The Nspire can compute logarithms easily by using the log key, on the left hand side. The Nspire allows the user to input any base for the logarithm function. Notice how nicely the pretty print feature works.



2. Complex numbers

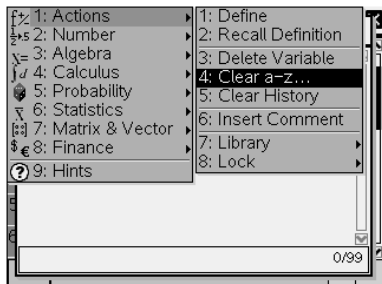
The imaginary number i is found on the π key on the bottom left of the keypad.

Operations on complex numbers are performed by using any of the arithmetic operators.



CHAPTER 2 - FACTORING

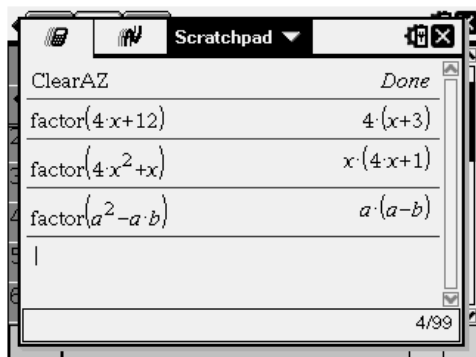
It is always a good idea to delete all one-character variables before beginning a new calculator session. The easiest way to do so is to press menu, Actions, Clear a-z..



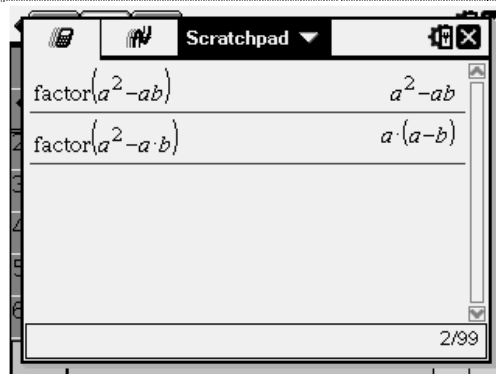
Most of the routine tasks in algebra, including factoring, are found by pressing menu, Algebra.

Here are a few examples of factoring:

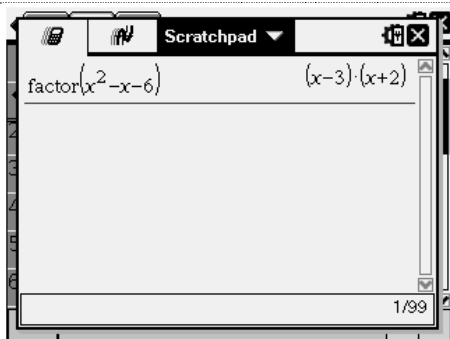
common term



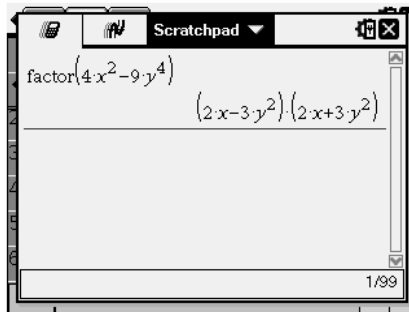
NOTE WELL: It is **necessary** to write the multiplication symbol between the a and b variables. If it is left out, as it is in the first example to the right, the Nspire treats ab as a single variable and won't factor the expression.



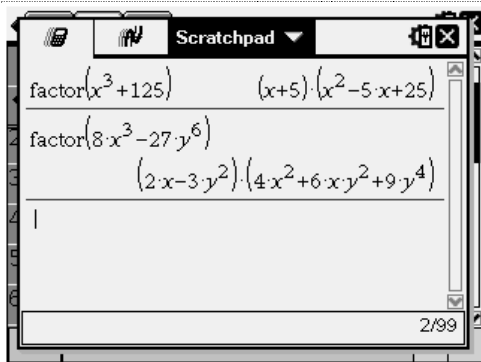
trinomials



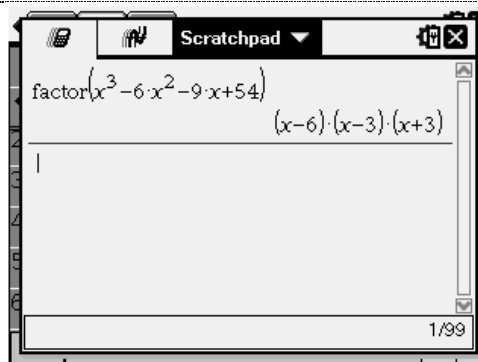
difference of two squares



sum and difference of two cubes

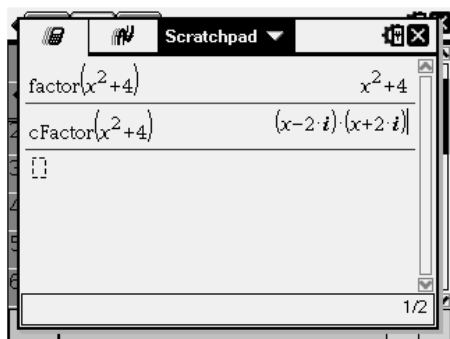


grouping



Factoring over the complex numbers

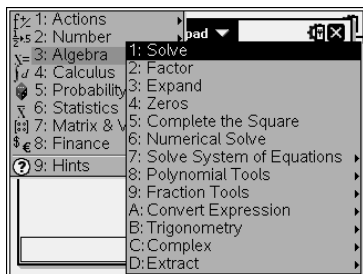
In order to factor over the complex numbers, you must use the command `cFactor`.



CHAPTER 3 - SOLVING EQUATIONS and INEQUALITIES

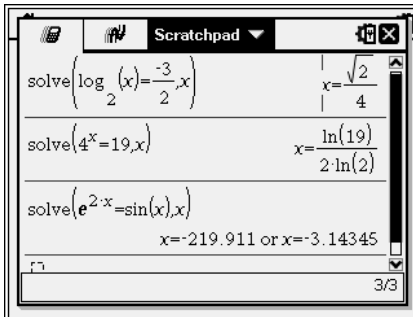
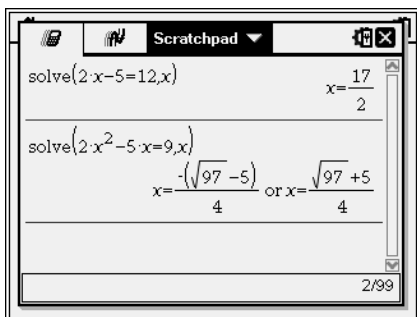
1. linear, polynomial, logarithmic, exponential, rational, absolute value, radical.

We execute the **solve** function from the calculator window by pressing menu, Algebra, Solve.

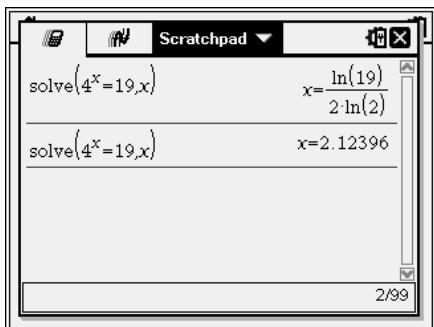


On the Nspire, if we wish to solve $2x-5=12$ for x , we write **solve(2x-5=12,x)**

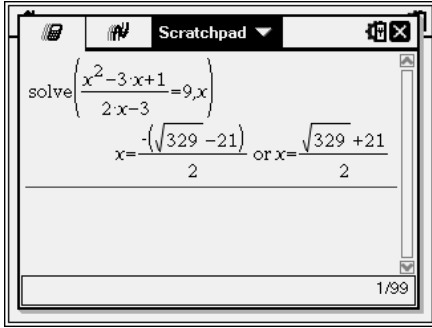
Here are some examples of solving equations.



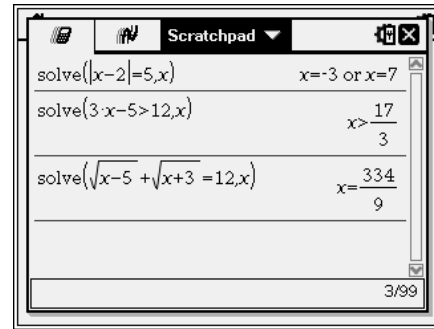
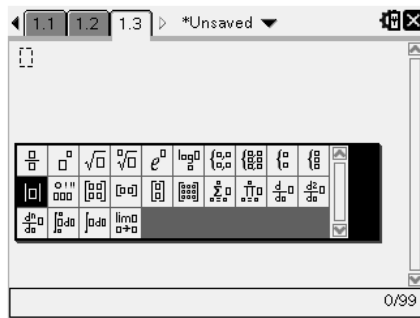
RECALL: Pressing ctrl-enter gives a decimal approximation.



The next example is a particularly difficult equation to solve by hand; the Nspire does it in a snap.

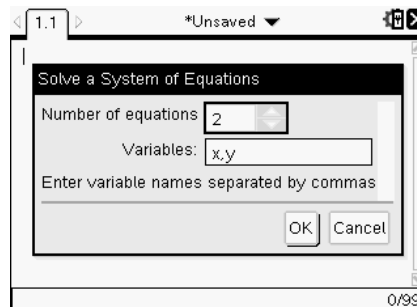
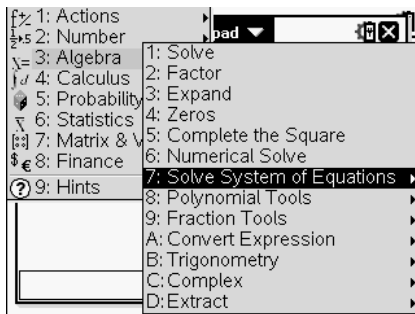


Below we solve an absolute value equation, a linear inequality, and a radical equation. The absolute value command can be found by pressing the templates key, the left part of the catalog button, as shown in the screen below on the left.



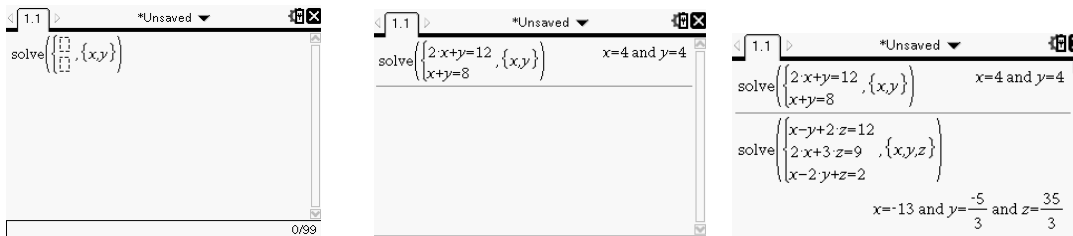
2. Systems of Equations

Solving systems of equations on the Nspire is simple. Press menu, Algebra, Solve System of Equations.



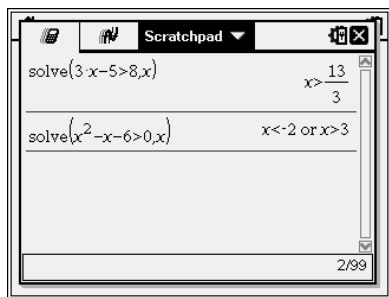
At this point you can select how many equations you wish.

As shown below, a template comes up in which all you need to do is fill in the equations. These two examples show a system in 2 variables, and a system in three variables.



3. Solving non-linear inequalities

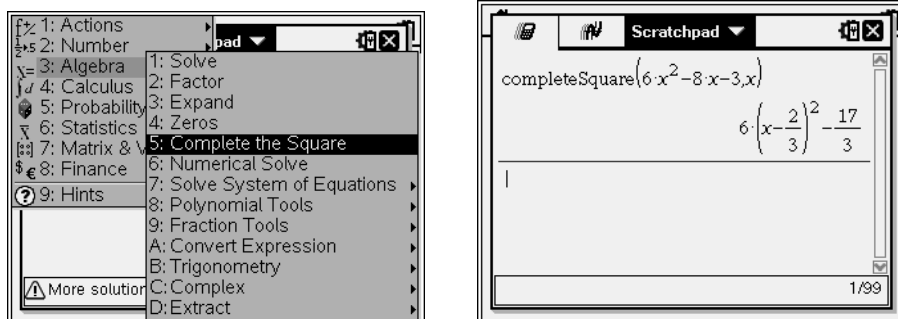
The Nspire can solve *non-linear* inequalities, as well as *linear* inequalities, as the following shows:



4. Completing the Square

This command allows the user a simple way to complete the square of a quadratic function, which can be useful in solving and graphing.

While in a calculator page, press menu, Algebra, Complete the Square, as shown below. To execute, enter a quadratic function and the variable.

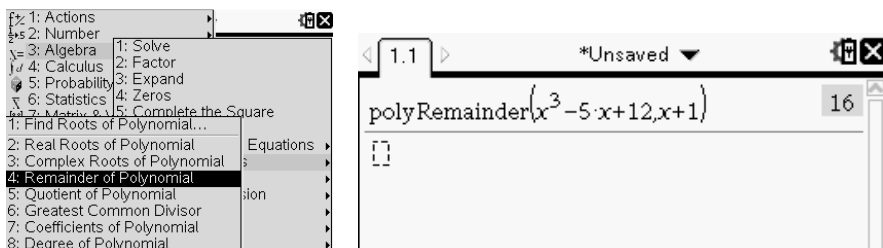


5. Polynomial Tools

There is a host of tools to be found under this option, found by pressing menu, Algebra, Polynomial Tools. The second window shows all of the options available.

Here are a few examples of what is possible.

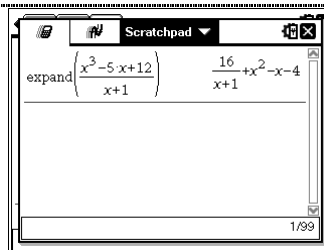
Find the remainder when $x^3 - 5x + 12$ is divided by $x + 1$:



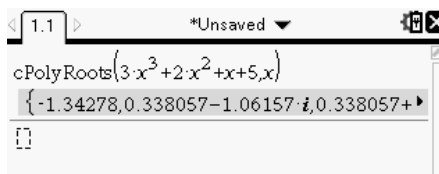
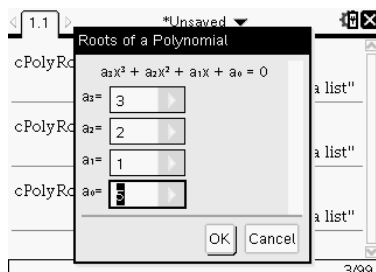
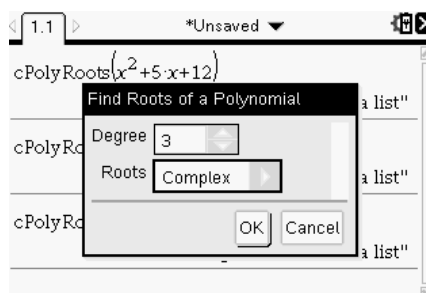
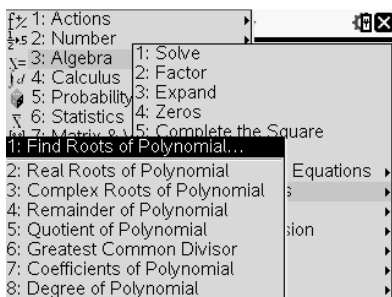
This result can also be seen by executing

the command $\text{expand}\left(\frac{x^3 - 5x - 12}{x + 1}\right)$,

which gives a more complete result of this division.



Find all the complex roots of the polynomial $3x^3 + 2x^2 + x + 5$:

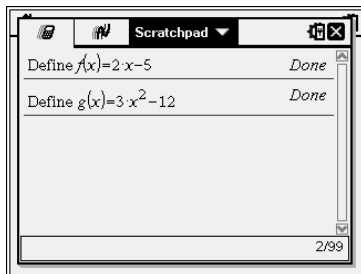


CHAPTER 4 - FUNCTIONS

1. Defining a function

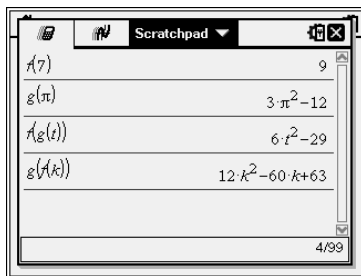
The Define command is found by pressing menu, Actions, Define.

Here are some examples.



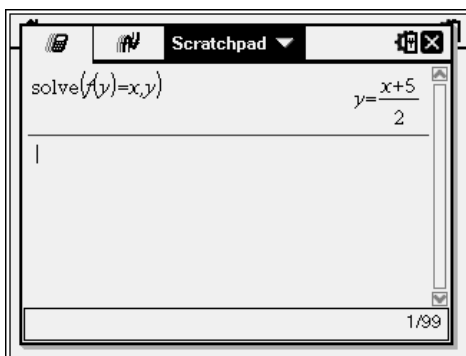
2. Evaluation and Composition of functions

Once functions have been defined, it is possible to evaluate them at particular values, and to compose them.



3. Finding the inverse of a function

The inverse, $f^{-1}(x)$, of the function defined above by $f(x) = 2x-5$ can be found by executing the command: $\text{solve}(f(y)=x,y)$, as shown below.

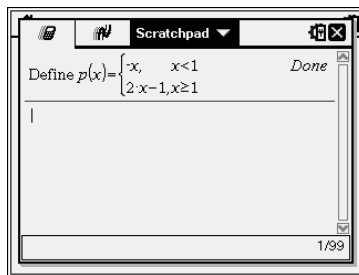
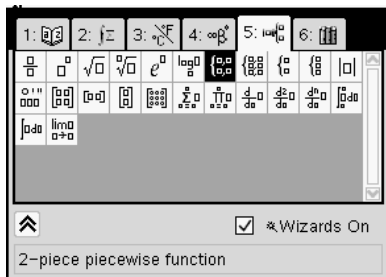


4. Piecewise definition of a function

The Nspire has an elegant way of defining a piecewise function.

If we wish to define the function $h(x) = \begin{cases} -x, & x < 1 \\ 2x - 1, & x \geq 1 \end{cases}$,

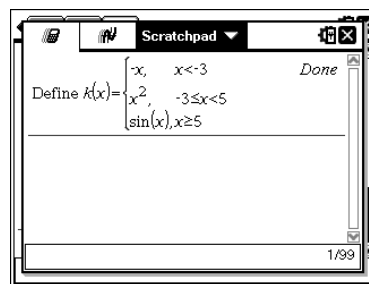
we access the piecewise-defined function from the catalog, option 5, top row, or by pressing the template key. Note the bottom of the first screen states piecewise function.



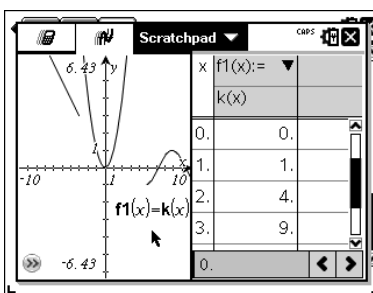
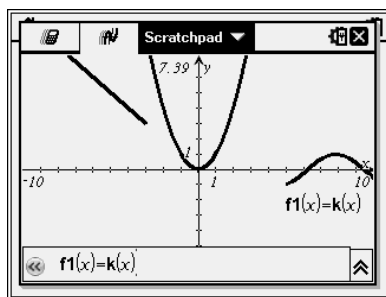
If we wish to define

$$k(x) = \begin{cases} -x & x < -3 \\ x^2 & -3 \leq x < 5, \\ \sin(x) & x \geq 5 \end{cases}$$

we execute the following command:

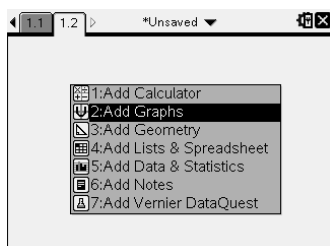


Once $k(x)$ has been defined as above, it can be assigned to $f1$ by entering $k(x)$ as shown below. Once this has been done, it is a simple matter to graph $k(x)$ and view a table of values. The table of values can be added to the graph window by pressing ctrl-t . To remove the table, highlight the graph window (ctrl-tab) and press ctrl-t .



CHAPTER 5 - GRAPHING

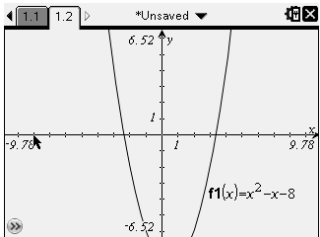
Obviously, the Nspire **graphing** calculator is well-suited for graphing all kinds of functions. The work that we will do with graphing is a time when it is best to work within a new document Press the home key, New Document, Add Graphs.



1. Graphing functions

A function is entered at the bottom, in the graph entry window. To access other functions, press the up or down arrow. The Nspire can hold up to 99 functions in a graphing page.

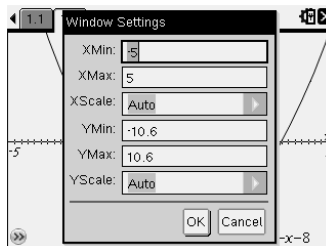
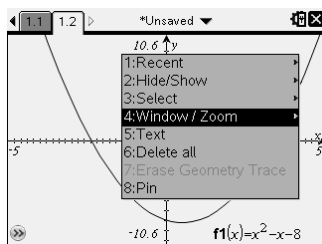
Here we graph $y = x^2 - x - 8$:



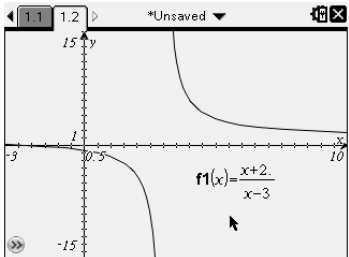
Note well:
To display the function entry window, press ctrl-g. This toggles the function entry window on and off.

There are a variety of ways to adjust the viewing window.

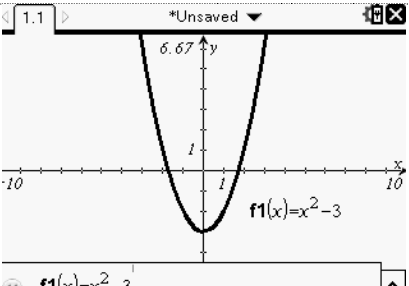
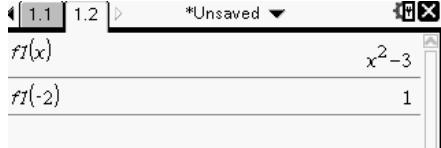
- You can click on one of the axes, grab it (ctrl-hand), and drag.
- Or you can double-click on the number to the right or left of either axis, and type in a new extreme value.
- Or finally, you can press ctrl-menu, 4: Window/Zoom, and then window settings, where you may have complete control over the window. This last option is shown below.



When a rational function is graphed, the Nspire "understands" any points of discontinuity, and draws the graph correctly.

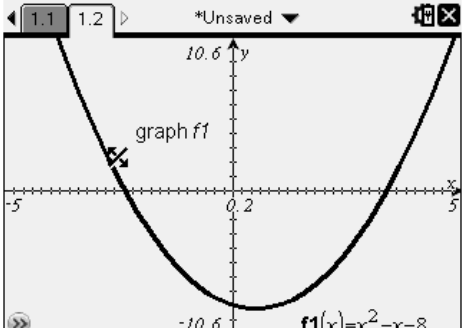
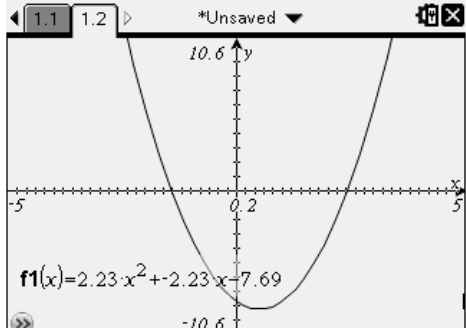
<p>The following is the graph of</p> $y = \frac{x+2}{x-3}$	
--	--

NOTE: Within the same document, a function which is defined in a graph entry window can be used in a calculator window by referencing it as "f1(x)", etc.

<p>For example, in a graphing window we define f1(x) as x^2-3,</p> 	<p>and then in a calculator window, we can reference this function and perform operations.</p> 
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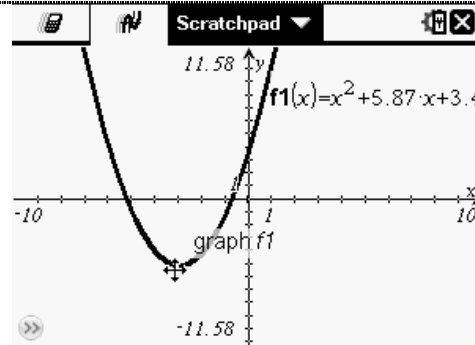
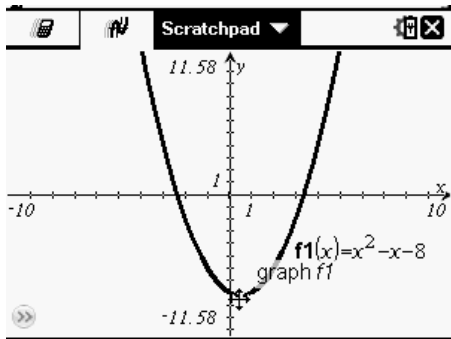
2. Manipulating the graph of a function

There are three basic ways to deform the graph of a function: it can be stretched, translated, or rotated. To select the graph, hover over it and press ctrl-hand.

<p>A graph can also be stretched by hovering over the graph until the cursor turns into a cross-hair, as shown below, and dragging.</p> 	<p>As the graph is deformed, the equation on-screen will change accordingly.</p> 
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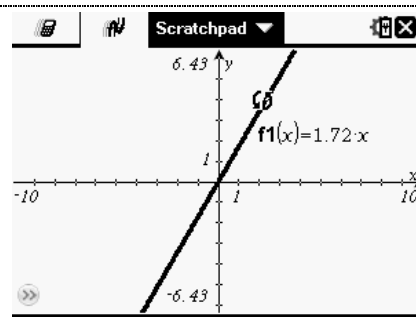
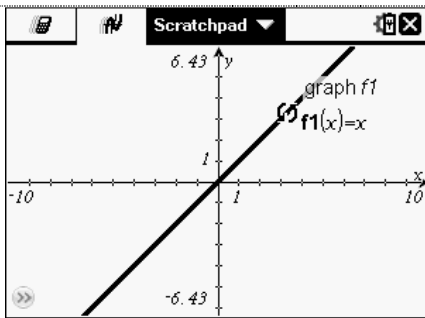
The graph can be **translated** by hovering until the cursor changes into a 4-dimensional arrows, as shown below. Note that this will only happen at the vertex of a parabola.

Similarly, as the graph is moved, its equation changes on-screen.



Finally, a graph can be **rotated** by hovering until the cursor changes into curved arrows, as shown below. A parabola cannot be rotated because it would no longer be a function. We demonstrate this feature with the graph of $y = x$.

We see that the equation changes as the graph is rotated.

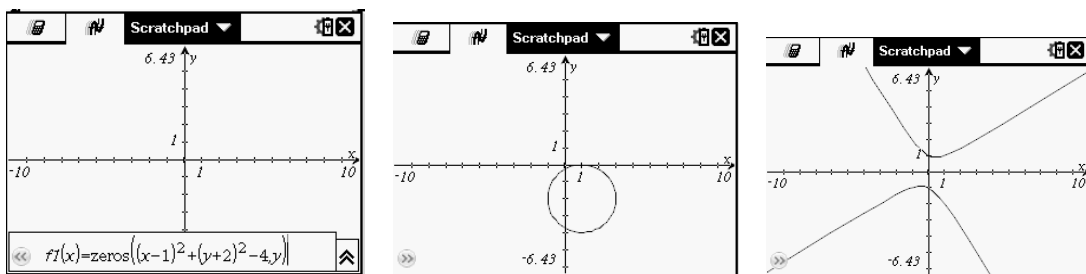


3. Graphing Relations

The Nspire will only graph functions. If we wish to graph a relation which is not a function, we can *trick* the Nspire by using the **zeros** command.

If we wish to graph a simple circle, like $(x-1)^2 + (y+2)^2 = 4$, we execute the command **zeros((x-1)² + (y+2)² - 4,y)**. The command **zeros** can be typed, or accessed from the catalog menu, page 1.

This graph is shown below, as well as the graph of another relation, $xy - x^2 + y^2 = 1$.

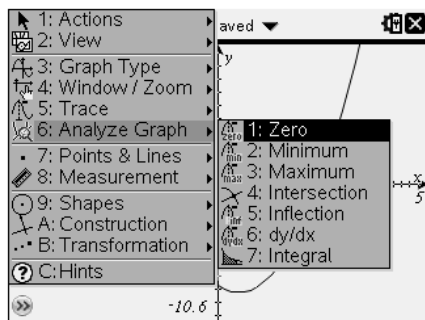


4. Extreme values; zeros

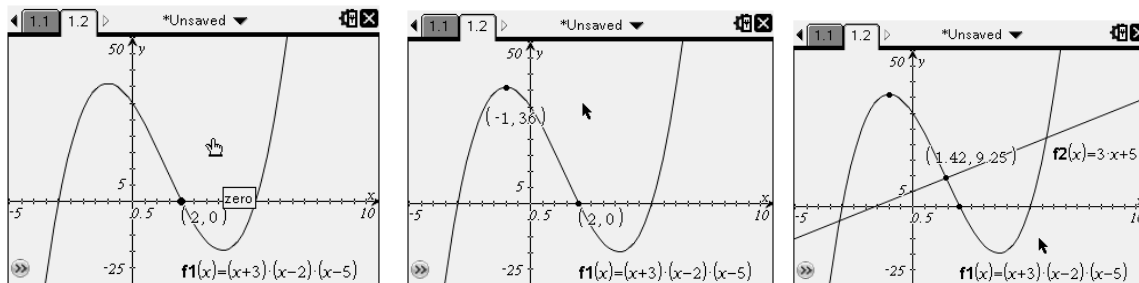
Just like other graphing calculators, the Nspire can find the zeros, and the maximum and minimum values of a function that has been graphed.

With a graph displayed, there are many ways to analyze it.

Press menu, 6: Analyze Graph to bring up the menu.

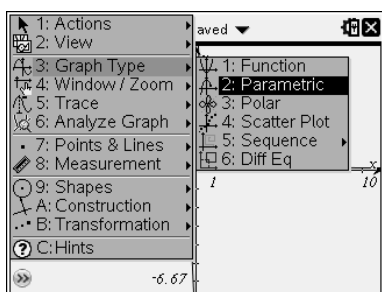


The first window below shows how to find a root; the second one an extreme value. In each case, the user must indicate the lower and upper bounds by using the arrow keys. The third window shows the location of the intersection of two curves.



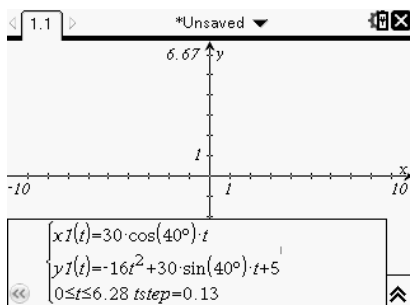
5. Graphing Parametric Relations

To graph parametric equations, the graph mode must be set to parametric. While in a graph page, press menu, graph type, parametric. Notice how the graph input window changes.

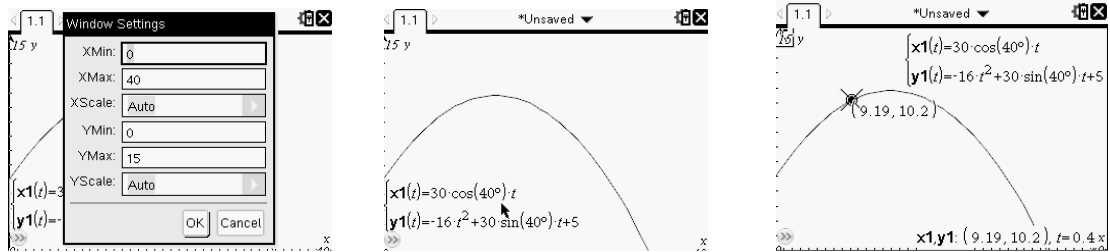


Enter a pair of parametric equations. Note that the independent variable is t . An example is shown below. These are the equations that describe the path of a ball that is thrown with an initial velocity of 30 fps at an angle of 40 degrees to the horizontal, from an initial height of 5 ft.

Note: The degree symbol, $^\circ$, can be found by pressing the $\text{?!} \blacktriangleright$ key.



Shown below is an appropriate window, and the resulting graph. Note the effect of choosing menu, 5: Trace. Not only are you given the x- and y-coordinates, but also the corresponding value of time t .



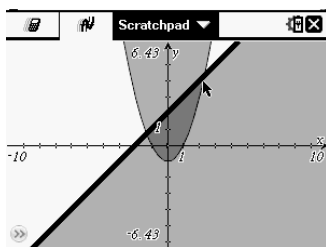
6. Graphing Inequalities

If the "=" sign in the function entry line is erased, the window below pops up, which allows the user to determine what kind of inequality to graph,

In this example, we will look at the intersection of the graphs of $y \geq x^2 - 1$ and $y < x + 2$.

<p>Note that when we input \geq $x^2 - 1$, instead of f1,</p>	<p>the f1 changes to y. This is because the graph is <i>not</i> a function.</p>	<p>Here is the graph of the inequality.</p>

Here is the graph of the two inequalities. Notice that the darker region represents the intersection, or where *both* $y \geq x^2 - 1$ and $y < x + 2$ are true.

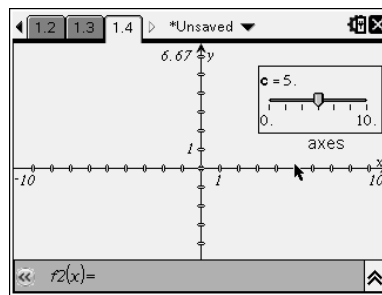
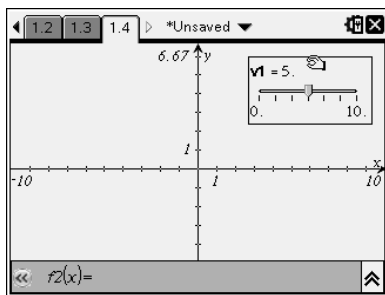


7. Using the slider

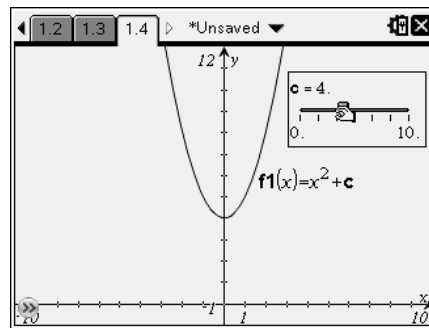
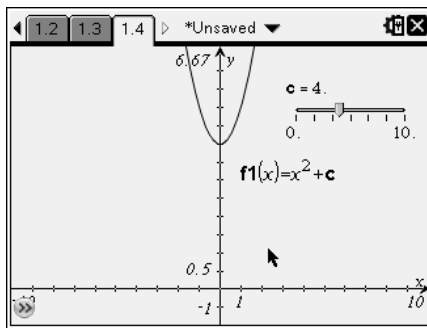
When studying graph transformations, it is often helpful to graphically examine what happens to the shape of a graph as a given parameter changes.

For example, we may wish to learn how the parameter c affects the graph of $y = x^2 + c$. We could graph a sequence of these functions manually, but using a slider helps to automate this process.

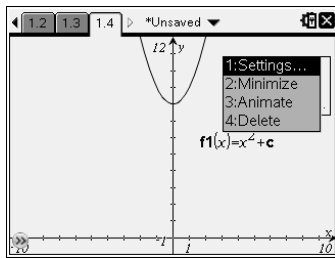
To insert a slider, press menu, Actions, Insert Slider. The slider values initially range from 0 to 10, with an initial value of 5 and a step size of 1. Note that the parameter is initially named $v1$. Click and change the name, in this case to c . The slider box can be moved anywhere on the screen by clicking and grabbing.



Now you can enter the desired function on the entry line, using the parameter c . Then you can position the cursor on the slider bar, and grab and drag the slider.

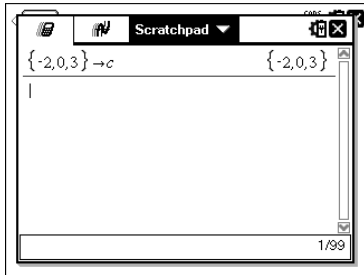


You can also move the cursor to the slider box and press ctrl-menu to bring up the menu shown below. From here you can change the slider settings, minimize the slider window, and even animate the process. Pressing ctrl-z will stop the animation.

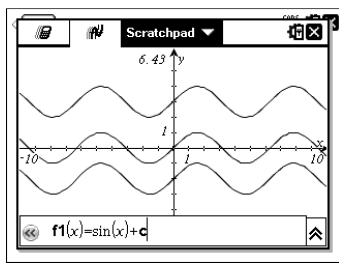


Here is another way to see the effects of transformation. Suppose we want to see the differences in the graphs of $\sin(x) + c$, where c has values $-2, 0$ and 3 .

We can accomplish this by defining the variable c to contain these three values.



We can then graph $\sin(x) + c$, and we can examine the three graphs.

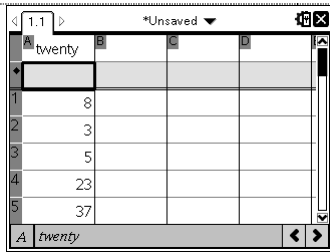


CHAPTER 6 - SINGLE VARIABLE STATISTICS

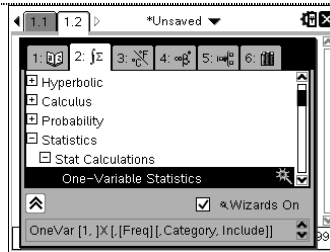
This is a topic with which every high school should be familiar. Given a set of data, we will demonstrate how the Nspire can be used to find the mean, median, mode, quartile values, and the standard deviation. It can also be used to draw a histogram and a box-and-whisker plot.

1. Finding single variable statistics

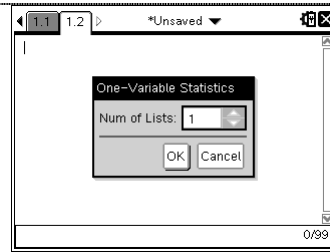
We begin in a new document, opening a Lists and Spreadsheets page. Enter a column of data, and give it a name at the top of the column, which in this case "twenty". This example has 20 data between 0 and 100.



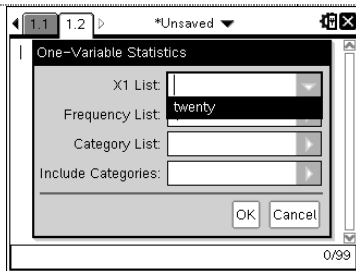
Open a new calculator page, press catalog, page 2, Statistics, Stat Calculations, One-Variable Statistics.



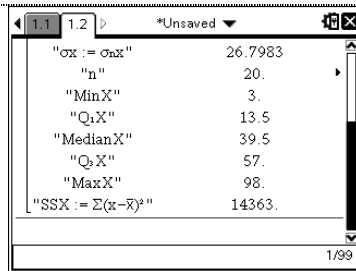
Press enter, and the following window will display:



Press OK. In the choice X1 list, press the right-arrow and select "twenty".



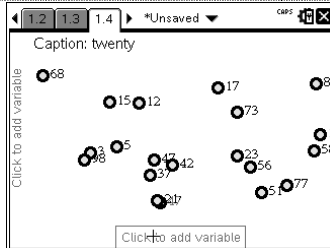
Press enter, and the full set of data are displayed.



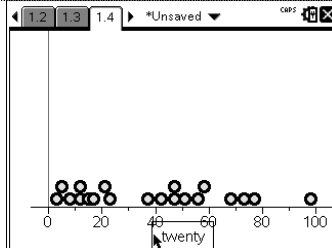
The mean value, standard deviation, number of data, minimum value, first quartile, median, third quartile and maximum value are displayed. Other data are also displayed that are not as important to this study.

2. Drawing a histogram and box-and-whisker plot

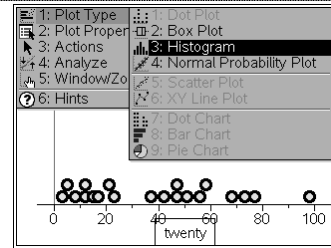
To draw a histogram, open a new Data and Statistics page.



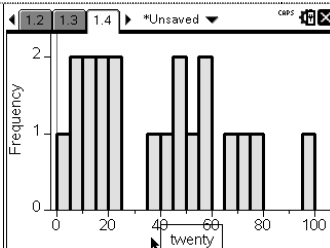
Click in the bottom window and select "twenty".



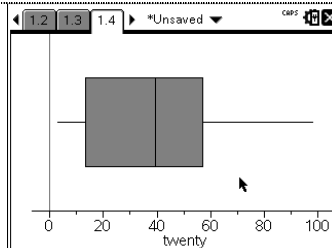
Press menu, Plot Type, Histogram.



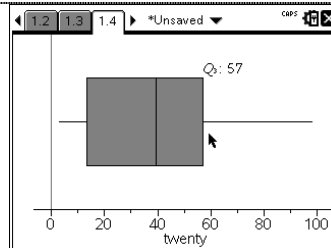
The complete histogram is now displayed.



A box-and-whisker plot is created similarly. Press menu, Plot Type, Box Plot.



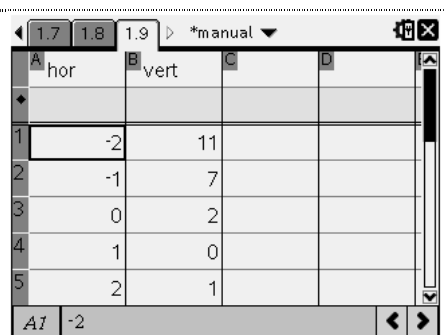
By hovering over the plot, the Nspire will display the different pieces of data that the plot reflects. For example, the screen below shows that the third quartile is 57.



CHAPTER 7 - REGRESSION

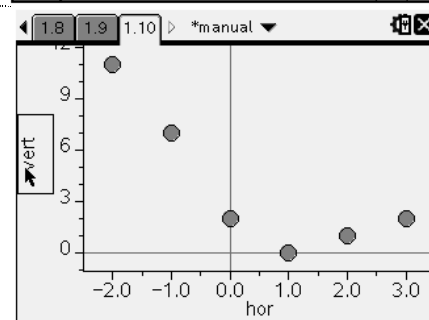
To perform regression on a set of data, open a new document (press home), then open a Lists & Spreadsheet page (ctrl-doc).

1. Enter your data in the two columns, labeling each column at the top. In this case, the data in column A is labeled hor, and the data in B is vert.

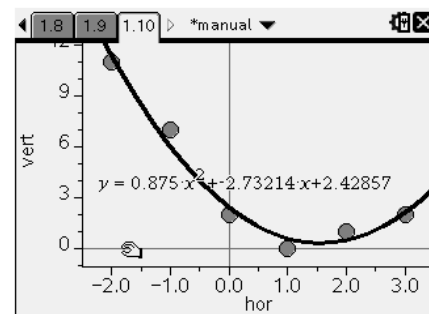


	A hor	B vert	C	D
1	-2	11		
2	-1	7		
3	0	2		
4	1	0		
5	2	1		

2. To plot the data points to determine what kind of regression might be best, open a Data & Statistics page, drag to the bottom (click) and to the left (click) and select the appropriate variables.



3. This looks like the graph of a quadratic function. To perform the regression, press menu, Analyze, Regression, Show Quadratic. Notice that the equation and the graph are shown on the same graph as your data points.



Other types of regression can be performed similarly, such as linear, exponential, logistic, etc.

For another way to perform regression and get complete statistics for the result, go back to your Lists & Spreadsheets page with the data entered, and put your cursor in the cell labeled C1.

	A hor	B vert	C	D
1		-2	11	
2		-1	7	
3		0	2	
4		1	0	
5		2	1	

Press menu, Statistics, Stat Calculations, and then pick the appropriate regression, which in this case is Quadratic Regression. You should get the window shown below.

Quadratic Regression

X List: C1

Y List:

Save RegEqn to: f3

Frequency List: 1

Category List:

Include Categories:

OK Cancel

Press the click button in the X list and Y list entries, and select the appropriate choice, as shown below.

Notice that the regression equation will automatically be stored in the function labeled f3. You can then switch to the graph window, and graph that function.

Press enter, and the regression equation and information will be dumped into your spreadsheet.

Notice the value for the correlation, R^2 . The closer this value is to 1, the better the data points fit the regression equation.

Quadratic Regression

X List: hor

Y List: vert

Save RegEqn to: f3

Frequency List: 1

Category List:

Include Categories:

OK Cancel

	C	D	E	F
1			=QuadReg	
2		RegEqn	a*x^2+b*...	
3		a	0.875	
4		b	-2.73214	
5		c	2.42857	
6		R ²	0.979161	

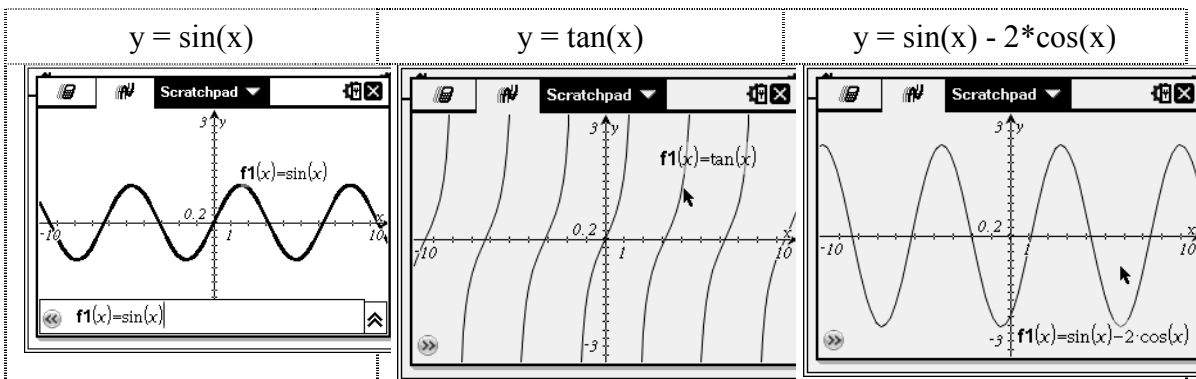
CHAPTER 8 - TRIGONOMETRY

The Nspire has all six trig functions and their inverse functions built in. They may be accessed by pressing the trig button on the left of the calculator.

1. Graphing Trigonometric Functions

Graphing trig functions works the same as graphing any function. It is best to select radian measure, which can be accessed under Settings by pressing the home button.

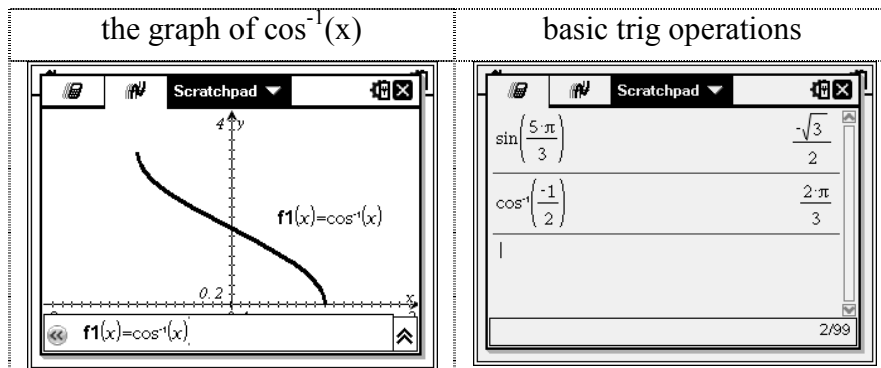
Examples:



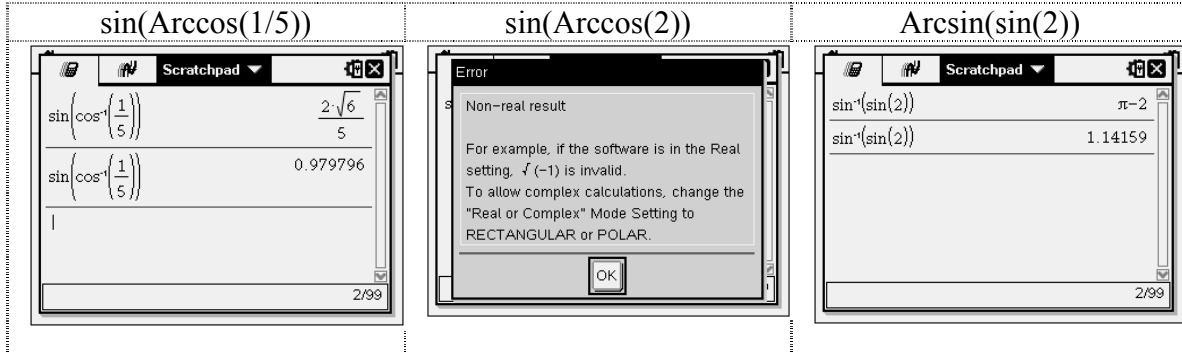
2. Inverse Trig Functions

The inverse trig functions are located on the same key as the trig functions.

Examples:



3. Evaluating compositions of trig and inverse trig functions

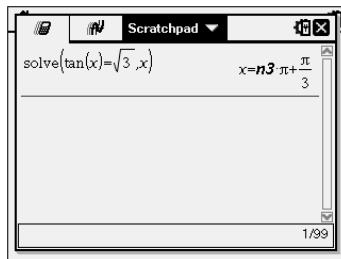


The last example is an important one, since it indicates that the Nspire "understands" the appropriate range of the Arcsin function.

4. Trigonometric Equations

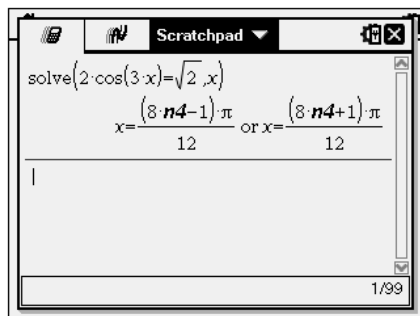
Solving equations with trig functions works the same as solving any kind of function.

Examples:

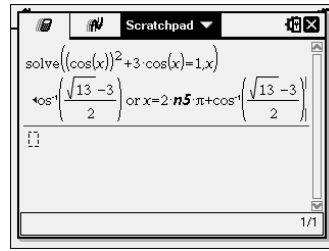
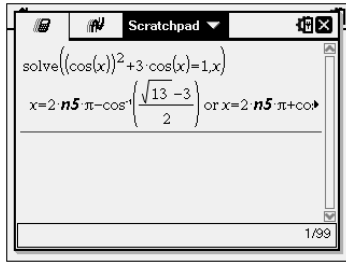


NOTE WELL: The statement $x = n3\pi + \pi/3$ means that solutions are of the form $\pi/3 + k\pi$, where k is an integer. $n3$ represents any integer value. For successive calculations, the number following n increases by 1, such as $n4$, $n5$, etc.

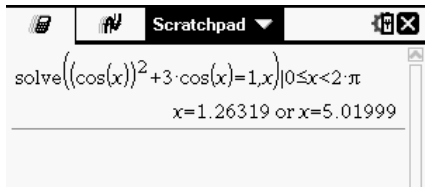
Notice the next example's use of $n4$, $n5$.



Here is the solution of $\cos^2(x) + 3\cos(x) = 1$



NOTE: To get solutions in the interval $[0, 2\pi)$, we use the command $|0 \leq x < 2\pi$ immediately after the "solve" command, and then press ctrl-enter. The | symbol is found by pressing ctrl-=.



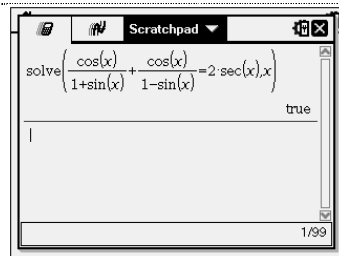
5. Trigonometric Identities

While work with identities must continue to be done by hand to ensure appropriate comprehension of key trig ideas, the Nspire can help to validate an identity.

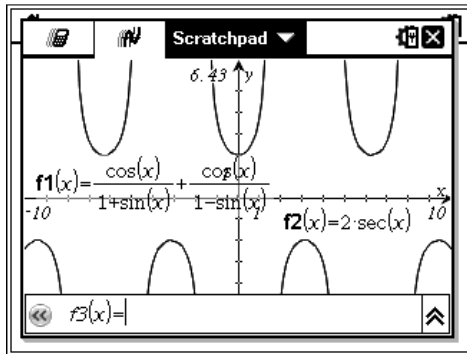
Here is an example of "verifying" an identity:

$$\frac{\cos(x)}{1 + \sin(x)} + \frac{\cos(x)}{1 - \sin(x)} = 2 \sec(x)$$

The fact that the Nspire returns "true" for this equation means that it is true for all x , and thus is an identity.

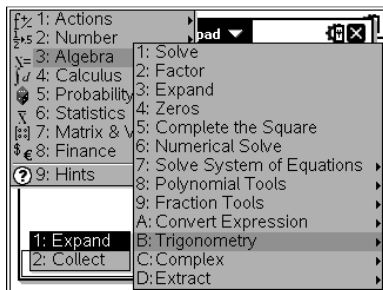


Also, we can graph each of these on the same axes, using different styles for each, to help convince us that the identity is indeed true.

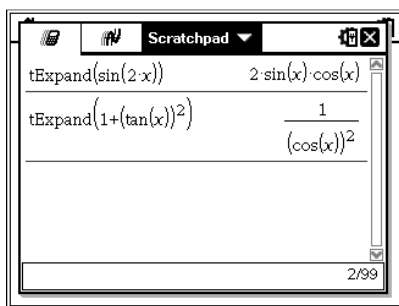


Finally, it is possible to use the `texpand` (trig expand) command to be reminded of identities.

The `texpand` command is found by pressing menu, Algebra, Trigonometry, Expand, as shown below.



The following window shows how `texpand` can remind us that $\sin(2x)$ equals $2 \cdot \sin(x) \cdot \cos(x)$, and that $1 + \tan^2(x) = \frac{1}{\cos^2(x)}$, or $\sec^2(x)$.



6. Law of Sines and Cosines

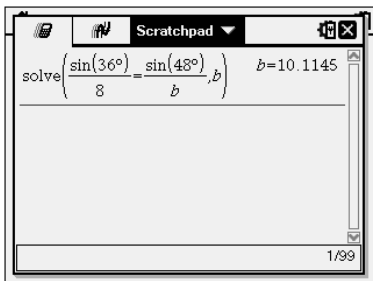
The Nspire can be used in these type of problems very easily, since all that is really required is solving an equation.

Here is an example for the Law of Sines:

Find side b given that side $a = 8$, angle $A = 36$ degrees and angle $B = 48$ degrees.

We want to solve $\frac{\sin(36)}{8} = \frac{\sin(48)}{b}$ for b .

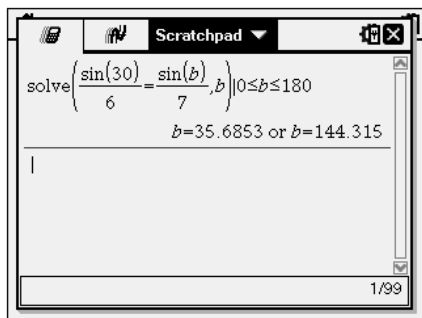
Note the use of the degree symbol (found by pressing the $\text{?!}\blacktriangleright$ key). This overrides the radian measure in Settings. The approximate result is obtained by pressing ctrl-enter.



Here is an example of the ambiguous case, for which the Nspire conveniently delivers both of the possible values. In this case, we have changed our default to degree measure.

Find angle b if side $a = 6$, side $b = 7$, and angle $A = 30$.

Here we want to solve $\frac{\sin(30)}{6} = \frac{\sin(b)}{7}$

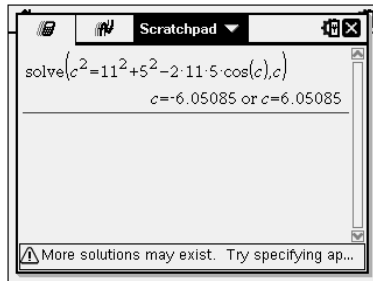


In the context of the problem we can only accept angle measures between 0 and 180. That is accomplished by typing $|0 \leq b \leq 180$ immediately after the "solve" statement. So the two solutions are about 35° and 144° .

The following is an example that uses the Law of Cosines:

Find side c if side $a = 11$, side $b = 5$ and angle $C = 20$.

We execute the command $\text{solve}(c^2=11^2+5^2-2(11)(5)\cos(20),c)$.



Here we need to eliminate the first, extraneous solution, since it is a negative number.

CHAPTER 9 - Spreadsheets , Sequences and Series

1. Using the Spreadsheet

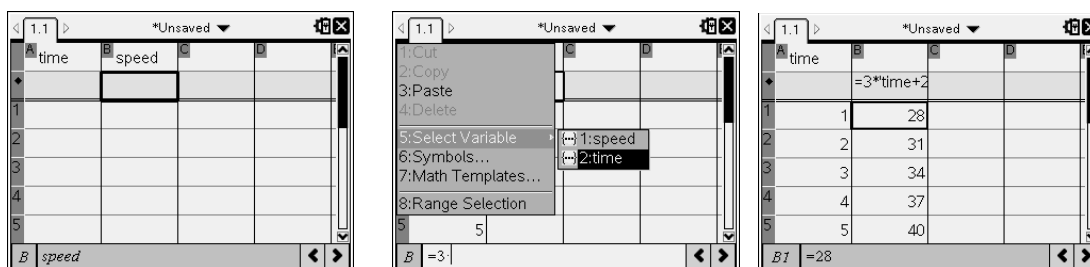
It is possible to use the Nspire as a spreadsheet, in much the same way as Excel operates.

Open a new Lists and Spreadsheets page. Name each column, as shown below in the first screen.

Data can be entered for the time column, values 1 through 5.

For the speed column, we will use the formula “speed = 3 times time plus 25”.

To enter this formula, place the cursor in the cell immediately below the cell that contains “speed”. Type “=3*” and then press ctrl, menu, Select Variable and highlight “time”. See the second screen below. Then press “+25” and press enter. This will fill in the values for the speed column. This is shown in the third screen.

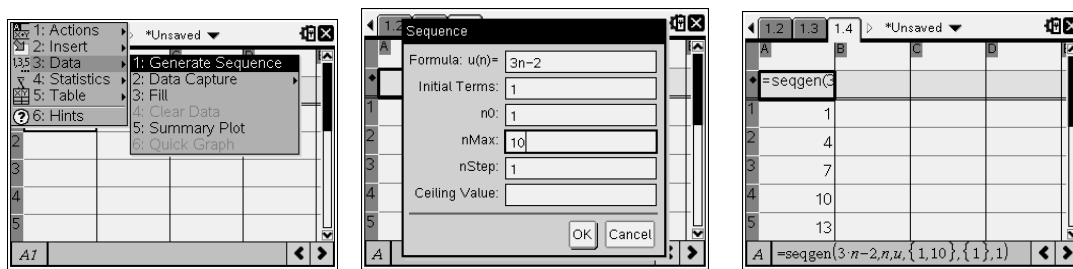


Just like with Excel, there is a lot of power in the spreadsheet functionality of the Nspire.

2. Sequences and Series

To generate a sequence, open a Lists and Spreadsheets page.

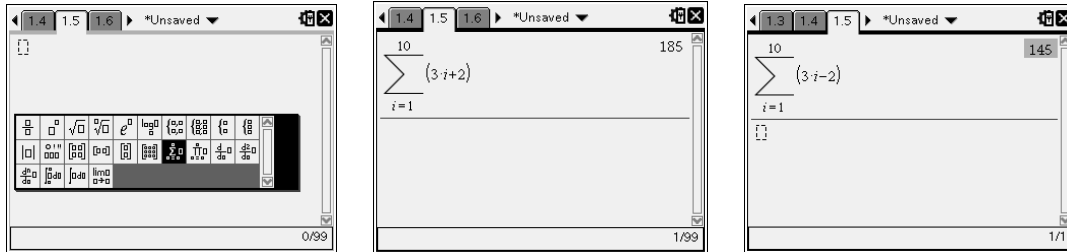
Move the cursor to the header row and press menu, Data, Generate Sequence, as shown below. Fill in the table to match the desired sequence, $\{3n-2\}$, as shown in the second screen. The result is shown in the third screen.



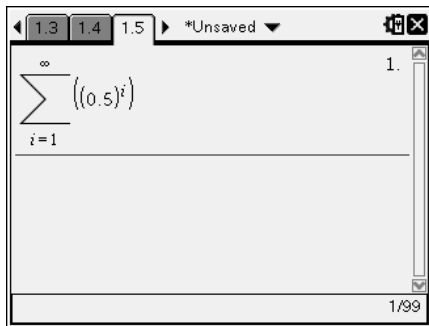
One way to get the sum of the ten terms of this sequence is to put your cursor in B1, and type “=sum(” and then press ctrl-menu and select Range Selection. Place the cursor in cell A1, and while holding the shift key, down-arrow until all ten values are selected. Press enter, and the sum will be displayed in B1.

Another way to find the sum of this sequence, $\{1,4,7,10,13,16,19,22,25,28\}$ is to use the sum template (found on the template button), shown below. We first must open a calculator window.

Fill in the parameters and function, as shown in the second screen below.



As a final example, observe how easily the Nspire evaluates an infinite series:

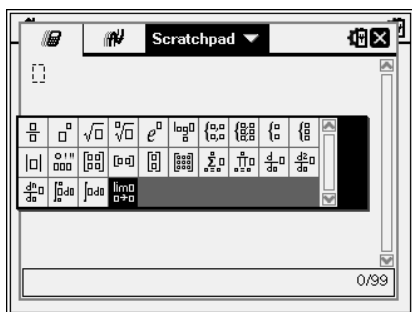


CHAPTER 10 - LIMITS

The Nspire can be used to investigate problems that involve limits.

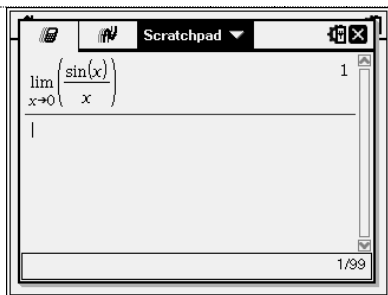
To compute a limit, state the function and the value at which the limit is to be found.

The limit command is found on the templates key, which is the same button as the catalog key. Notice that the Nspire allows us to compute a one-sided limit.



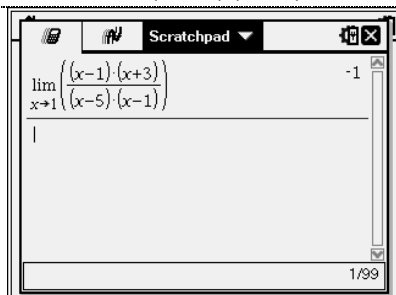
Examples:

$$\lim_{x \rightarrow 0} \frac{\sin(x)}{x}$$

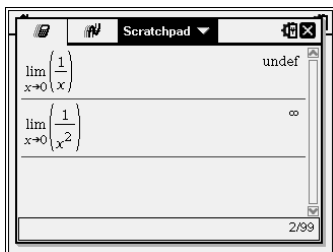


The following example illustrates how to find the y-value at a "hole" or removable discontinuity of a rational function.

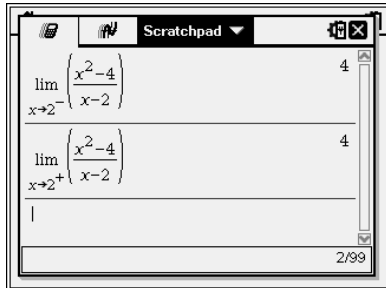
$$\lim_{x \rightarrow 1} \frac{(x-1)(x+3)}{(x-5)(x-1)}$$



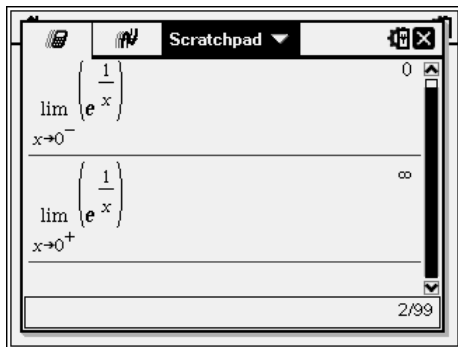
Note the difference between the following two non-existent limits, $\lim_{x \rightarrow 0} \frac{1}{x}$ and $\lim_{x \rightarrow 0} \frac{1}{x^2}$



We can also use the Nspire to find left and right hand limits.
 For a left-hand limit, enter the negative sign above the limit value; for a right-hand limit, use the addition sign.



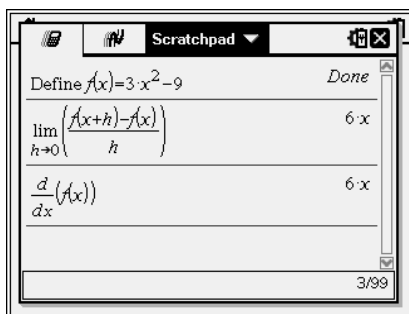
Here are some more interesting examples of one-sided limits:



For a final example, consider the following important concept from differential calculus.

Define $f(x) = 3x^2 - 9$, and evaluate the limit of $\frac{f(x+h) - f(x)}{h}$ as h approaches 0.

This is the definition of the derivative, and this result should agree with the derivative of $f(x)$, as the following shows.



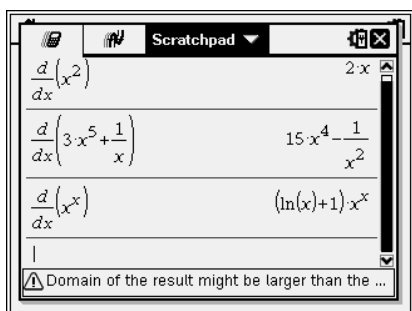
□

CHAPTER 11 - CALCULUS

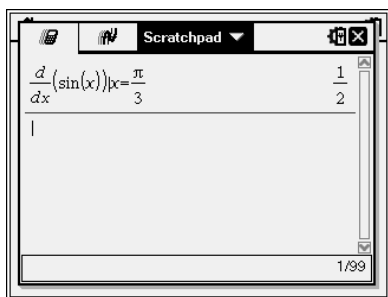
The Nspire, especially OS 3.0, is well-suited to provide additional insight into calculus, by graphical and numerical methods.

1. Differentiation

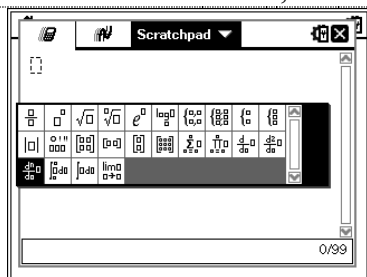
The following examples show the notation used to find a derivative. The derivative key is found by pressing the template key, or by pressing shift - . Here are a few examples:



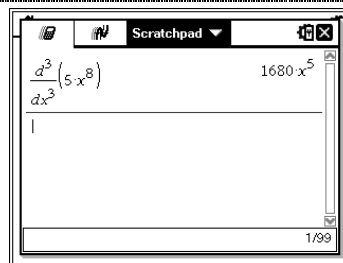
It is also possible to compute a derivative, and evaluate it at a specific point. The following example shows how we can find the derivative of $\sin(x)$ and evaluate it at $x = \pi/3$, giving the result of $1/2$. The "such that" symbol, |, is found on the same key as the inequality signs. The pi symbol is found by pressing the π key.



To compute the second or higher order derivatives, access the templates and use the option in the first column, second row.



This example shows that the third derivative of $5x^8$ is $1680x^5$

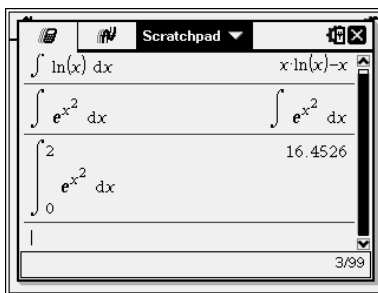
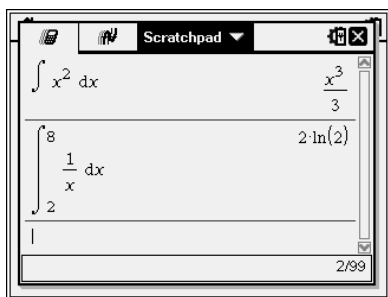


2. Integration

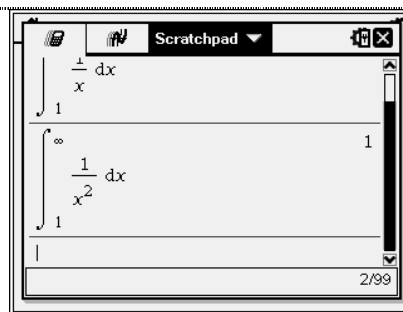
The integral key is also found on the template key, and note that there are separate keys for indefinite and definite integrals. The shortcut for an integral is shift +.

Be advised that the constant term, C, is not printed in the result for an indefinite integral.

Also note that in the second screen, the Nspire simply returns the input for $\int e^{x^2} dx$ since there is no antiderivative of e^{x^2} . The last entry shows that it is possible to compute the **definite** integral of e^{x^2} .

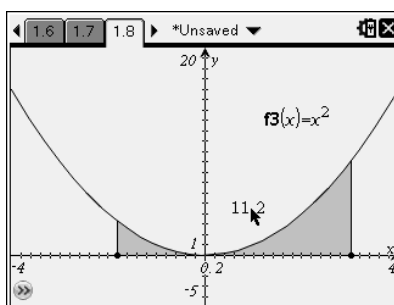
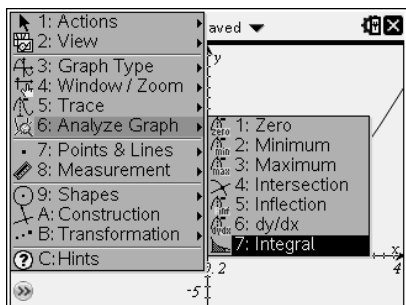


The Nspire can also handle improper integrals. The infinity symbol is found by pressing the π key.



The Nspire can also evaluate definite integrals **graphically**.

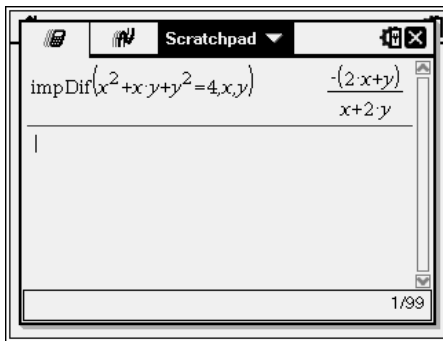
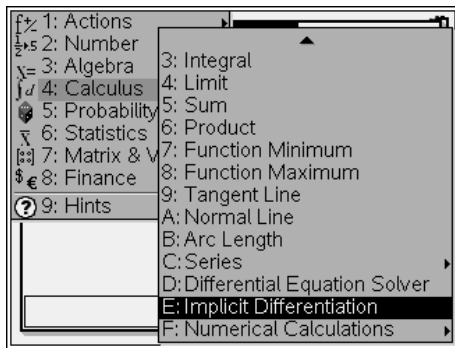
For any graph, press menu, Analyze Graph, Integral. Choose the lower bound, choose the upper bound, and press enter. The shaded region will be displayed, and the numerical integral, which in this case is 11.2, will be displayed.



3. Implicit differentiation

Suppose we wish to find dy/dx given the relation $x^2 + xy + y^2 = 4$. This is an example of a relation in which solving for y explicitly may not be easy or even possible.

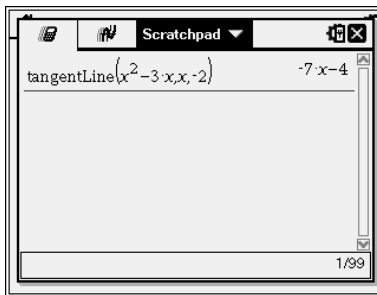
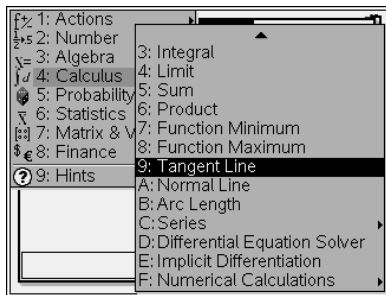
We access the ImpDif command by pressing menu, Calculus, and then E:Implicit Differentiation. The following example shows how it can be executed.



4. Tangent lines

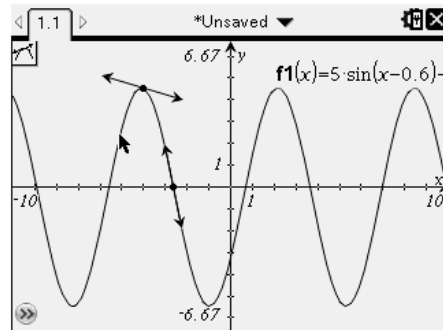
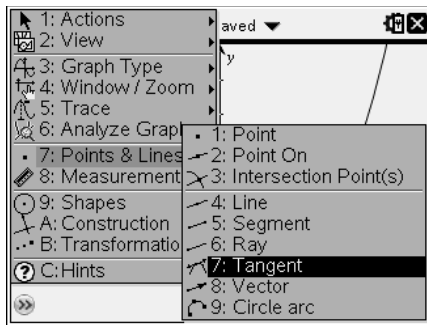
This is a topic that the Nspire handles algebraically and graphically.

If we want the equation of a tangent line to a function at a given point, we can execute the command `tangentLine`, which accepts as parameters the function, variable, and point at which to find the tangent line. The `tangentLine` command is found under the Calculus menu, as is shown below.

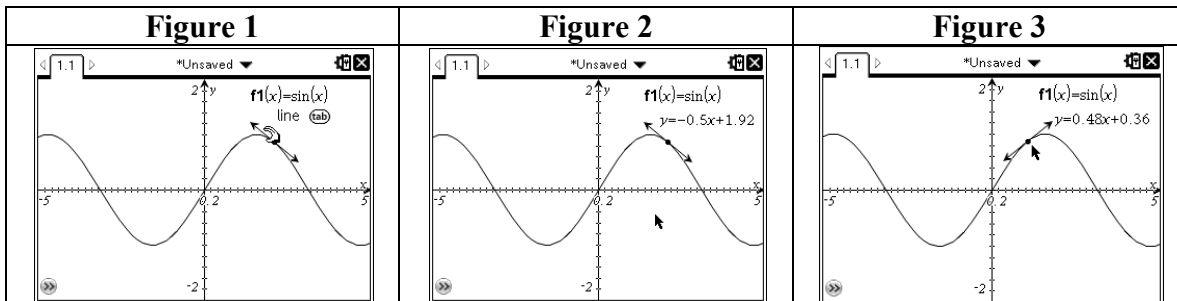


We can also have the Nspire *draw* the tangent line to the graph of a function.

In a graphs page (in a document, not on the scratchpad), with a graph on the screen, press menu, Points & Lines, Tangent. Select the graph, and choose a point and press enter. The tangent line will be drawn. It is possible to grab the tangent line and move it along the graph, noticing how the tangent line changes.

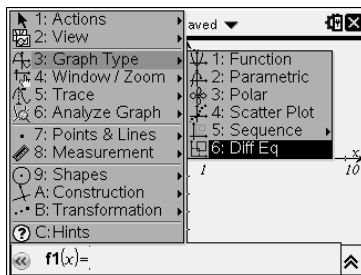


To display the equation of the tangent line, hover over it until you see the word "line" (Figure 1), press ctrl-menu and then Coordinates and Equations. The equation of the tangent line will appear (Figure 2). If you then grab and move the point, the equation of the tangent line will change dynamically (Figure 3).

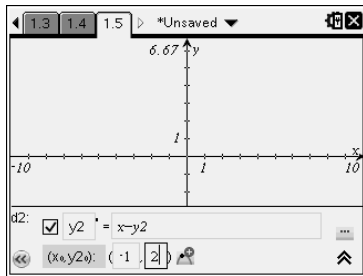


5. Slope Fields

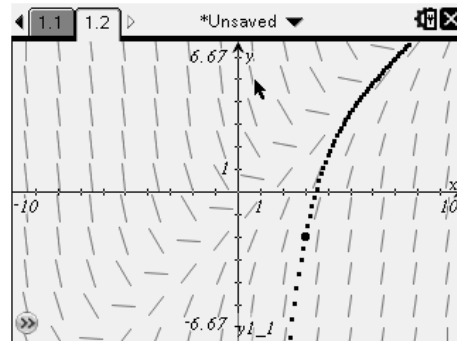
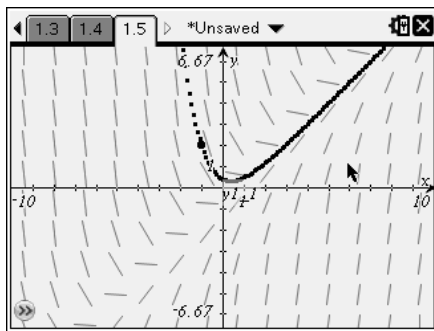
The Nspire with OS 3.0 can sketch the slope field for a differential equation. A slope field is a way to graphically see a solution to a differential equation. Open a new graph page and press menu, Graph Type, Diff Eq.



Enter the differential equation, using x and y_n , where n corresponds to the subscript on y on the entry line. Enter the initial condition as shown, which is $(-1,2)$. Use tab to move the cursor.



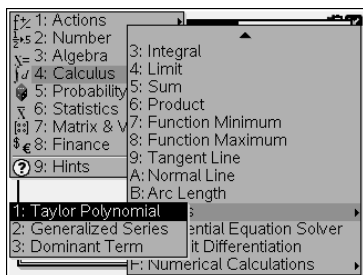
Press enter, and the slope field and specific solution are drawn.



Notice how different the solution looks if we select $(3, -2)$ as an initial point, shown in the right graph.

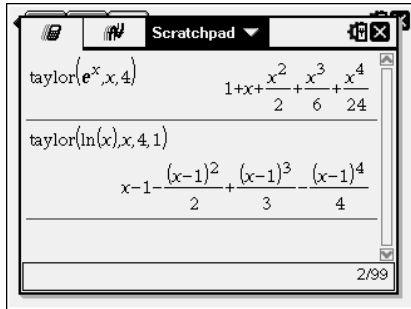
6. Taylor Series

To compute a Taylor series, we execute the command Calculus, Series, Taylor Polynomial.

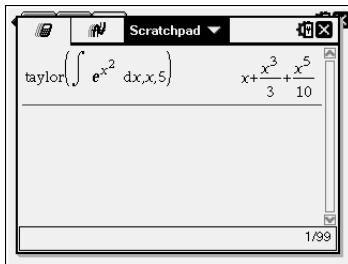


The first example shows the 4th degree Taylor polynomial for e^x , and the second the 4th degree Taylor polynomial for $\ln(x)$ centered around $x=1$. Notice the *fourth* parameter in

this call, which determines the center as "1". Without this parameter, the center is assumed to be zero.



Note that this last example shows how we may find a series expansion for $\int e^{x^2} dx$, even though this expression does not have an antiderivative



6. Solving DEs and IVPs

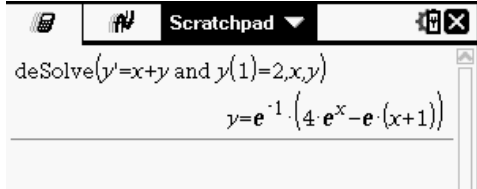
The Nspire CAS handles the solution of a differential equation (DE) and an initial value problem (IVP) very simply.

Consider the differential equation $\frac{dy}{dx} = x + y$. While this looks simple enough, solving such a DE by hand is beyond the scope of BC Calculus. To solve it using the Nspire, we execute the following command, found by pressing menu, Calculus, Differential Equation Solver: `desolve(y' = x+y,x,y)`.

It returns the general solution, where **c1** is any non-zero constant.

the menu choice for solving a differential equation	the written command	the command executed

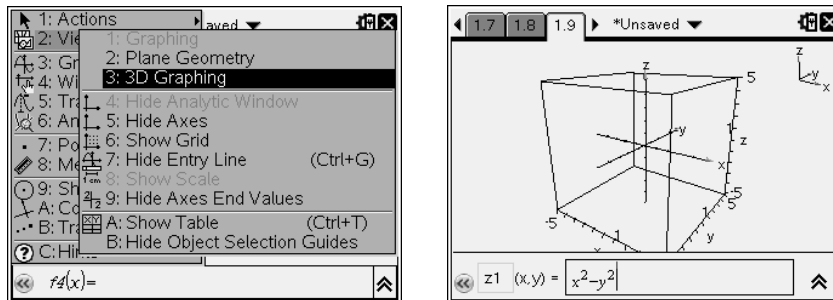
If we want to solve the IVP $\frac{dy}{dx} = x + y$, with initial condition $y(1) = 2$, we use the same command with the given addition: `desolve(y' = x+y and y(1)=2,x,y)`. Note that the result is an **exact** solution.



8. 3-D Graphing

To make a 3D graph, you must be in a graphing page, and not the scratchpad grapher. Although this is a topic ordinarily covered in multivariable calculus, it is mentioned here to help complete the chapter on calculus.

In a graph page, press menu, View, 3D Graphing, as shown below. Enter a function in two variables, such as $x^2 - y^2$.



Press enter and the graph will be displayed. It can be reoriented by pressing the arrow keys. A different view is shown in the second screen.

