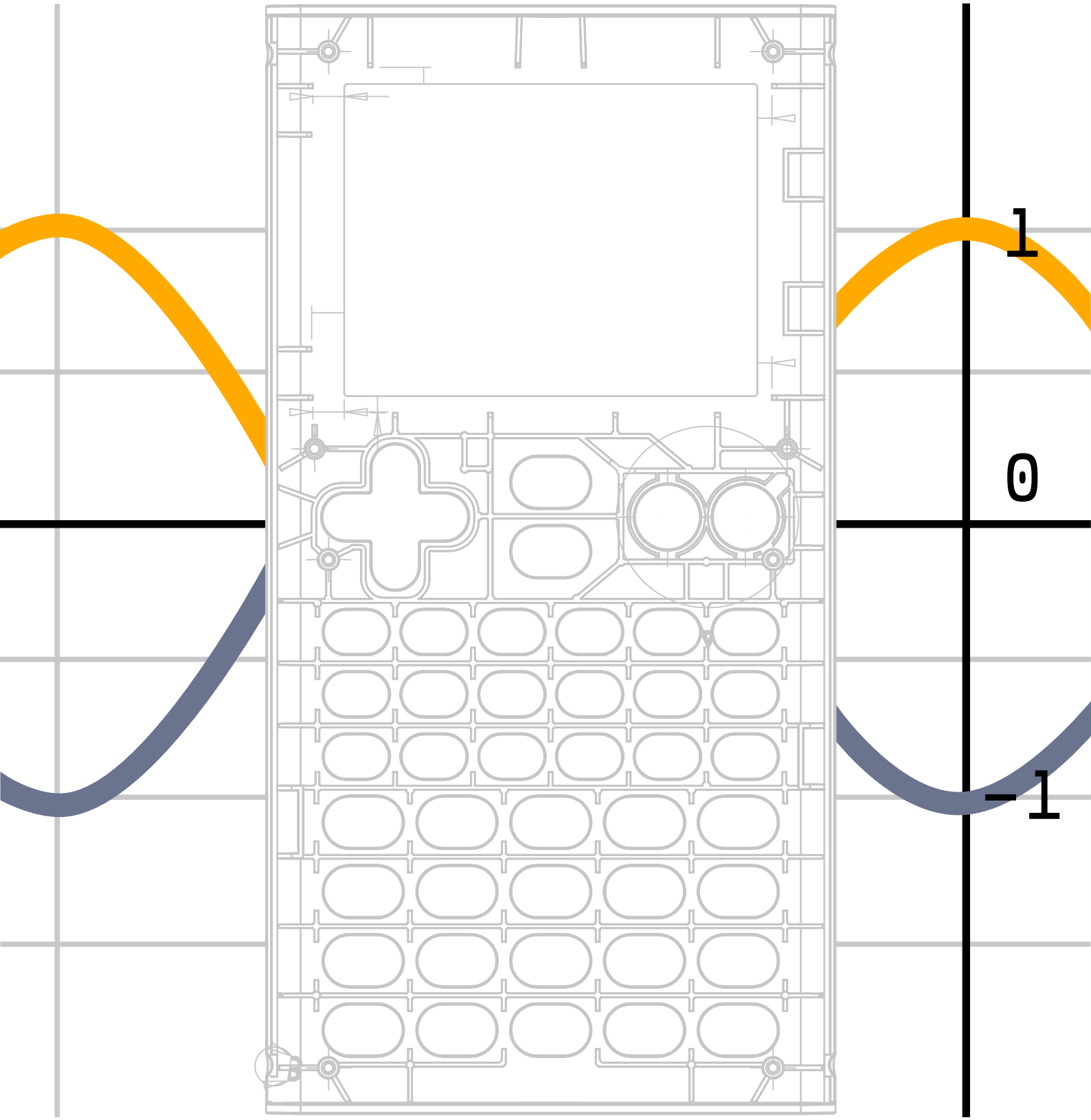
NUMWORKS

User manual



Version 21.0.0

Contents

Chapter 1

Calculation

To enter the **Calculation** application, highlight the app using the directional keys. Press the OK key to enter the application. This application allows you to perform a variety of computations involving complex numbers, matrices, trigonometry, combinatorics, derivatives, integrals, and unit conversions.

1.1 Getting started

1.1.1 Performing a calculation

Begin by entering the **Calculation** application. Do this by highlighting the app on the home screen using the arrow keys. Press the OK key to confirm.
To enter your first calculation:

1. When you enter the **Calculation** application, the cursor will begin in the editing bar at the bottom of the screen. This is where you will enter your expression.
2. Once you have entered the desired expression, press the EXE key to receive your result.

The result of your most recent calculation will appear in the calculation history located just above the editing bar. The history lines include the calculation entered, which appears on the left, and the result, which appears on the right. You will receive both an exact result and a decimal result for your calculation when applicable. Exact results are displayed in black and the decimal results are displayed in gray.

1.1.2 Navigating the calculation history

You may navigate between elements of the calculation history lines by using the ▲ ▼ and ◀ ▶ keys. Once an element is selected, it will be highlighted in gray. Selecting an

element within a history line allows you to view all information relevant to your calculation. For example, calculations using decimal numbers will return only a decimal result. To view the exact result, select your desired history line and the exact result will appear.

> To facilitate reading, the result of calculations with a decimal number is always given in decimal form: $0.1+0.3$ will return 0.4 while $\frac{1}{10}+\frac{3}{10}$ will give $\frac{2}{5}$.

1.1.3 Using the most recent result in a new calculation

The exact result of your most recent calculation may be used in the expression of a new calculation. To do this, press the Ans key. The expression **Ans** will appear in the editing line. This expression represents the result of your most recent calculation. You may then perform calculations on this result.
You may also perform a single operation directly to your most recent result by pressing an operation key. For example, you can add 5 to your last calculation by pressing the + key followed by the 5 key. The calculation editor will display **Ans+5**. Once executed, the value of your most recent result will replace **Ans**.

> Because the NumWorks calculator only contains one minus key, pressing the (-) key will display **-** to represent a negative value. Press the (-) again to display **Ans-**.

1.1.4 Using an element from the calculation history in a new calculation

Results and previous entries in the calculation history may be used in the expression of a new calculation. Use the ▲ ▼ and ◀ ▶ keys to highlight your desired element. You may choose between the exact and approximate results. Once your element is highlighted, press the OK key to confirm. The element is then displayed in the editing bar at the bottom of the screen.

1.1.5 Deleting line items in the calculation history

Line items in the calculation history may be deleted. To delete a line, use the ▲ ▼ keys to highlight an item from the line you wish to delete. Press clear to delete the line.
To delete all lines of the calculation history, press shift followed by clear.

1.2 Performing calculations with complex numbers

1.2.1 Choosing the complex format of the results

With the NumWorks calculator, you may calculate using both complex and real numbers. Your results may be displayed in three different forms:

1. Cartesian: the calculation of $\sqrt{-1}$ will give the result i
2. Polar: the calculation of $\sqrt{-1}$ will give the result $e^{1.570796*i}$
3. Real: the calculation of $\sqrt{-1}$ will give the result "unreal"

   When the calculator is using polar form, the angle in the exponent is always given in radians, even if the calculator is set in degrees mode.

To choose the form:

1. Press to begin on the home screen.
2. Highlight the **Settings** application with the directional keys.
3. Press the OK key to confirm.
4. Choose **Complex format** and press OK to confirm.
5. Select your desired form with the ▲ ▼ keys and confirm with OK

1.2.2 Calculating values with complex numbers

The modulus, argument, real part, imaginary part and conjugate can be calculated while in the **Calculation** application. There are three ways to calculate these values:

- First option: Toolbox menu

  1. While in the **Calculation** application, press the paste key to view the toolbox menu.
  2. Use the ▲ ▼ keys to scroll down the menu.
  3. Select **Complex numbers**.
  4. Confirm with the OK key.
  5. You may now select which value you would like to calculate.

- Second option: Manual entry

  You may manually enter the functions used to calculate these values. Enter these syntaxes to calculate your desired value:

  - Modulus : `abs(z)`
  - Argument : `arg(z)`
  - Real part : `re(z)`
  - Imaginary part : `im(z)`
  - Conjugate : `conj(z)`

- Third option: Additional results

  1. Enter a complex number in the editing field.
  2. Press the EXE key.
  3. Press the ▲ key to highlight the most recent result.
  4. Press the ▶ key to highlight the three dots.
  5. Press the OK key to open the additional results.
  6. Use the directional keys to navigate through all possible additional results.

1.3 Performing calculations with matrices

1.3.1 Entering a matrix

When entering a matrix in the Calculation application, a template will appear in the editing bar. Grey boxes indicate a space that can be filled with a number. Yellow boxes indicate a space that must be filled to complete the matrix. There are two ways to enter a matrix:

- First option: Toolbox menu

  1. While in the **Calculation** application, press the paste key to view the toolbox menu.
  2. Use the ▲▼ keys to scroll down the menu.
  3. Select **Matrices and vectors**.
  4. Confirm with the OK key.
  5. Select **New matrix**.
  6. Confirm with the OK key. The matrix template will appear in the editing bar.
  7. Enter your desired numbers.

- Second option: Manual entry

  1. Press the shift key.
  2. Press the e^x key. You can also press ln. The matrix template will appear in the editing bar.
  3. Enter your desired numbers.

1.3.2 Storing a matrix

You may store a matrix and access it in the variables menu. This allows you to use the matrix in later calculations. To store a matrix:

1. Create your matrix.
2. Use the ▷ key to navigate to the right of your matrix.
3. Press shift
4. Press sto→ F x,y. An arrow should appear in the editing bar.
5. Enter your desired letter or string. Press ALPHA alpha followed by the letter(s).
6. Confirm by pressing EXE

   To use a capital letter, press shift then ALPHA alpha. Your desired letter will now be entered as a capital letter.

1.3.3 Performing calculations with matrices

You can perform calculations using more than one matrix:

- Addition of two matrices: `M1+M2`
- Subtraction of two matrices: `M1-M2`
- Multiplication of two matrices (matrix product) : `M1*M2`

You can also perform calculations with a number and a matrix:

- Multiplication of a matrix by a scalar: `4*M1`
- Power of a matrix: `M1^5`
- Inverse of a matrix: `M1^(-1)`

1.3.4 Operations and important values of matrices

The inverse, determinant, transpose, trace and size can be found for a matrix. There are three ways to determine these values:

- First option: Toolbox menu

  1. While in the **Calculation** application, press the paste key to view the toolbox menu.

2. Use the ▲▽ keys to scroll down the menu.
3. Select **Matrices and vectors**.
4. Confirm with the OK key.
5. Select which option you would like to find. Additional options are found in the **Matrices** submenu.

- Second option: Manual entry

  You may manually enter the functions used to calculate these values. Enter these syntaxes to calculate your desired value:

  - Inverse : `inverse(M)`
  - Determinant : `det(M)`
  - Transpose : `transpose(M)`
  - Trace : `trace(M)`
  - Size : `dim(M)`
  - Row echelon form: `ref(M)`
  - Reduced row echelon form: `rref(M)`

- Third option: Additional results

1. Enter a matrix in the editing field.
2. Press the EXE key.
3. Press the ▲ key to highlight the most recent result.
4. Press the ▷ key to highlight the three dots.
5. Press the OK key to open the additional results.
6. Use the directional keys to navigate through all possible additional results.

1.4 Performing calculations with lists

1.4.1 Creating a list

There are three ways to create a list of values:

- First option: Toolbox menu

1. While in the **Calculation** application, press the paste key to view the toolbox menu.
2. Use the ▲▽ keys to scroll down the menu.
3. Select **Lists**.

4. Select the `New list` option.
5. Enter the values of your list using the number keys.
6. Use the key to enter a comma between each value.

You can also generate a list using a function:

1. Within the **Lists** section of the Toolbox, select the `{f(k)}` option.
2. Enter your function.
3. Enter your upper bound. For example `k 5` will create a list of 5 values using your function.

- Second option: Manual entry

  1. While in the **Calculation** application, press the shift key followed by the log key to start your list.
  2. Enter the values of your list using the number keys and a comma between each value.
  3. End your list by pressing the shift key followed by the) key.

- Third option: Data tables

  Lists are automatically created for the columns of the data tables in the **Statistics** (N1, V1, etc) and **Regression** (X1, Y1, etc) applications.

1.4.2 Storing a list

You may store a list in the variables menu. This allows you to use the list in later calculations or within other applications. To store a list:

1. Create your list.
2. Use the ▷ key to navigate to the right of your matrix.
3. Press shift
4. Press sto→ F x,y. An arrow should appear in the editing bar.
5. Enter your desired letter or string. Press ALPHA alpha followed by the letter(s).
6. Confirm by pressing EXE

   To use a capital letter, press shift then ALPHA alpha. Your desired letter will now be entered as a capital letter.

1.4.3 Call an entry

You can call an element using parentheses. In all lists, the index of the first element is 1. To call the fourth element of the list L, you can therefore type `L(4)`.

1.4.4 Performing calculations

You can perform calculations using one or more lists:
Assume `L` is a stored list.

- Add a value to each entry of a list: `L+2`
- Subtract a value to each entry of a list: `L-2`
- Multiply each entry of a list by a value: `L*2`
- Divide each entry of a list by a value: `L/2`

Assume `L` and `R` are stored lists with the same number of elements.

- Addition of the corresponding elements of two lists: `L+R`
- Subtraction of the corresponding elements of two lists: `L-R`
- Multiplication of the corresponding elements of two lists: `L*R`
- Division of the corresponding elements of two lists: `L/R`

1.4.5 Computing statistics

The following statistical values can be computed for a given list:

- Mean : `mean(L)`
- Standard deviation : `stddev(L)`
- Sample standard deviation: `samplestddev(L)`
- Median : `med(L)`
- Variance : `var(L)`

To compute a statistical value of a list:

1. Press the paste key to view the toolbox menu.
2. Select **Lists**.
3. Select **Statistics**.
4. Select the option for the statistical value you need.

1.4.6 Performing operations

The following operations can be performed on a given list:

- List length : `dim(L)`
- Minimum : `min(L)`
- Maximum: `max(L)`
- Ascending sorting : `sort(L)`
- Sum of elements : `sum(L)`
- Product of elements : `prod(L)`

To perform an operation on a list:

1. Press the paste key to view the toolbox menu.
2. Select **Lists**.
3. Select **Operations**.
4. Select the operation you need.

1.5 Performing calculations with units and constants

1.5.1 Entering a calculation with units and constants

You may use units and constants in your calculations. Once you perform your calculation, the result will be returned along with the most suitable unit. There are two ways to enter units and constants:

- First option: Toolbox menu
    1. While in the **Calculation** application, press the paste key to view the toolbox menu.
    2. Use the ▲ ▼ keys to scroll down the menu.
    3. Select **Units and constants**.
    4. Confirm with the OK key.
    5. Choose from multiple constants and types of measurement: length and angle, time and frequency, volume and area, mass, electricity, force and pressure, energy and power, temperature, other units and constants.

6. Once you have chosen your desired constant or unit of measurement, confirm with the OK key.
7. Your constant or unit of measurement will appear in the editing bar. Use the ◁ ▷ keys to enter the desired numbers before your units, if needed.

- Second option: Manual entry
  If you know your desired unit or constant's abbreviation, you may choose to enter your calculation manually. To do this:

  1. Press ALPHA alpha
  2. Enter your unit or constant abbreviation using the alpha keys.

  To lock your keyboard in alphabetical mode, press ALPHA alpha twice. This will allow you to enter letters without pressing ALPHA alpha each time. Press ALPHA alpha to unlock alpha mode.

1.5.2 Converting units

To convert units, use the arrow on the keyboard accessible via shift and then sto→ F x^y. For example, to convert 185 minutes to hours, type: `185min→h`.

You may also choose `a→b` in the toolbox menu.

1.6 Displaying additional results on a calculation

When you complete a calculation, the NumWorks calculator searches for relevant additional results.
It is possible to navigate in the calculation history to show additional information on the results of particular calculations. If three dots appears on the right side of a calculation when an item is highlighted in the calculation history, additional results are available. Highlight the three dots and press the OK key to display the additional results.

1.6.1 Additional results for integer solutions

When the result is an integer, the calculator gives the following additional results:

- scientific notation
- decimal form
- hexadecimal form
- binary form
- prime factorization

1.6.2 Additional results for solutions with fractions

When the result is a fraction, the calculator gives the following additional results:

- mixed fraction
- Euclidean division of the numerator by the denominator

1.6.3 Additional results for basic functions

When the result is the output of a basic function, the calculator gives the following additional results:

- a graphical representation of the curve of the basic function
- the point on the curve
- the curve equation

1.6.4 Additional results for calculations using trigonometric functions

When the result or the input involves a trigonometric funcion like `sin(x)` or `arccos(x)`, the calculator gives the following additional results:

- a representation of the unit circle on a polar grid
- the angle in both radians and degress
- the value of cosine, sine and tangent evaluated at the angle

1.6.5 Additional results for solutions with complex numbers

When the result is a complex number, the calculator gives the following additional results:

- a representation in the complex plane
- absolute value (modulus)
- argument
- real part
- imaginary part

1.6.6 Additional results for matrices

When the result is a matrix, and if possible, the calculator gives the following additional results:

- the determinant
- the inverse
- the row echelon form
- the reduced row echelon form
- the trace

1.6.7 Additional results for vectors

When the result is a vector, the calculator gives the following additional results:

- a graphical representation
- the magnitude
- the corresponding unit vector
- the angle with the positive x-axis

1.6.8 Additional results for calculations with units

When the result contains units, the calculator gives the following additional results:

- results written as an imperial decomposition (for example, a result of `38in` will return `1yd+2in` in the additional results window).
- results in base SI units (for example, a result of `38in` will return `0.9662m` in the additional results window).
- a comparison with up to two reference values, one larger and one smaller than your result.

Chapter 2

Grapher

To enter the **Grapher** application, highlight the app using the directional keys. Press the OK key to enter the application. This application allows you to view the graph of a function, curve, conic and inequality, view the coordinates of your points, determine key characteristics, and consult a table of values.

2.1 Getting started

2.1.1 Viewing the graph

To plot a graph or curve, you must first enter the expression. To enter your expression:

1. Highlight **Add an element** and confirm by pressing the OK key.
2. Choose the type of expression you wish to use or select the Empty template.
3. Input or adjust your expression.
4. Confirm by pressing the OK key.
5. Select the **Plot graph** button at the bottom of the screen or the **Graph** tab at the top of the screen.

The graph or curve will appear in the **Graph** tab.

> You can begin entering the expression of your function immediately upon entering the **Grapher** application.

2.1.2 Viewing the table of values

The table of values for an expression can be found in the **Table** tab. There are two ways to access it.

- First option: From the **Expressions** tab

  1. Highlight **Display values** at the bottom of the screen.
  2. Confirm by pressing the OK key.

  The table of values is displayed.

- Second option: From any tab

  1. Highlight the **Table** tab at the top of the screen.
  2. Confirm by pressing the OK key.

  The table of values is displayed.

2.2 Using the Expressions tab

2.2.1 Adding an element to the list of expressions

You can add several types of elements to the list of expressions: functions, inequalities, polar curves, conics and more. To add an element:

1. Highlight **Add an element** at the bottom of the expressions list.
2. Confirm by pressing the OK key and choose the type of expression you wish to use.
3. A new item appears in the list. You can directly enter its expression with the keyboard.

   You can also create a function in the **Calculation** application. See the **Variables** section.

2.2.2 Editing an expression

You can change an expression in the list by highlighting it and pressing the OK key. The expression can now be edited and you can use the ◁ and ▷ keys to move the cursor within the expression.

For function composition, use the name of an existing function in the function expression. An example of a possible expression: $cos(f(x))$.

2.2.3 Changing the plot restriction of a function or curve

It is possible to change the plotting domain of a function or curve to restrict its plotted domain. To do so:

1. Highlight the box containing the three dots to the right of the function/curve in the list of expressions.
2. Confirm by pressing the OK key. A menu of options will appear for your expression.
3. Highlight **Plot restriction**.
4. Press the OK key.
5. Edit the values. For example, enter `-10` for **Xmin** and `10` for **Xmax**
6. Highlight **Confirm**.
7. Confirm with the OK key.

Once you have selected the values for your desired plot restriction, the curve or graph in the **Graph** tab will only be visible within the bounds you have set.

2.2.4 Plotting points

To plot a point, use the **Point** template or add an expression in the form `(2,3)`.
To plot a list of points, use the **List of points** template or add an expression in the form `{(2,3),(3,5)}`

> It is also possible to plot a list of points using a saved list or dataset from the **Regression** application. For example, $(X1, Y1)$ will plot the points using the `X1` and `Y1` lists in the Regression application.

2.2.5 Plotting inverse functions

To add an inverse function, add an expression that is a function of y. For example, $x = sin(y)$

> It is also possible to graph the inverse of a function that is already defined. For example, if $f(x)$ is defined, you can graph its inverse by adding the expression $x = f(y)$.

2.2.6 Plotting piecewise functions

To add a piecewise function, use the **Piecewise function** template and enter the desired expressions and domains.

> Logic statements can be used in the domain field of a piecewise function and are available in the **Logic** section of the **Toolbox**.

2.2.7 Plotting polar and parametric curves

It is possible to work with polar and parametric curves in the **Grapher** application without changing the mode of the calculator.
The expression of a polar function requires use of the θ symbol as a variable. This symbol can be entered by pressing the (cut / x,n,t) key.
The expression of a parametric function needs to be typed as a column vector of size 2. The first component is the expression of `x(t)` while the second component is the expression of `y(t)`.

> Templates for polar and parametric curves are available once **Add an element** has been selected.

2.2.8 Plotting inequalities

To add an inequality, use the **Inequality** template and enter the desired expression. You can also create an inequality using the following symbols.

- Less than, <: (shift) followed by (< / √ K)
- Greater than, >: (shift) followed by (> / x² L)
- Less than or equal to, ≤: Open the (paste") and select ≤
- Greater than or equal to, ≥: Open the (paste") and select ≥

> The "less than or equal to" symbol can also be entered by first inputting the < symbol followed by the = symbol.

2.2.9 Enabling or disabling an element in the list

You can disable an element without deleting it from the expression list. When you disable an element, it will appear in gray in the expression list. You can edit the expression, but its graph and table of values will not appear in the **Graph** and **Table** tabs. To disable an element:

1. Highlight the box with the three dots to the right of the expression from the expression list.
2. Confirm by pressing the OK key. A menu of options will appear for the expression.
3. Highlight **Show in Graph and Table**.
4. Press the OK key. This will disable the element. To reactivate the element, repeat these steps.

2.2.10 Removing an element from the list

You can delete an element from the expression list. To delete the element:

1. Highlight the element you wish to delete.
2. Press the clear key.

   You can also delete an element within the menu opened with the three dots to the right of the expression.

2.2.11 Renaming a function

You can change the name of a function on the expression list. To rename a function:

1. Highlight the function you wish to rename.
2. Press the OK key to open the editing bar
3. Use the navigation keys to move the cursor to the function name.
4. Press clear to delete the function name.
5. Enter the new name of the function.

2.2.12 Changing the color of a graph

When you add a new element, a color is automatically assigned and will be used when plotting the expression. To change the color:

1. Select the box with the three points to the right of the expression you wish to change.
2. Confirm by pressing the OK key to open the options menu.
3. Choose **Color** and select the color of your choice.

2.2.13 Obtain additional information about a conic or a line

For conic sections and linear expressions, it is possible to view additional details calculated from the expression (eccentricity, semi-major axis, slope, etc.)

1. Select the box with the three points to the right of the conic or linear expression.
2. Confirm by pressing the OK key to open the options menu.
3. Choose **Details** to access additional information about the conic or line.

2.3 Using the Graph tab

2.3.1 Displaying interest points

When you first view the graph of an expression, the selected curve automatically shows **points of interest** in black. Interesting points include maximums, minimums, intercepts and intersections.

2.3.2 Adjusting the display window

You can adjust the display window in the **Graph** tab to fit your needs. This includes: editing your X and Y values, zooming in and out, and more. There are three menus that allow you to adjust your graphing window: **Auto**, **Axes** and **Navigate**. To adjust your graphing window:

1. Highlight your desired menu. The menus are located underneath the tabs near the top of the screen.
2. Confirm by pressing the OK key.

Auto

The NumWorks graphing calculator will adapt to display the best possible view of your curve. Once you enter your function, the resulting axes will be chosen automatically. When **Auto** is active, a yellow circle will appear to the right of its name. Once you exit this window, either with the directional keys or by changing the settings, Auto will be disabled and the yellow circle will disappear.

> You can also highlight **Auto** and press the OK key to disabled the **Auto** mode.

Axes

The **Axes** menu allows you to make manual changes to the axes of your graphing window. To make changes to the X or Y values:

1. Highlight **Axes**.
2. Press the (OK) key to enter the menu.
3. Highlight **Values of X** or **Values of Y**
4. Confirm with the (OK) key.
5. Enter your desired **Minimum** and **Maximum** values. To allow the calculator to choose automatically, select **Auto** at the top of the screen.
6. Highlight **Confirm** at the bottom of the screen.
7. Confirm with the (OK) key.

You can make your axes equal inside the **Axes** menu. To do this, highlight **Make axes equal** and confirm with the (OK) key. Selecting this option will lengthen the shortest axis to match the longest. When your axes are not equal, a symbol will appear beside the **Axes** menu.

Navigate

Select **Navigate** to work with the interactive display window:

- (◁) / (△) / (▷) / (▽): move the window
- (+) / (−): zoom in/zoom out

  You can press (+) and (−) at anytime while in the **Graph** tab to zoom in/out.

2.3.3 Moving the cursor in the graph window

You can move the cursor using the four directional arrows:

- (◁) / (▷): Move the cursor on a curve to the right or left.
- (△) / (▽): Move the cursor to a curve above or below the curve you are on.

  When tracing a curve, the cursor automatically snaps to interest points and the legend indicates what kind of point it is.

2.3.4 Moving the cursor to a point on the graph

You can view the coordinates of any point on the graph. This information will appear in the legend at the bottom of the screen.
To select a specific point given an x-value:

1. Highlight the **Calculate** menu.
2. Press the (ok) key to open the options menu. You can also open this menu with the (paste") or (ok) keys while your cursor is on the curve of interest.
3. Highlight **x**.
4. Confirm with the (ok) key.
5. Enter the value of X for the point you wish to discover.
6. Confirm with the (ok) key. The cursor is now on the point you requested.

   You can also enter the value of X directly in the graphing window. To enter a negative value, first enter the number and then add the negative symbol before it.

To select a specific point given an y-value:

1. Highlight the **Calculate** menu.
2. Press the (ok) key to open the options menu. You can also open this menu with the (paste") or (ok) keys while your cursor is on the curve of interest.
3. Highlight **y** or **f(x)**.
4. Confirm with the (ok) key.
5. Enter the value of Y for the point you wish to discover.
6. Confirm with the (ok) key. The cursor is now on the point you requested.

   You can also **Find X given Y** in the **Find** menu.

2.3.5 Displaying the value of a derivative of a function at a point

You can view the value of a derivative of a function at a point on your curve.

1. Highlight the **Calculate** menu.
2. Press the (ok) key to open the options menu. You can also open this menu with the (paste") or (ok) keys while your cursor is on the curve of interest.

3. Select **Options**.
4. Highlight **Value of the derivative**.
5. Confirm with the OK key. This will toggle the **Value of the derivative** mode on.
6. Press the ⮌ key to return to the graphing window. The value of the derivative will be located in the legend near the bottom of the screen.

   If you would like to no longer display the value of the derivative of a function at a point, repeat these steps.

2.3.6 Using the Find menu

The **Find** menu allows you to find x given y, identify intersection points, minima and maxima and zeros, draw tangents with their equation and calculate integrals and area between curves. To locate the **Find** menu:

1. Highlight the **Calculate** menu.
2. Press the OK key to open the options menu. You can also open this menu with the paste" or OK keys while your cursor is on the curve of interest.
3. Highlight **Find**.
4. Press the OK key.

You can now choose which value you would like to discover. Use the ▵ ▿ keys to scroll through the menu and the OK key to select.

Find X given Y

To determine the X value for a given Y value, use the **Find X given Y** feature. Enter the desired Y value and **Confirm**.
The cursor is now at the point with the Y value you requested. If multiple points exist for your Y value, you can navigate between them with the ▹ ◃ keys.

> For the inverse image to be found the point must be located in the current graphing window.

Intersection

You can find the intersection of two functions. The **Intersection** option will appear only if you are working with two or more functions. Highlight **Intersection** and press the OK key.
The cursor is now at the point where your curves intersect. If multiple intersection points exist, you can navigate between them with the ▹ ◃ keys.

Maximum / Minimum

You can find the maximum and minimum of your function. Highlight either **Maximum** or **Minimum** and press the (OK) key.
The cursor is now at the maximum/minimum point. If multiple minimum/maximum points exist, you can navigate between them with the ▷ ◁ keys.

Zeros

You can find the point(s) where the value of your function is zero. Highlight **Zeros** and press the (OK) key.
The cursor is now at a point where the value of the selected function is zero. If multiple zeros exist, you can navigate between them with the ▷ ◁ keys.

Tangent

You can observe the line tangent to the curve at a point. Highlight **Tangent** and press the (OK) key. The line tangent to your selected point will appear. Use the directional arrows to change the point or manually enter the X value of the point using the keyboard. The equation of the tangent line is given in the legend at the bottom of the screen.

Integral

You can evaluate an integral. To obtain the value of an integral:

1. Highlight **Integral**.
2. Press the (OK) key.
3. You will be returned to the graphing window. In the legend, you will be prompted to **Select lower bound**. Use the ◁ ▷ keys to position the cursor on the lower bound. You can also enter the value of the lower bound with the keyboard.
4. Press the (OK) key to confirm your selection.
5. You will now be prompted **Select upper bound**. Use the ◁ ▷ keys to position the cursor on the upper bound. You can also enter the value of the upper bound with the keyboard. Use the (⮌) key to return to the previous step if you would like to change your lower bound.
6. Press the (OK) key to confirm your selection.
7. The value of the integral you wish to evaluate is shown in the legend at the bottom of the screen. Press the (⮌) key to calculate a new integral.

   Press the (OK) key if you wish to exit the **Integral** mode.

Area between curves

If more than one function is plotted, you can find the area between curves. To compute the area between curves:

1. Highlight **Area between curves**.
2. Press the OK key.
3. You will be returned to the graphing window. In the legend, you will be prompted to **Select lower bound**. Use the ◁ ▷ keys to position the cursor on the lower bound. You can also enter the value of the lower bound with the keyboard.
4. Press the OK key to confirm your selection.
5. You will now be prompted **Select upper bound**. Use the ◁ ▷ keys to position the cursor on the upper bound. You can also enter the value of the upper bound with the keyboard. Use the ⮌ key to return to the previous step if you would like to change your lower bound.
6. Press the OK key to confirm your selection.
7. The value of the area between the two curves is shown in the legend at the bottom of the screen. Press the ⮌ key to calculate a new integral.

2.4 Using the Table tab

2.4.1 Reading the table of values

When you enter the **Table** tab, x values will automatically range from 0-10. There will be a column for the values of f(x) at a given x value. There will be a column for each function you enter.

2.4.2 Setting the interval in the table of values

You can fill the table of values with values of x in any interval of your choice. To do this:

1. Highlight **Set the interval** in the **Table** tab.
2. Confirm by pressing the OK key.
3. Enter the desired values of **X start** and **X end**.
4. Choose the step value between each x value. For example, the table will have an initial step value of one.
5. Highlight **Confirm**.

6. Press the OK key to finalize your interval. The table will now display the interval you have chosen.

   You can also highlight the **x** cell and press the OK key to enter the **Set the interval** menu.

2.4.3 Entering values of x into the table

You can manually enter values into the **x** column and receive the corresponding values in the **f(x)** column. Highlight the cell you wish to change and enter your desired value with the numeric keys. Confirm by pressing the OK key.

2.4.4 Deleting table values

You can delete single rows as well as the entire first column. To delete a row, highlight the row you wish to delete and press the clear key.
To delete the column of x values:

1. Highlight the **x** cell at the top of the first column.
2. Press the OK key. An options menu will appear.
3. Highlight **Clear column**.
4. Press the OK key.
5. An empty value table appears on the screen. You can now enter values in the **x** column manually or with the **Set the interval** option.

2.4.5 Displaying exact values for the output

You can display the exact values of the output of each expression instead of decimal approximations. To view exact values:

1. Highlight **Exact results** in the **Table** tab.
2. Confirm by pressing the OK key. The table will now display exact values.

2.4.6 Displaying the derivative function values

You can display a column of derivative function values in the table. To view this column:

1. Highlight the cell that contains the name of your desired function.
2. Press the OK key. An options menu will appear.

3. Highlight **Derivative column**.
4. Press the (OK) key to toggle on the derivative column.
5. Press the (⮌) key to return to the table. The derivative function column will appear to the right of the function you selected.

   If you would no longer like to view the derivative function column, highlight the first cell of the column and press the (OK) key. Highlight **Hide derivative function** and press the (OK) key. The derivative function column is no longer displayed.

Chapter 3

Equations

To enter the **Equations** application, highlight the app using the directional keys. Press the (ok) key to enter the application. This application allows you to solve equations and systems of equations with both exact and numerical solutions.

3.1 Getting started

3.1.1 Solve an equation

Enter an equation

You can begin entering your equation as soon as you enter the **Equations** application. You can also choose to utilize one of the equation templates.
To enter an equation without utilizing a template:

1. Begin entering your equation as soon as you enter the **Equations** section.
2. You can utilize any lower case letter as a variable. To use x as your unknown value, press the (cut x,n,t) key.
3. To input the equal sign, press (shift) followed by the (π) key. If you confirm without an equal sign in your equation, $= 0$ will be added automatically.
4. Press the (ok) key to confirm.

To use an equation template:

1. Highlight **Add equation**.
2. Press the (ok) key. The list of equation templates will appear.
3. Highlight your desired template.

4. Confirm with the ok key. Your equation template will now be located in the editing field.
5. Use the directional keys and numerical keys to adjust the desired equation as needed.
6. Confirm with the ok key.

Solutions

To obtain the solution(s) of your equation:

1. Enter the equation(s) you wish to solve.
2. Highlight **Solve the equation** at the bottom of the screen.
3. Press the ok key to receive the solution(s).

The solution is given in exact and approximate form. For quadratic and cubic equations, the discriminant (Δ) is also given.

General case

Most often, solutions are computed numerically and their value is often approximated.
When you press the **Solve the equation** button, the application may require you to set an interval in which to search for the solution.
Set the values of **Xmin** and **Xmax** and highlight **Solve the equation**. Confirm with the ok key.
If there are many solutions, the calculator will only display the first ten.

3.1.2 Solving a system of equations

Entering a system of equations

You can enter more than one equation to be solved as a system. To enter a system of equations:

1. Enter the first equation in your system manually or using a template.
2. Highlight **Add equation**.
3. Enter the second equation in your system manually or using a template.
4. Continue as needed to complete your system.

   You can add up to 6 equations.

Solutions

The application solves linear systems with real or complex coefficients.
To obtain the solutions, highlight **Solve the system** at the bottom of the screen and press the (OK) key.
The application gives the solutions in exact and decimal form. It also indicates if there are infinitely many solutions or if there is no solution.

> When a linear system has infinitely many solutions, the calculator provides the **parametrized form** of the solutions.

Chapter 4

Statistics

To enter the **Statistics** application, highlight the app using the directional keys. Press the OK key to enter the application. This application allows you to study single variable data sets and view statistical values relevant to your set: mean, standard deviation, minimum or maximum and more. You may also view graphical representations of your data with boxplots, histograms, cumulative relative frequncy graphs and normal probablity plots.

4.1 Getting started

4.1.1 Entering data into the table

You must first enter your data into the table. You may add up to 3 data tables.

- In the first column (**Value V1**), enter the values of your data set.
- In the second column (**Frequency N1**), enter the frequencies associated with each value in your data set, i.e. the number of occurrences of each value.

When you begin entering data in the **Value VI** column, the **Frequency N1** column is automatically filled with the value 1, indicating the value appears only once in the set. If the value appears more than once in your data set, you can enter the same value multiple times or change the frequency in the second column.
For example, consider the following data set: 1, 1, 1, 2, 3, 3, 4, 5, 5.
To enter this statistical data in the table:

Value V1	Frequency N1
1	3
2	1
3	2
4	1

5	2

4.1.2 Viewing graphical representations of your data

After entering your data in the **Data** tab, you may view a graphical representation of your data. To view a graph:

1. Use the directional keys to highlight the **Graph** tab at the top of the screen.
2. Confirm by pressing the OK key.
3. Select the graph type of interest.

You can view your data using the following graphical representations:

- Histogram
- Boxplot
- Cumulative Relative Frequency Graph
- Normal Probability Plot

4.1.3 Displaying statistics

After entering your data in the **Data** tab, you can display the statistics: mean, standard deviation, median, etc. To view the statistics:

1. Select the **Stats** tab at the top of the screen.
2. Confirm by pressing OK.

You can now view all statistics available for your data set.

4.2 Using the Data tab

4.2.1 Deleting a row from a data table

To delete a row from a data table:

1. Highlight a single cell in the row that you wish to delete.
2. Press the clear key. The row has been deleted.

   To change a value, highlight the desired cell and enter a new value with the numerical keys.

4.2.2 Clearing a column from a data table

You may clear an entire column from any data table. Clearing the **Value V1** column also clears the **Frequency N1** column. Clearing the **Frequency N1** column will fill each cell in the column with the value 1. To clear an entire column from a data table:

1. Highlight the name of the column you want to clear. For example, highlight **Value V1** to clear the first column of the first data table.
2. Confirm by pressing the OK key. The column options menu will open.
3. Highlight **Clear table V1/N1**.
4. Confirm with the OK key. The column has been cleared.

   You can also clear a column by pressing the clear key when a column name is highlighted.

4.2.3 Generating a list with a formula

You may fill a column of a data table using a formula. To fill a column with a formula:

1. Highlight the name of the column you wish to fill. For example, highlight **Value V2**.
2. Confirm by pressing the OK key.
3. The column options menu opens. Highlight **Fill with a formula**.
4. Confirm with the OK key.
5. Select a list function from the templates or use the **Empty** template to create your own.
6. You can also enter a formula using the name of another column. For example, if you would like column **Value V2** to be filled with the values of **V1** divided by 2, use the Empty template and write `V1/2` in the editing field at the bottom of the screen.
7. Confirm with the OK key.

   You can re-evaluate or edit the formula by returning to the **Fill with formula** option.

4.2.4 Sorting a list by increasing values

You may sort a list in a data table by increasing values. This classification affects the column associated with the list (**Value** or **Frequency**).

1. Highlight the name of the column you would like to sort.
2. Confirm with the OK key.
3. The column options menu opens. Highlight **Sort**.
4. Confirm with the OK key. The items of your list have been sorted.

4.2.5 Displaying cumulative frequencies

You may view a column of cumulative frequencies for your data set. To view cumulative frequencies:

1. Highlight the name of the column for which you would like to see the cumulative frequencies.
2. Confirm with the OK key.
3. The column options menu opens. Highlight **Cumulative frequencies**.
4. Press the OK key to toggle on the option.
5. Press the ⮌ key to return to the Data tab and view the column of cumulative frequencies.

4.2.6 Hiding a data set

You may hide a data set so that it does not appear in the graphs or summary statistics. To hide a data set:

1. Highlight the name of the column you would like to hide.
2. Confirm with the OK key.
3. The column options menu opens. Highlight **Show in Graphs and Stats**.
4. Press the OK key to toggle off the option.
5. Press the key to return to the Data tab.

When a data set is hidden, the table and its values will be gray.
To show a hidden data set, repeat the steps above to toggle back on the option.

4.3 Using the Graph tab

4.3.1 Selecting a graphical representation

You can view your data with a boxplot, histogram, cumulative relative frequncy graph or normal probability plot. To select a graphical representation:

1. Use the directional keys to highlight the **Graph** tab at the top of the screen.
2. Confirm by pressing the OK key.
3. Select the graph type of interest.

Once a graph is selected, you can return to the graph selection menu by selecting the `Type` menu.

4.3.2 Viewing data with histogram

Navigating a histogram

When viewing data with a **histogram**, you will see the interval, frequency and relative frequency in the banner at the bottom of the screen for each bin.
To navigate between the bins in the histogram, use the ◁ ▷ keys.
To navigate between data sets, use the △ ▽ keys.

Setting the histogram parameters

You may change the width and starting value of the histogram bins. To do this:

1. Highlight the Settings menu and press the OK key.
2. The histogram settings menu opens. Enter the values for the **Bin width** and **X start**.
3. Highlight **Confirm** and press the OK key.

4.3.3 Viewing data with a boxplot

Navigating a boxplot

When viewing data with a **boxplot**, the banner at the bottom of the screen will display a value of the 5-number summary. These values include:

- Minimum
- First quartile

- Median
- Third quartile
- Maximum

To navigate between statistics, use the ◁ ▷ keys.
To navigate between data sets, use the △ ▽ keys.

Displaying outliers

By default, outliers will automatically be displayed as individual points on the boxplot. To disable outliers:

1. Highlight the Settings menu and press the OK key.
2. The boxplot settings menu opens. Highlight **Display outliers**.
3. Press the OK key to toggle off the option.
4. Press the ⮌ key to return to the boxplot.

4.3.4 Viewing data with a cumulative relative frequency graph

Navigating a cumulative relative frequency graph

When viewing data with a **cummulative relative frequency graph**, the banner at the bottom of the screen will display a value and its cumulative relative frequency.
To navigate through values, use the ◁ ▷ keys.
To navigate between data sets, use the △ ▽ keys.

> When viewing the cumulative frequency plot, use the numerical keys to input a value and jump to the point on the graph.

4.3.5 Viewing data with a normal probability plot

Navigating a normal probability plot

When viewing data with a **normal probability plot**, the banner at the bottom of the screen will display a value and its expected z-score.
To navigate through values, use the ◁ ▷ keys.
To navigate between data sets, use the △ ▽ keys.

4.4 Using the Stats tab

The **Stats** tab displays the statistics calculated using the data entered in the **Data** tab. The full name of the descriptive statistic is listed along with a symbol:

- Number of data points: **n**
- Minimum: **Min**
- First quartile: **Q1**
- Median: **Med**
- Third quartile: **Q3**
- Maximum: **Max**
- Range: **R**
- Interquartile range: **IQR**
- Mean: **μ**
- Standard deviation: **σ**
- Variance: **σ2**
- Sample mean: **x̄**
- Sample standard deviation: **s**
- Sample variance: **s2**
- Sum of values: **Σx**
- Mode: **Mod**
- Mode frequency: **Modf**

Chapter 5

Regression

To enter the **Regression** application, highlight the app using the directional keys. Press the OK key to enter the application. This application allows you to perform statistical computations on two-dimensional data sets.

5.1 Getting started

5.1.1 Entering your data into the table

When you enter the **Regression** app, you must enter your data into a two-column table. You may add up to 3 data tables.

- In the first column (X1), enter the values of the first variable of your data set.
- In the second column (Y1), enter the values of the second variable of your data set.

5.1.2 Viewing a scatterplot

Once you have entered your data into the table, you may view a scatterplot of your data. To do this:

1. Highlight the **Graph** tab at the top of the screen.
2. Confirm with the OK key.

You will see the points that represent your data. The coordinates of the selected point will be displayed in the bottom banner along with the correlation coefficent, r.

5.1.3 Plotting a regression model

Once you have created a scatterplot, you may plot a regression model. To do this:

1. While on the **Graph** tab, press the OK key to view a list of regression model options.
2. Highlight the model you would like to use.
3. Confirm with the OK key.

You can now use the ▽/△ keys to move from a data point to the regression model. When the model is select, the bottom banner will include the predicted value and the equation.

5.1.4 Displaying statistical values

Once you have entered your data into the table in the **Data** tab, you may view the statistical values: mean, standard deviation, median, etc.

1. Highlight the **Stats** tab at the top of the screen.
2. Confirm with the OK key. You will see the table of statistical values.

5.2 Using the Data tab

5.2.1 Clearing an element from a data table

To clear an element from a data table:

1. Highlight the cell that you wish to clear.
2. Press the clear key. The cell has been cleared.

   To change a value, highlight the desired cell and enter a new value with the numerical keys.

5.2.2 Clearing a column from a data table

You may clear an entire column from any data table. To clear an entire column from a data table:

1. Highlight the name of the column you want to clear. For example, highlight **X1** to clear the first column of the first data table.
2. Confirm by pressing the OK key. The column options menu will open.

3. Highlight **Clear column**.
4. Confirm with the OK key. The column has been cleared.

   You can also clear a column by pressing the clear key when a column name is highlighted.

5.2.3 Generating a list with a formula

You may fill a column of a data table using a formula. To fill a column with a formula:

1. Highlight the name of the column you wish to fill. For example, highlight `Y1`.
2. Confirm by pressing the OK key.
3. The column options menu opens. Highlight **Fill with formula**.
4. Confirm with the OK key.
5. Select a list function from the templates or use the **Empty** template to create your own.
6. You can also enter a formula using the name of another column. For example, if you would like column `Y1` to be filled with the values of `X1` divided by 2, write `X1/2` in the editing field at the bottom of the screen.
7. Confirm with the OK key.

   You can re-evaluate or edit the formula by returning to the **Fill with formula** option.

5.2.4 Sorting a list by increasing values

You may sort a list in a data table by increasing values.

1. Highlight the name of the column you would like to sort.
2. Confirm with the OK key.
3. The column options menu opens. Highlight **Sort by increasing values**.
4. Confirm with the OK key. The items of your list have been sorted.

5.2.5 Changing the regression model in the Data tab

You may change the regression model you'll use directly in the Data tab.
To change the regression model you are using:

1. Highlight the name of a column.
2. Confirm with the OK key. The options menu will open.
3. Highlight **Model**.
4. Confirm with the OK key.
5. Highlight your desired model.
6. Confirm with the OK key.

5.3 Using the Graph tab

5.3.1 Adjusting the display window

You may adjust the display window in the **Graph** tab to fit your needs. This includes: editing your X and Y values, zooming in and out, and more. There are three menus that allow you to adjust your graphing window: **Auto**, **Axes** and **Navigate**. To adjust your graphing window:

1. Highlight your desired menu. The menus are located underneath the tabs near the top of the screen.
2. Confirm by pressing the OK key.

   You may press + and − to zoom in/out while in the **Graph** tab.

Auto

The NumWorks graphing calculator will adapt to display the best possible view of your regression. Once you enter your data, the resulting axes will be chosen automatically. When **Auto** is active, a yellow circle will appear to the right of its name. Once you exit this window, either with the directional keys or by changing the settings, Auto will be disabled and the yellow circle will disappear.

You may also highlight **Auto** and press the OK key to disabled the **Auto** mode.

Axes

The **Axes** menu allows you to make manual changes to the axes of your graphing window. To make changes to the X or Y values:

1. Highlight **Axes**.
2. Press the (OK) key to enter the menu.
3. Highlight **Values of X** or **Values of Y**
4. Confirm with the (OK) key.
5. Enter your desired **Minimum** and **Maximum** values. To allow the calculator to choose automatically, select **Auto** at the top of the screen.
6. Highlight **Confirm** at the bottom of the screen.
7. Confirm with the (OK) key.

You may make your axes equal inside the **Axes** menu. To do this, highlight **Make axes equal** and confirm with the (OK) key. Selecting this option will lengthen the shortest axis to match the longest. When your axes are not equal, a symbol will appear beside the **Axes** menu.

Navigate

Select **Navigate** to work with the interactive display window:

- ◁ / △ / ▷ / ▽: move the window
- (+) / (−): zoom in/zoom out

5.3.2 Navigating through the data points of a scatterplot

You can move the cursor using the four directional arrows:

- ◁/▷ : move the cursor from point to point.
- △/▽ : move the cursor from the data points of one set to another data set.

5.3.3 Regression

Plotting a regression model

Once you have created a scatterplot, you may plot a regression model. To do this:

1. Open the **Regression** menu.
2. Highlight the regression model you would like to use.
3. Confirm with the OK key.

You can now use the ▲/▼ keys to move from a data point to the regression model. When the model is select, the bottom banner will include the predicted value and the equation.

> Once a model regression model is selected, the equation of the model can be accessed in other applications from within the **var** menu.

Viewing regression information

Once a regression model has been plotted, you can view additional information about the model in the **Regression** menu including:

- the regression equation
- the correlation coefficent (for linear models only)
- the coefficient of determination, r^2

Viewing a residual plot

The **Regression** menu also gives you access to a residual plot. To view the residual plot:

1. Open the **Regression** menu.
2. Navigate down to **Residual plot**.
3. Confirm with the OK key.

You can now use the ◀/▶ keys to move the cursor to view data points and their corresponding residual value.

Making predictions

You may look for a specific point on the regression model for a given x or predicted y value. In other words, you may predict a value of Y given X and a determine the value of X needed for a given predicted Y.

1. Open the **Regression** menu.

2. Navigate down to **Predict Y given X** if you know the value of X or **Find X given predictd Y** if you want to know the value of X given a predicted Y.
3. Confirm with the (ok) key.
4. Enter your value.
5. Highlight **Confirm**.
6. Press the (ok) key.

The cursor will move to the desired point. You may view the coordinates of this point at the bottom of the screen.

Changing the regression model

You may change the regression model you use. The available models are:

- Linear `ax + b`
- Linear `a + bx`
- Proportional
- Quadratic
- Cubic
- Quartic
- Logarithmic
- Exponential `a*b^x`
- Exponential `a*e^(bx)`
- Power
- Trigonometric
- Logistic
- Median-Median

To change the regression model you are using:

1. Open the **Regression** menu.
2. While highlighting **Model**, confirm with the (ok) key.
3. Highlight your desired model.
4. Confirm with the (ok) key. You have now changed the regression model.

Removing a regression

You may remove a regression model from the scatterplot. To remove the regression model:

1. Open the **Regression** menu.
2. Navigate to **Remove regression**.
3. Confirm with the (OK) key.

5.4 Using the Stats tab

The **Stats** tab displays statistical variables calculated using the data in the **Data** tab. The following datas are calculated:

- Mean of x_i and y_i
- Sum of x_i and y_i
- Sum of the squares of x_i and y_i
- Standard deviation of x_i and y_i
- Variance of x_i and y_i
- Sample standard deviation of x_i and y_i
- Number of data points
- Covariance
- Sum of $x_i \times y_i$

If a model has been plotted, the **Stats** tab will also display:

- Correlation coefficient r (for linear models)
- Regression equation
- Regression equation parameters
- Residual standard deviation
- Coefficient of determination r^2

Chapter 6

Sequences

To enter the **Sequences** application, highlight the app using the directional keys. Press the OK key to enter the application. This application allows you to plot both recursive and explicit sequences, view a table of their values and compute the sum of their terms.

6.1 Getting started

6.1.1 Plotting sequences

To plot a sequence:

1. Highlight **Add sequence**.
2. Confirm with the OK key.
3. Highlight which type of expression you would like to enter: explicit expression of the sequence (based on n), recursive first order (expression based on the previous term) or recursive second order (expression based on the two previous terms).
4. Confirm with the OK key. The editing field will appear at the bottom of the screen.
5. Enter the expression of the sequence you wish to plot. To use the variable n within the expression of the sequence, press the x,n,t key. To use a recursive formula, use the **Toolbox** menu shortcuts by pressing the key. In this case, you must indicate the value of the first term of the sequence.
6. Confirm with the OK key.
7. Highlight the **Plot Graph** button at the bottom of the screen or the **Graph** tab at the top of the screen.
8. Confirm with the OK key.

You are now in the **Graph** tab and your sequence has been plotted. You can move the cursor using the directional arrows and read the coordinates of the points at the bottom of the screen.

> To view the options menu of the sequence on which the cursor is located, press the (ok) key. You can also highlight **Calculate** and press the (ok) key.

6.1.2 Displaying the table of values

The table of values for the sequence can be found in the **Table** tab. There are two ways to access it.

- First option: from the **Sequences** tab
  1. Highlight **Display values** at the bottom of the screen.
  2. Confirm with the (ok) key. The table is displayed.
- Second option: from any tab
  1. Highlight the **Table** tab at the top of the screen.
  2. Confirm with the (ok) key. The table is displayed.

6.2 Using the Sequences tab

6.2.1 Adding a sequence to the list

You can add up to 3 sequences to the list. To add a sequence to the list:

1. Highlight **Add sequence** at the bottom of the list.
2. Confirm with the (ok) key.

Then choose the type of sequence you wish to plot and enter its expression.

6.2.2 Editing the expression of a sequence

You can edit the expression of a sequence on the list by highlighting it and pressing the (ok) key.
The sequence editing field is then displayed at the bottom of the screen.

6.2.3 Activating or deactivating a sequence on the list

You can deactivate a sequence without completely deleting it from the sequences list. To do this:

1. Highlight the name of the sequence in the list.
2. Press the OK key to open the options menu for the sequence.
3. Highlight **Show in Graph and Table** and press the OK key to toggle the status of the sequence.
4. Return to the sequence list by pressing ⮌. Repeat the steps to re-activate the sequence.

   Inactive sequences will appear on the list in gray. You can edit their expressions, but these sequences will not be shown in the **Graph** and **Table** tabs.

6.2.4 Deleting the expression of a sequence

You can delete the expression of a sequence and enter a new one. To do this:

1. Highlight the expression of the sequence you want to delete.
2. Press the clear key. The expression has been deleted.

6.2.5 Removing a sequence from the list

You can permanently remove a sequence from the list. To delete a sequence:

1. Highlight the name of the sequence you wish to remove from the sequence list.
2. Press the OK key to open the options menu for the sequence.
3. Highlight **Delete sequence**.
4. Confirm with the OK key. The sequence will disappear from the list.

   You can also delete a sequence from the list by highlighting the name of a sequence and pressing the clear key.

6.2.6 Changing the type of sequence

There are three types of expressions to use for your sequences. The types of expression available for use:

- Explicit expression of the sequence: based on n.
- Recursive first order: expression based on the previous term.
- Recursive second order: expression based on the two previous terms.

To change the type of sequence used:

1. Highlight the name of the sequence you wish to change.
2. Press the ok key to open the options menu for the sequence.
3. Highlight **Sequence type**.
4. Confirm with the ok key.
5. Highlight the type of expression you would like.
6. Confirm with the ok key. The type of the sequence has been changed. If you chose to define the sequence with a recursive expression, you must provide the first term.

   When you change the type of a sequence, the expression previously entered for that sequence is deleted.

6.2.7 Entering the expression of a recursive sequence

You can enter the expression of a recursive sequence. For example, enter: $u_{n+2} = u_{n+1} + u_n$. You can use the two previous terms in the expression (u_{n+1} and u_n).
To enter the expression of a recursive sequence:

1. Press the paste key while editing your expression.
2. Highlight the term you need to complete the expression.
3. Confirm with the ok key.

You can also manually enter the term you would like: type `u(n+1)` for u_{n+1} and `u(n)` for u_n.

When entering a recursive sequence, you must define the first terms of the sequence. Enter the required terms in the list below the expression of the recursive sequence.

6.2.8 Changing the first term index

You can change the first term index of your sequence. To do this:

1. Highlight the name of the sequence to edit.
2. Press the OK key to open the options menu for the sequence.
3. Highlight **First term index**.
4. Enter the desired value.
5. Confirm with the OK key.
6. Press the ⮌ key to return to the **Sequences** tab. Your first term index has been changed.

6.2.9 Changing the color of a sequence

When you add a new sequence, a color is automatically assigned and will be used when plotting the sequence. To change the color:

1. Highlight the name of the sequence whose color you wish to change.
2. Confirm by pressing the OK key to open the Sequence options menu.
3. Choose **Color** and select the color of your choice.

6.3 Using the Graph tab

6.3.1 Moving the cursor in the graph window

You can move the cursor using the four directional arrows:

- ◁ / ▷: Move the cursor to the right or left.
- △ / ▽: Move the cursor to a sequence above or below the sequence you are on.

  The cursor indicates which sequence is selected. Be sure to have the correct sequence selected before performing calculations.

6.3.2 Adjusting the display window

You can adjust the display window in the **Graph** tab to fit your needs. This includes: editing your X and Y values, zooming in and out, and more. There are three menus that allow you to adjust your graphing window: **Auto**, **Axes** and **Navigate**. To adjust your graphing window:

1. Highlight your desired menu. The menus are located underneath the tabs near the top of the screen.
2. Confirm by pressing the ok key.

Auto

The NumWorks graphing calculator will adapt to display the best possible view of your sequence. Once you enter your sequence, the resulting axes will be chosen automatically. When **Auto** is active, a yellow circle will appear to the right of its name. Once you exit this window, either with the directional keys or by changing the settings, Auto will be disabled and the yellow circle will disappear.

> You can also highlight **Auto** and press the ok key to disabled the **Auto** mode.

Axes

The **Axes** menu allows you to make manual changes to the axes of your graphing window. To make changes to the X or Y values:

1. Highlight **Axes**.
2. Press the ok key to enter the menu.
3. Highlight **Values of X** or **Values of Y**
4. Confirm with the ok key.
5. Enter your desired **Minimum** and **Maximum** values. To allow the calculator to choose automatically, select **Auto** at the top of the screen.
6. Highlight **Confirm** at the bottom of the screen.
7. Confirm with the ok key.

You can make your axes equal inside the **Axes** menu. To do this, highlight **Make axes equal** and confirm with the ok key. Selecting this option will lengthen the shortest axis to match the longest. When your axes are not equal, a symbol will appear beside the **Axes** menu.

Navigate

Select **Navigate** to work with the interactive display window:

- ◁ / △ / ▷ / ▽: move the window
- + / −: zoom in/zoom out

  You can press + and − at anytime while in the **Graph** tab to zoom in/out.

6.3.3 Moving the cursor to a given index

1. When the cursor is on the sequence for which you are looking for a particular value, press OK.
2. The plot options menu opens, select **Go to** and confirm.
3. Enter the index of the point on which you want to move the cursor.
4. Select the **Confirm** button and press OK.

The cursor is now on the point you requested.
You can also type directly on the keyboard the value of the index to bring it to the requested point.

6.3.4 Calculating the sum of the terms

To calculate the sum of terms for any sequence:

1. Make sure your cursor is located on the sequence you wish to work with.
2. Press the OK key. The plot options menu will open.
3. Highlight **Sum of terms**.
4. Confirm with the OK key.
5. Enter the first term. Use the ◁ ▷ keys to position the cursor on the first term. You can also manually enter the value of n with the keyboard.
6. Confirm with the OK key.
7. Enter the last term in the same way.
8. Confirm with the OK key. You can return to the previous step by pressing the ⮌ key. If you do this, you will be asked to enter the first term again.
9. The value of the sum you would like to calculate is shown in the display bar at the bottom of the screen.

   To exit the **Sum of terms** mode, press the OK key.

6.3.5 Plotting a cobweb graph

It is possible to represent a recursive sequence with a cobweb graph to study its convergence. To plot a coweb graph:

1. Make sure your cursor is located on the recursive sequence you wish to work with.
2. Press the OK key. The plot options menu will open.
3. Highlight **Cobweb graph**.
4. Confirm with the OK key.
5. Use the ▷ ◁ keys to navigate to the next and previous terms respectively.
6. Press the ⮌ key to exit the cobweb graph.

   The + z − keys allow you to zoom in and out around the selected term.

6.4 Using the Table tab

6.4.1 Modifying the interval of the table of values

When in the **Table** tab, you can fill the table of values with values of n in any interval of your choice. There are two ways to do this:

- First option
  1. Highlight **Set the interval**.
  2. Confirm with the OK key. The options menu will open.
  3. Enter the values of **N start** and **N end** with the numeric keys.
  4. Enter the step value.
  5. Highlight **Confirm**.
  6. Confirm with the OK key. The new table will reflect the interval you have specified.
- Second option
  1. Highlight the **n** cell at the top of the first column.
  2. Confirm with the OK key.
  3. Highlight **Set the interval**.
  4. Confirm with the OK key. The options menu will open.
  5. Enter the values of **N start** and **N end** with the numeric keys.

6. Enter the step value.
7. Highlight **Confirm**.
8. Confirm with the OK key. The new table will reflect the interval you have specified.

6.4.2 Entering values of n into the table

To manually enter values of n into the table:

1. Highlight your desired cell in the first column (**Column n**).
2. Enter a value of n using the numerical keys.
3. Confirm with the OK key.

6.4.3 Displaying the sum of terms column

You can display a column that shows the **sum of the terms** in the table. To view this column:

1. Highlight the cell that contains the name of your desired sequence.
2. Press the OK key. An options menu will appear.
3. Highlight **Show the sum of terms**.
4. Press the OK key to toggle on this feature.
5. Press the ⮌ key to return to the table. The **sum of terms** column will appear to the right of the sequence you selected.

   If you would no longer like to view the sum of terms column, highlight the first cell of the column and press the OK key. Highlight **Hide the sum of terms** and press the OK key. The column is no longer displayed.

6.4.4 Deleting all table values

1. Highlight the **n** cell at the top of the first column.
2. Confirm with the OK key. An options menu will appear.
3. Highlight **Clear column**.
4. Confirm with the OK key. An empty value table will appear on the screen. You can now enter values in the **n** column manually or fill automatically.

   You can delete a row from the table by highlighting it and pressing the clear key.

Chapter 7

Distributions

To enter the **Distributions** application, highlight the app using the directional keys. Press the OK key to enter the application. This app allows you to study different probability distributions such as Binomial, Normal, Chi-squared and many others.

7.1 Getting started

7.1.1 Calculate a probability

The **Distributions** application allows you to calculate probabilities from a continuous or discrete probability distribution. It is structured in 3 steps:

Step 1: Choose the probability distribution

Highlight the probability distribution you would like to use with the directional arrows. Then confirm by pressing OK to continue to the next step.
You may choose between 6 continuous distributions and 3 discrete distributions.
Continuous distributions:

- Uniform distribution
- Exponential distribution
- Normal distribution
- Chi-square distribution
- Student's t-distribution
- Fisher's F-distribution

Discrete distributions:

- Binomial distribution
- Geometric distribution
- Hypergeometric distribution
- Poisson distribution

Step 2: Enter the parameters

Now that you have selected a distribution, you must enter your desired parameters. To do this:

1. Enter the value of the parameter(s)
2. Highlight **Next**.
3. Confirm with the OK key. This will take you to the next step.

The following list includes the parameters for each distribution:

- Binomial
  - n : number of trials
  - p : success probability
- Uniform
  - a, b : bounds of the interval
- Exponential
  - λ : parameter
- Normal
  - μ : mean
  - σ : standard deviation
- Chi-square
  - k : degrees of freedom
- Student's t
  - k : degrees of freedom

- Geometric
  - p : success probability
- Hypergeometric
  - N : population size
  - K : total of items with feature
  - n : sample size
- Poisson
  - λ :parameter
- Fisher's F
  - $d1$: degrees of freedom of the numerator
  - $d2$: degrees of freedom of the denominator

Step 3: Calculate probabilities

Calculating a probability To calculate a probability:

1. Highlight the bound in which you need to enter your value.
2. Enter the value.
3. Confirm by pressing the (OK) key.

You may now read the result of the probability calculation.

7.1.2 Modifying the bounds

You can modify the type of bounds for your probability calculations.

- $$X \leq a$$
- $$a \leq X$$
- $$a \leq X \leq b$$

- $$X = a$$

The last option may only be used for discrete distributions.
To modify the bounds of your probability calculation:

1. Navigate to the image at the top left of the screen.
2. Confirm with the (ok) key.
3. A drop-down menu opens. Choose the type of bounds you would like.
4. Confirm with the (ok) key.

You have changed the type of bounds for calculating your probabilities.

7.1.3 Calculating the inverse

You may calculate a in $P(a \leq X) = p$ for a given p probability value. To do so:

1. Highlight the field in which the probability value is located.
2. Enter your value.
3. Confirm by pressing the (ok) key.

The calculator will display the value of a.

7.1.4 Solving for μ and σ

You may calculate the value of μ or σ from a Normal probability distribution.
To do this, simply leave the value to be calculated (μ or σ) blank in the second step and then enter the value of the probability. The calculator will then give the requested value below the graph.

Chapter 8

Inference

To enter the **Inference** application, highlight the app using the directional keys. Press the OK key to enter the application. This app allows you to perform hypothesis tests and construct confidence intervals.

8.1 Getting started

The first screen of the application allows you to choose between **Tests** and **Intervals**.

8.1.1 Tests

This section allows you to perform hypothesis tests. The following types of tests are available:

- z-test for a proportion or the difference of two proportions
- t-test or z-test for a mean or the difference of two means
- t-test for a slope
- chi-square goodness-of-fit test or chi-square homogeneity/independence test

For each of these tests, the interface first allows you to define your null hypothesis and your alternative hypothesis (this step is implicit in the chi-square test). You then enter your sample data.
The calculator then calculates the test statistic and P-value. A graphical representation is also available with the P-value and rejection region shaded.

8.1.2 Intervals

This section is used to construct confidence intervals. The following types of intervals are available:

- z-interval for a proportion or the difference of two proportions
- t-interval or z-interval for a mean or the difference of two means
- t-interval for a slope

For each of these types of intervals, you are first prompted to enter sample data. The calculator then provides the critical value, standard error and margin of error. It also provides the endpoints of the interval as well as a visual representation.

> You can then use the copy key to copy the calculated interval and paste it into another application.

Chapter 9

Finance

To enter the **Finance** application, highlight the app using the directional keys. Press the OK key to enter the application.

9.1 Getting started

The first screen of the application allows you to choose between **Simple Interest** and **Compound Interest**.

9.1.1 Solving a finance problem

You can choose the parameter to be solved in the context of simple or compound interest and then enter the data so that the calculator calculates the value sought.

1. Choose Simple interest or Compound interest
2. Choose the parameter you want to calculate
3. Enter the known values
4. Select Confirm to solve

Chapter 10

Elements

To enter the **Elements** application, highlight the app using the directional keys. Press the OK key to enter the application. This application offers a periodic table of elements.

10.1 Getting started

10.1.1 Find an element

You can use the directional keys to naviage through the table of elements. You can also search for an element by typing the **name of the element** or its **atomic number** to find it in the table.
To search for an element:

1. Use the numeric keys to enter an element's atomic number.
2. Alternatively, use the ALPHA alpha key followed by an alphabetic key to start entering the name of the element.
3. The name of the element will start to autocomplete.
    - To accept the suggestion, press the ▷ or OK key.
    - To decline the suggestion, press ⮌ or just continue typing.
    - To get a new suggestion, press the △ or ▽ key.

10.1.2 View an element

The name of the selected element is displayed above the table with its **symbol**, **atomic number** and **mass number**. The legend at the bottom of the screen indicates the **family** of the element.
Pressing OK or EXE allows you to view the information of the selected element. Here you will find the following **properties**:

- Atomic number
- Mass number
- Molar mass
- Electronic configuration
- Electronegativity
- Family
- Atomic radius
- State
- Melting temperature
- Boiling temperature
- Volumic mass
- Affinity
- Ionization

10.1.3 Change the display

You can change the display of the table of elements to observe different properties. The legend at the bottom of the screen will display the value of the selected property for the selected element. By default, the elements are presented by **families**: Alkalines, Alkaline-earth metals, Transition metals, etc.
Other displays include:

- s/p/d/f blocks
- Metals
- Molar mass
- Electronegativity
- Melting temperature
- Boiling temperature
- Atomic radius

Chapter 11

Python

The version of Python available on your NumWorks calculator is MicroPython 1.17, compatible with Python 3.4.

11.1 Scripts

11.1.1 The script list

When you enter the application, you can see the list of saved scripts. When you first use the application, four scripts are defined as examples: `squares.py`, `parabola.py`, `mandelbrot.py` and `polynomial.py`.

11.1.2 Adding and removing a script from the list

You can add up to 8 scripts on the list.

1. Select the **Add a script** cell at the bottom of the list.
2. Confirm by pressing OK.

A new script appears on the list. You can then enter a name for your new script.
To delete a script, select the settings icon next to the script name and press OK. Choose **Delete script** and press OK.

11.1.3 Renaming a script

To change a script name, select the settings icon next to the script name and press OK. Choose **Rename script** and press OK to confirm. You can now change the name of the script.

11.1.4 Editing a script

To write to a script, simply select the script name and press (ok). The editor opens and you can write your code inside.

To help you write, press (paste"). A menu will open with some shortcuts to make editing easier. The menu **Loops and Tests** offers pre-filled blocks for `for` and `while` loops, `if` tests and a series of **conditions**. The menu **Catalog** lists the functions present in Python and gives a short description of them. You can also use the (copy ; var) key to display the list of functions defined in your scripts as well as the global variables.

If you want to copy and paste part of a text, select the characters to be copied by holding down the (shift) key and using ◁ or ▷. Then press (shift) and then (copy ; var) to copy the selection. Press (shift) and then (paste") to paste it.

11.1.5 Autocompletion

The script editor has an autocompletion feature. When you begin typing, the app will make a suggestion in gray.

- To accept the suggestion, press the ▷ or (ok) key.
- To decline the suggestion, press (⮌) or just continue typing.
- To get a new suggestion, press the △ or ▽ key.
- All possible suggestions from the prefix you entered are listed in the menu of the (copy ; var) key.

11.1.6 Disabling automatic import into the shell

Automatic import is automatically enabled for your scripts. This means that the command `from script_name import *` is systematically entered when the shell is opened so that you can use the functions you defined in the scripts inside the console.

To disable automatic import of a script, select the settings icon next to the script name and press (ok). Choose **Auto import in shell** and press (ok) to toggle the switch. The switch turns grey and the script will no longer be activated automatically.

11.2 The shell

At the bottom of the list of scripts is the **Python shell** button which allows access to the interactive shell of Python.

The triple arrows **>>>** prompt you to enter a command.

You can use the shortcuts on the (paste") menu to make text entry easier. The menu of the (copy ; var) key displays the list of functions and global variables contained in the imported scripts.

To interrupt the execution of a script, press the ⎋ key on the keyboard. If the script is stuck in an infinite loop, press and hold ⎋ and repeat until the script is interrupted.

11.3 Modules

The modules present in this version of Python are: `math`, `cmath`, `matplotlib.pyplot`, `random`, `turtle`, `ion`, `time` and `kandinsky` modules.

11.3.1 The math module

Here is the complete description of the `math` module. You can get this list on your calculator by pressing paste and going to **Modules** then **math**.

`e` The constant `e=2.718281828459045`.

`pi` The constant `pi=3.141592653589793`.

`sqrt(x)` Square root, type `sqrt(x)` for $\sqrt{x}$.

`pow(x,y)` Power, type `pow(x,y)` for x^y.

`exp(x)` Exponential, type `exp(x)` for e^x.

`expm1(x)` Exponential minus 1, type `expm1(x)` for $e^x - 1$.

`log(x)` Natural logarithm: `log(x)` calculates $ln(x)$.

`log2(x)` Base-2 logarithm, type `log2(x)` for $\frac{ln(x)}{ln(2)}$.

`log10(x)` Base-10 logarithm, type `log10(x)` for $\frac{ln(x)}{ln(10)} = log(x)$.

`cosh(x)` Hyperbolic cosine.

`sinh(x)` Hyperbolic sine.

`tanh(x)` Hyperbolic tangent.

acosh(x) Inverse hyperbolic cosine.

asinh(x) Inverse hyperbolic sine.

atanh(x) Inverse hyperbolic tangent.

cos(x) Cosine in radians.

sin(x) Sine in radians.

tan(x) Tangent in radians.

acos(x) Arc cosine.

asin(x) Arc sine.

atan(x) Arc tangent.

atan2(y,x) Type `atan2(y,x)` to calculate $atan(\frac{y}{x})$.

ceil(x) Ceiling.

copysign(x,y) Returns `x` with the sign of `y`, for instance `copysign(3,-1)=-3`.

fabs(x) Absolute value, `fabs(x)` returns $\mid x \mid$.

floor(x) Floor, type `floor(x)` to calculate $\lfloor x \rfloor$.

fmod(a,b) `fmod(a,b)` returns a modulo b.

frexp(x) Mantissa and exponent of `x`: for instance, `frexp(10)` returns `(0.625,4)` because $10 = 0.625 \times 2^4$.

gcd(a,b) Greatest common divisor or `a` and `b`.

ldexp(x,i) Inverse of `frexp(x)`, that is $x \times 2^i$.

modf(x) Fractional and integer parts, for instance `modf(5.1)=(0.1,5.0)`.

isfinite(x) Checks if `x` is finite.

isinf(x) Checks if `x` is infinite.

isnan(x) Checks if `x` is `NaN`.

trunc(x) Returns `x` truncated to an integer, for instance `trunc(6.7)=6`.

radians(x) Converts `x` from degrees to radians, for instance `radians(180)` returns `3.141592653589793`.

degrees(x) Converts `x` from radians to degrees, for instance `degrees(pi)` returns `180`.

erf(x) Error function, $erf(x) = \frac{2}{\pi}\int_0^x e^{-t^2}\,\mathrm{d}t$.

erfc(x) Complementary error function, $erfc(x) = 1 - erf(x)$.

gamma(x) Gamma function.

lgamma(x) Log-gamma, $lgamma(x) = ln(gamma(x))$.

11.3.2 The cmath module

This is the complete description of the `cmath` module. You can get this list on your calculator by pressing paste and going to **Modules** then **cmath**.

e The constant `e=2.718281828459045`.

pi The constant `pi=3.141592653589793`.

phase(z) Phase of `z` in radians, for instance `phase(1j)=1.570796326794897`.

polar(z) Representation of `z` in polar coordinates: `polar(1j)` returns `(1.0, 1.570796326794897)`.

rect(z) Representation of `z` in cartesian coordinates: `rect(1,pi/4)` returns `0.70710+0.70710j`.

exp(x) Exponential function, for instance `exp(i*pi/4)` returns `0.70710+0.70710j`.

log(x) Natural logarithm, for instance `log(1j)` returns `1.570796326794897j`.

sqrt(x) Square root.

cos(x) Cosine.

sin(x) Sine.

11.3.3 The matplotlib.pyplot module

This is the complete description of the `matplotlib.pyplot` module. You can get this list on your calculator by pressing paste and going to **Modules** then **matplotlib.pyplot**.

arrow(x,y,dx,dy) Draws an arrow from point `(x,y)` to point `(x+dx,y+dy)`. It is possible to use an optional argument to adjust the size of the arrow by writing: `head_width = 0.1`. Another optional argument can be used to choose the color of the line by writing: `color="red"`.

axis((xmin,xmax,ymin,ymax)) Sets the display window to `(xmin,xmax,ymin,ymax)`. The `axis()` instruction returns the list of values for the axes boundaries. In addition, `axis("off")` or `axis(False)` hides the axes while `axis("on")` or `axis(True)` displays them. To reset the axes with the automatic setting, you can use the `axis("auto")` instruction.

bar(x,height,bin_width,bottom) Draws a bar plot using the values in the `x` list and the counts in the `height` list. The last two arguments are optional. The `bin_width` argument allows you to set the width of the bars whose default value is 0.8. The `bottom` argument is the list of the starting ordinates of the bars, set to 0 by default. It is possible to place an optional argument to choose the color of the line by writing: `color="red"`.

grid() Displays the grid if it is hidden or hides the grid if it is displayed. The `grid(True)` and `grid(False)` instructions allow you to show or hide the grid.

hist(x,bins) Plots a histogram using the values in the `x` list. The second argument is optional. If the second argument is an integer, it sets the number of rectangles that constitute the histogram. This number is 10 by default. If the second argument is a list, it allows you to choose the bins of the histogram. For example, if `bin` is `[0,1,3,5]`, the

bins will be: `[0,1[`, `[1,3[` and `[3,5]`. It is possible to place an optional argument to choose the color of the line by writing: `color="red"`.

`plot(x,y)` Plots the `y` list versus the `x` list. The `(x,y)` points are connected by segments. If only one `y` list is given, the `x` is assumed to be `[0,1,2,3...]`. The `color` argument is optional. It allows you to choose the color of the line.

`scatter(x,y)` Plots a scatterplot based on `(x,y)` values. The arguments of the function can be numbers or lists of the same length. It is possible to place an optional argument to choose the color of the line by writing: `color="red"`.

`show()` Draws the figure.

`text(x,y,"text")` Displays the text set as an argument at the `(x,y)` coordinates.

11.3.4 The numpy module

Here is the complete description of the `numpy` module. You can get this list on your calculator by pressing paste and going to **Modules** then **numpy**.

`array(list)` Creates an array from a list.

`arange(start,stop)` Returns an array of integers from `start` to `stop-1`.

`concatenate((a,b))` Returns an array that joins array `b` to array `a`.

`linspace(start,stop,n)` Returns an array of `n` values evenly spaced over the specified interval.

`ones(n)` Returns an array of size `n` filled with ones.

`zeros(n)` Returns an array of size `n` filled with zeros.

`array.flatten()` Returns a copy of an array collapsed into one dimension.

`array.reshape((n,m))` Transforms an array to an array of size `(n,m)`.

`array.shape` Returns the size of the array in the form `(n,m)`.

array.tolist() Converts an array into a list.

array.transpose() Returns a transposed array.

argmax(a) Returns the indicies of the maximum values.

argmin(a) Returns the indicies of the minimum values.

dot(a,b) Returns the dot product of two arrays.

cross(a,b) Returns the cross product of two arrays.

max(a) Returns the maximum of the elements.

min(a) Returns the minimum of the elements.

mean(a) Returns the mean of the elements.

median(a) Returns the median of the elements.

polyfit(x,y,d) Fits a polynomial regression of degree `d` to the points `(x,y)` Returns a vector of coefficents that minimizes the squared error in the order `d`, `d-1`,...`0`.

polyval(p,x) Evaluates the polynomial `p` at `x`.

size(a) Returns the number of elements in the array.

sort(a) Sorts the array in ascending order.

std(a) Returns the standard deviation of the elements.

sum(a) Returns the sum of the elements.

11.3.5 The turtle module

This is the complete description of the `turtle` module. You can get this list on your calculator by pressing paste and going to **Modules** then **turtle**.

`forward(x)` Move forward by `x` pixels.

`backward(x)` Move backward by `x` pixels.

`right(a)` Turn right by `a` degrees.

`left(a)` Turn left by `a` degrees.

`goto(x,y)` Move to (`x`,`y`) coordinates.

`setheading(a)` Set the orientation by `a` degrees.

`circle(r)` Circle of radius `r` pixels.

`speed(x)` Drawing speed (`x` between 0 and 10).

`position()` Return the current (`x`,`y`) location.

`heading()` Return the current heading.

`pendown()` Pull the pen down.

`penup()` Pull the pen up.

`pensize(x)` Set the line thickness to `x` pixels.

`write("text")` Writes the text placed as an argument at the position of the turtle.

`isdown()` Return `True` if the pen is down.

`reset()` Reset the drawing.

`showturtle()` Show the turtle.

`hideturtle()` Hide the turtle.

`color('c')` or **`color(r,g,b)`** Set the pen color.

colormode(x) `colormode(1.0)` changes the color mode to 1.0 and the colors must be defined by tuples of type `(0.5,1.0,0.5)` while `colormode(255)` changes the color mode to 255 and the colors are then defined by tuples of type `(128,255,128)`. By default the color mode is 255.

blue Blue color.

red Red color.

green Green color.

yellow Yellow color.

brown Brown color.

black Black color.

white White color.

pink Pink color.

orange Orange color.

purple Purple color.

grey Gray color.

11.3.6 The random module

This is the complete description of the `random` module. You can get this list on your calculator by pressing paste and going to **Modules** then **random**.

getrandbits(k) Returns an integer with `k` random bits.

seed(x) Initialize the random number generator.

randrange(start,stop) Returns a random number in `range(start,stop)`.

randint(a,b) Returns an integer in [a,b].

choice(list) Returns a random number in the list.

random() Returns a random floating point number in [0,1).

uniform(a,b) Returns a random floating point number in [a,b].

11.3.7 The kandinsky module

This is the complete description of the **kandinsky** module. You can get this list on your calculator by pressing paste and going to **Modules** then **kandinsky**.

color(r,g,b) Defines the color from the values of r,g,b. You can also simply use a tuple to define a color: (r,g,b).

get_pixel(x,y) Returns the pixel x,y color as a tuple (r,g,b).

set_pixel(x,y,color) Colors the pixel x,y of the color color.

draw_string(text,x,y,[color1],[color2]) Displays text from the pixel x,y. The arguments color1 (text color) and color2 (background color) are optional.

fill_rect(x,y,width,height,color) Fills a rectangle at pixel (x,y) with the color color.

11.3.8 The ion module

This is the description of the **ion** module. You can get this list on your calculator by pressing paste and going to **Modules** then **ion**.

keydown(k) Returns True if the k key in argument is pressed and False otherwise.
The other items in this menu indicate the syntax used to identify the keys on the keyboard.

11.3.9 The time module

Here is the description of the **time** module. You can get this list on your calculator by pressing paste and going to **Modules** then **time**.

monotonic() Returns the value of the clock at the time the function is called.

sleep(t) Pauses execution for **t** seconds.

11.4 Toolbox and var keys

11.4.1 The var key

In the script editor, the menu of the key lists the autocompletion suggestions available.
In the execution console, the menu of the key lists all the functions defined in your imported scripts (not containing any error) as well as the global variables.

11.4.2 The Toolbox key

The key menu contains four sections for faster editing of your scripts.

Loops and tests Contains instructions for **for** and **while** loops as well as **if** tests.

Modules Contains the functions available in the **math**, **cmath**, **random**, **matplotlib.pyplot**, **ion**, **time**, **turtle** and **kandinsky** modules.

Catalog Contains the functions that can be used in Python, especially those of the modules but also functions like **print()** and **input()**. An alphabetical search with the letters of the keyboard is possible.

Functions Contains instructions for defining a function: **def function(argument):** and **return**.

Chapter 12

Settings

12.1 Angle measure

If you choose **Degrees**, all arguments of the trigonometric functions will be considered to be in degrees and the inverse trigonometric functions will give results expressed in degrees.

If you choose **Radians**, all arguments of the trigonometric functions will be considered as being in radians and the inverse trigonometric functions will give results expressed in radians.

If you choose **Gradians**, all arguments of the trigonometric functions will be considered to be in gradians and the inverse trigonometric functions will give results expressed in gradians.

The unit of angles is displayed in the top banner of the screen as **deg**, **rad** or **gon**.

12.2 Result format

If you choose **Decimal**, the numerical values will be displayed according to calculator presets so that they are as appropriate as possible for each application.

If you choose **Scientific**, the numerical values will be displayed in scientific form. A **sci** indicator then appears in the top banner of the screen to indicate that your results are displayed in scientific notation.

If you choose **Engineering**, the numerical values will be displayed in engineering form. An **eng** indicator then appears in the top banner of the screen to indicate that your results are displayed in engineering notation.

You can choose the number of digits to display for the results by directly modifying the value in the section **Significant figures**. The maximum number of digits that can be displayed is 14.

12.3 Writing format

You may choose the editing mode of mathematical expressions: in one line (linear) or in two dimensions (natural).

12.4 Complex format

If you choose **Real**, complex results will not be displayed.
If you choose $a + ib$, complex results will be displayed in rectangular form.
If you choose $re^{i\theta}$, complex results will be displayed in polar form. In this case, the argument in the exponential will always be given in radians, even if the angle unit is set to **Degrees**.

12.5 Brightness

Adjust the brightness of your calculator with this slider.

12.6 Python font size

The **Python font size** section allows you to change the font size used in the shell and editor of the Python applications

12.7 Language

The **Language** section allows you to change the language you wish to use. You may choose: **English**, **French**, **Spanish**, **German**, **Dutch**, **Italian** and **Portuguese**.

12.8 Country

The **Country** section allows you to change your country. You may choose: **Germany**, **Canada**, **Spain**, **United States**, **France**, **International**, **Italy**, **Netherlands**, **Portugal** and **United Kingdom**.
This setting allows you to define the mathematical conventions used. If you want to use American mathematical definitions and conventions, choose **United States**.

12.9 Test mode

The **Test mode** section allows you to activate **Exam modes** as well as the **Press-to-test** feature.

12.9.1 Exam mode

Some exams require the calculator to activate a specific exam mode. To activate an exam mode:

1. Enter the list of exams by highlighting **Exam mode** and pressing the (ok) key.
2. Select the exam of interest.
3. Read the warning and **Confirm**

The following exam modes are available:

- STAAR exam mode (Texas)
- Keystone exam mode (Pennsylvania)
- SC exam mode (South Carolina)
- IB exam mode

12.9.2 Press-to-test

Press-to-test allows you to deactivate features for class and exams.

Activating press-to-test

Highlight **Press-to-test** then press (ok).
Toggle off the features you wish to deactivate.
Navigate down to the **Activate test mode** button and press (ok) to activate the test mode.
A message appears indicating that the activation of the exam mode will erase the data.
Choose **Confirm** and press (ok).
You are now in test mode.

What happens when you activate the test mode?

Enabling the test mode deletes all recorded data: calculation history, variables, function list, statistical series, Python scripts, etc.
When the test mode is active, the selected features will be disabled and a symbol appears in the yellow band at the top of the screen.

12.9.3 Deactivating Exam mode or Press-to-test mode

You may only exit the test mode by connecting the calculator to a computer via a USB cable. As soon as you connect the machine, a message will appear that prompts you to exit exam mode. Highlight **Confirm** and press the OK key.

12.10 About

The **About** section displays the software version number that is installed, the serial number of your calculator and the FCC ID.

12.11 Reset the calculator

The Reset the calculator button restarts the calculator as if you pressed the RESET button on the back of the device. You will lose all data saved on the device and the calculator will be completely reset.

Chapter 13

Variables

Store expressions, functions, lists, matrices and sequences in **Variables** for reuse in future calculations and across applications. Press the (copy ; / var) key to access the **Variables** menu, where all variables are listed.

Variable names (expression or function) can be chosen using the characters a..z, A..Z, 0..9, and _. A variable name cannot start with a number or contain more than 7 characters.

To enter a capital letter, press (shift) then (ALPHA / alpha) followed by the letter you desire.

13.1 The var key

13.1.1 Storing a variable

Press (copy ; / var) at any time to store a new variable.

Select **Define a new variable** and input your value or expression and a variable name.

> If a value is highlighted when (copy ; / var) is pressed, the **Define a new variable** will automatically display with the value filled in.

Expressions

The numeric variables available in the calculator are stored in the **Expressions** section in the (copy ; / var) menu.

To store a number as a variable to be used later:

1. Enter the desired number.
2. Press (shift) followed by (sto→ F / x,y).
3. Enter the desired variable name.

4. Press (EXE) to confirm.

   Example: to store 5 as a type `5→a`. Press (EXE) to confirm.

Functions

All stored functions can be found in the **Functions** section of the (copy ; var) menu.
To store a function as a variable:

1. Enter the function expression you would like to store.
2. Press (shift) followed by (sto→ F x^y).
3. Enter the desired variable name.

   Example: to store $f(x) = 2x + 3$ type: `2x+3→f(x)`. Press (EXE) to confirm.

Lists

Lists stored as variables can be found in the **Lists** section of the (copy ; var) menu.
To store a list as a variable:

1. Enter the list you wish to store.
2. Press (shift) followed by (sto→ F x^y).
3. Enter the desired variable name.
4. Press (EXE) to confirm.

   Example: to store $1, 2, 3$ as L type `{1,2,3}→L`. Press (EXE) to confirm.

Lists are automatically created and stored for the columns of the data tables in the **Statistics** (N1, V1, etc) and **Regression** (X1, Y1, etc) applications.

Matrices

Matrices stored as variables can be found in the **Matrices** section of the (copy ; var) menu.
To store a matrix as a variable:

1. Enter the matrix you wish to store.
2. Press (shift) followed by (sto→ F x^y).
3. Enter the desired variable name.

   Example: to store $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ in $m1$ type: `[[1,0][0,1]]→m1`. Press (EXE) to confirm.

Sequences

All stored sequences can be found in the **Sequences** section of the (copy ; var) menu.
It is only possible to create a sequence in the **Sequences** application.

13.1.2 Accessing stored variables

Press (copy ; var) at any time when editing text to open the **Variables** menu. Use this menu to access all variables stored in the calculator memory.
Press (OK) on the desired variable to insert it in your calculation.
Press (clear %) to delete the selected variable.

Chapter 14

Toolbox

The paste key gives you access to an organized library of advanced functions. Press the paste key at any time while editing a calculation or expression to view a menu of functions. The advanced functions available in the toolbox menu change according to the application you are using.
When viewing a graph, the paste key gives you access to settings and additional features.
When writing an expression, the first functions in the **Toolbox** menu include: **Absolute value**, **n-th root** and **Logarithm base a**. When inputting expressions for the **Grapher**, the menu will also include **Inequalities**. Within the **Sequences** applicaiton, the **Toolbox** menu will also include defined sequences.
The **Toolbox** menu is then divided into several thematic sub-sections:

- Calculus
- Complex numbers
- Probability
- Units and constants
- Matrices and vectors
- Lists
- Arithmetic
- Trigonometry
- Decimal numbers
- Logic

`abs(x)` Calculates the absolute value of the argument you enter in parentheses. `abs(-4.5)` gives the value of $|-4.5|$, that is 4.5.

root(x,n) Calculates the n-th root of a number. You must enter n and x in parentheses. `root(x,n)` gives the value of $\sqrt[n]{x}$. The value of n doesn't have to be an integer.

log(x,a) Calculates the logarithm with base a. You must enter a and x in parentheses. `log(x,a)` gives the value of $\log_a(x)$.

14.1 Calculus

diff(f(x),x,a) Calculates the derivative of a function at a point. `diff(f(x),x,a)` gives the value of $f'(a)$. For example, to calculate the derivative of a square root at 5: `diff(sqrt(x),x,5)`.

diff(f(x),x,a,n) Calculates the nth derivative of a function at a point. `diff(f(x),x,a,n)` gives the value of $f^n(a)$. For example, to calculate the 3rd derivative of a square root at 5: `diff(sqrt(x),x,5,3)`.

int(f(x),x,a,b) Calculates the integral of a function between two bounds. `int(f(x),x,a,b)` gives the value of $\int_a^b f(x)\,\mathrm{d}x$. For example, to calculate the integral of the square root between 0 and 5: `int(sqrt(x),x,0,5)`.

sum(f(n),n,nmin,nmax) Calculates the sums of terms in n. `sum(f(n),n,nmin,nmax)` gives the value of $\sum_{n=n_{min}}^{n_{max}} f(n)$.

product(f(n),n,nmin,nmax) Calculates the products of terms in n. `product(f(n),n,nmin,nmax)` gives the value of $\prod_{n=n_{min}}^{n_{max}} f(n)$.

14.2 Complex numbers

abs(x) Modulus of a complex number. `abs(2+3i)` gives the value of $\mid 2+3i \mid$.

arg(z) Argument of a complex number. `arg(2+3i)` gives the value of $arg(2+3i)$ in radians.

re(z) Real part of a complex number. For example, `re(2+3i)` returns 2.

im(z) Imaginary part of a complex number. For example, `im(2+3i)` returns 3.

conj(z) Conjugate of a complex number. `conj(2+3i)` returns the conjugate of $2+3i$, that is $2-3i$.

14.3 Probability

14.3.1 Combinatorics

binomial(n,k) Number of ways to choose a subset of size k elements, disregarding their order, from a set of n elements. For example, $\binom{n}{k}$ returns $\frac{n!}{k!(n-k)!}$.

permute(n,k) Number of different ordered arrangements of a k-element subset of an n-set. **permute(n,k)** returns A_n^k, that is $\frac{n!}{(n-k)!}$.

n! Returns the product of the entered integer and all integers below it. For example, 5! returns 120.

14.3.2 Distributions

Normal

normcdf(a,μ,σ) $P(X < a)$ where X follows the normal distribution $N(\mu, \sigma)$.

normcdfrange(a,b,μ,σ) $P(a < X < b)$ where X follows the normal distribution $N(\mu, \sigma)$.

invnorm(a,μ,σ) Returns m where $P(X < m) = a$ and X follows the normal distribution $N(\mu, \sigma)$.

normpdf(x,μ,σ) Probability density function of $N(\mu, \sigma)$.

Student's t

tcdf(a,k) $P(X < a)$ where X follows the t-distribution with k degress of freedom.

tcdfrange(a,b,k) $P(a < X < b)$ where X follows the t-distribution with k degress of freedom.

invt(a,k) Returns m where $P(X < m) = a$ and X follows the t-distribution with k degress of freedom.

tpdf(x,k) Probability density function of $t(k)$.

Binomial

binompdf(m,n,p) $P(X = m)$ where X follows the binomial distribution $B(n, p)$.

binomcdf(m,n,p) $P(X \leq m)$ where X follows the binomial distribution $B(n, p)$.

invbinom(a,n,p) Returns m where $P(X \leq m) = a$ and X follows the binomial distribution $B(n, p)$.

Poisson

poissonpdf(m,) $P(X = m)$ where X follows the Poisson distribution with parameter λ.

poissoncdf(m,) $P(X \leq m)$ where X follows the Poisson distribution with parameter λ.

Geometric

geompdf(m,p) $P(X = m)$ where X follows the geometric distribution with probability p.

geomcdf(m,p) $P(X \leq m)$ where X follows the geometric distribution with probability p.

geomcdfrange(m,n,p) $P(m \leq X \leq n)$ where X follows the geometric distribution with probability p.

invgeom(a,p) Returns m where $P(X \leq m) = a$ and X follows the geometric distribution with probability p.

Hypergeometric

hgeompdf(m,N,K,n) $P(X = m)$ where X follows the hypergeometric distribution with population size N, number of featured items K and sample size n.

hgeomcdf(m,N,K,n) $P(X \leq m)$ where X follows the hypergeometric distribution with population size N, number of featured items K and sample size n.

hgeomcdfrange(m,q,N,K,n) $P(m \leq X \leq n)$ where X follows the hypergeometric distribution with population size N, number of featured items K and sample size n.

invhgeom(a,N,K,n) Returns m where $P(X \leq m) = a$ and X follows the hypergeometric distribution with population size N, number of featured items K and sample size n.

14.3.3 Random

random() Returns a floating point number in [0,1).

randint(a,b) Returns a random integer in [a,b].

randintnorep(a,b,n) Returns n unique random integers in [a,b].

14.4 Units and constants

This menu contains sub-menus for constants and each type of measurement listed below. Units and constants can be selected from the menu or typed manually.

a→b This menu item is a template that allows you to perform a unit conversion.

14.4.1 Length and angle

Length

Imperial

Abbreviation	Unit
in	Inch
ft	Foot
yd	Yard
mi	Mile
au	Astronomical unit
ly	Light year
pc	Parsec

Metric

Abbreviation	Unit
pm	Picometer
nm	Nanometer
µm	Micrometer
mm	Millimeter
cm	Centimeter

`m`	Meter
`km`	Kilometer

Angle

Abbreviation	Unit
`°`	Degree
`°'"`	Degree minute second
`rad`	Radian
`gon`	Gradian

14.4.2 Time and frequency

Time

Abbreviation	Unit
`ns`	Nanosecond
`µs`	Microsecond
`ms`	Millisecond
`s`	Second
`min`	Minute
`h`	Hour
`day`	Day
`week`	Week
`month`	Month
`year`	Year

Frequency

Abbreviation	Unit
`Hz`	Hertz
`kHz`	Kilohertz
`MHz`	Megahertz
`GHz`	Gigahertz

14.4.3 Volume and area

Volume

Imperial

Abbreviation	Unit
`tsp`	Teaspoon
`tbsp`	Tablespoon
`floz`	Fluid ounce
`cup`	Cup
`pt`	Pint
`qt`	Quart
`gal`	Gallon

Metric

Abbreviation	Unit
`mL`	Milliliter
`cL`	Centiliter
`dL`	Deciliter
`L`	Liter

Area

Imperial

Abbreviation	Unit
`acre`	Acre

Metric

Abbreviation	Unit
`ha`	Hectare

14.4.4 Mass

Imperial

Abbreviation	Unit
`oz`	Ounce
`lb`	Pound
`shtn`	Short ton
`lgtn`	Long ton

Metric

Abbreviation	Unit
µg	Microgram
mg	Milligram
g	Gram
kg	Kilogram
t	Metric ton

14.4.5 Electricity

Current

Abbreviation	Unit
µA	Microampere
mA	Milliampere
A	Ampere

Voltage

Abbreviation	Unit
µV	Microvolt
mV	Millivolt
V	Volt
kV	Kilovolt

Resistance

Abbreviation	Unit
Ω	Ohm
kΩ	Kiloohm

Capacitance

Abbreviation	Unit
µF	Microfarad
mF	Millifarad
F	Farad

Others

Abbreviation	Unit
H	Henry
C	Coulomb
S	Siemens
T	Tesla

14.4.6 Force and pressure

Force

Abbreviation	Unit
mN	Millinewton
N	Newton
kN	Kilonewton

Pressure

Abbreviation	Unit
Pa	Pascal
hPa	Hectopascal
bar	Bar
atm	Atmosphere

14.4.7 Energy and power

Joule

Abbreviation	Unit
mJ	Millijoule
J	Joule
kJ	Kilojoule

Power

Abbreviation	Unit
µW	Microwatt
mW	Milliwatt
W	Watt

kW	Kilowatt
MW	Megawatt
GW	Gigawatt

Electronvolt

Abbreviation	Unit
meV	Millielectronvolt
eV	Electronvolt
keV	Kiloelectronvolt
MeV	Megaelectronvolt

14.4.8 Temperature

Abbreviation	Unit
K	Kelvin
°F	Fahrenheit
°C	Celsius

14.4.9 Others

Abbreviation	Unit
cd	Candela

Amount of substance

Abbreviation	Unit
µmol	Micromole
mmol	Millimole
mol	Mole

14.4.10 Constants

Abbreviation	Unit
c	Speed of light in a vacuum
e	Elementary charge
G	Gravitational constant
g0	Acceleration of gravity

`k`	Boltzmann constant
`ke`	Coulomb constant
`me`	Mass of an electron
`mn`	Mass of a neutron
`mp`	Mass of a proton
`Na`	Avogadro constant
`R`	Molar gas constant
`0`	Vacuum permittivity
`μ0`	Vacuum permeability
`hplanck`x	Planck permeability

14.5 Matrices and vectors

`New matrix or vector` Create a new matrix or vector. This option creates a template. Enter your numbers using the directional keys.

`transpose(M)` Transpose the matrix M. For instance, `transpose([[1,2][3,4]])` returns $\begin{bmatrix} 1 & 3 \\ 2 & 4 \end{bmatrix}$.

`dim(M)` Size of the matrix M. For instance, `dim([[1,2][3,4]])` returns `[2,2]`.

Matrices

`det(M)` Determinant of the matrix M. For instance, `det([[1,2][3,4]])` returns -2.

`inverse(M)` Inverse of the matrix M. For instance, `inverse([[0.25,0][0,0.25]])` returns $\begin{bmatrix} 4 & 0 \\ 0 & 4 \end{bmatrix}$.

`identity(n)` Identity matrix of size n.

`trace(M)` Trace of the matrix M. For instance, `trace([[1,2][3,4]])` returns 5.

`ref(M)` Returns the scaled shape of matrix M.

`rref(M)` Returns the scaled form of matrix M.

Vectors

Vectors can be row vectors or column vectors.

dot(U,V) Calculates the dot product of two vectors.

cross(U,V) Calculates the cross product of two vectors of size 3.

norm(U) Calculates the magnitude of a vector.

14.6 Lists

New list Create a new list. This option provides opening and closing curly braces. Enter your elements using the number keys with a comma to separate each element.

List of f(k) for k from 1 to n Create a new list using a function. This option creates a template. Enter your function f(k) and your upper bound.

Statistics

mean(L) Calculates the mean of L.

stddev(L) Calculates the standard deviation of L.

samplestddev(L) Calculates the sample standard deviation of L.

med(L) Calculates the median of L.

var(L) Calculates the variance of L.

Operations

dim(L) Returns the length of L.

min(L) Returns the minimum element of L.

max(L) Returns the maximum element of L.

sort(L) Sorts the elements of L in ascending order.

sum(L) Calculates the sum of the elements of L.

prod(L) Calculates the product of the elements of L.

14.7 Arithmetic

gcd(p,q) Greatest Common Divisor of two integers. For instance, `gcd(55,11)` returns 11. This function accepts more than two integers as arguments.

lcm(p,q) Least Common Multiple of two integers. For instance, `lcm(13,2)` returns 26. This function accepts more than two integers as arguments.

factor(n) Integer factorization of n. For instance, `factor(24)` returns $2^3 \times 3$.

Mixed fraction A template to input a mixed fraction.

rem(p,q) Remainder of the Euclidian division of p by q. For instance, `rem(50,45)` returns the remainder of the division of 50 by 45 that is 5.

quo(p,q) Quotient of the Euclidian division of p by q. For instance, `quo(80,39)` returns the quotient of the division of 80 by 39 that is 2.

14.8 Trigonometry

14.8.1 Hyperbolic

sinh(x) Hyperbolic sine.

cosh(x) Hyperbolic cosine.

tanh(x) Hyperbolic tangent.

arsinh(x) Inverse hyperbolic sine.

arcosh(x) Inverse hyperbolic cosine.

artanh(x) Inverse hyperbolic tangent.

14.8.2 Advanced

csc(x) Cosecant

sec(x) Secant

cot(x) Cotangent

arccsc(x) Arccosecant

arcsec(x) Arcsecant

arccot(x) Arccotangent

14.9 Decimal numbers

floor Floor function. For instance, `floor(5.8)` returns 5.

frac(x) Fractional part. For instance, `frac(5.8)` returns 0.8.

ceiling Ceiling function. For instance, `ceil(5.4)` returns 6.

round(x,n) Rounds a number to n digits after the decimal point. For instance round(8.6576,2) returns 8.66.

14.10 Logic

piecewise(-x,x<0,x,x 0 A piecewise template. Input an expression followed by its domain or conditions

Less than or equal to

Greater than or equal to

Different

and And

`or` Or (inclusive)

`not` Not

`xor` Or (exclusive)

`nor` Not or (inclusive)

`nand` Not and