NUMWORKS

User manual

Version 1.6.0

1. Calculation

1. Using the application

1.1. Doing a calculation

1. When you enter the **Calculation** application, the cursor is in the editing bar at the bottom of the screen. Enter your calculation in this edit bar.
2. Press the (EXE) key. The calculation is performed.

When a calculation is performed, it is displayed at the bottom of the calculation history. In the history line corresponding to this calculation, you will see the calculation you typed in at the top left and the result at the bottom right. The exact result is displayed in black while the approximate numerical result is displayed in grey.

For more readability, the result of the calculations involving a decimal number is always given in decimal form: $0.1 + 0.3$ will give 0.4 while $\frac{1}{10} + \frac{3}{10}$ will give $\frac{2}{5}$.

1.2. Using the result of the immediately preceding calculation

You can use the exact result of the calculation you just performed in the expression of a new calculation. To do so, press (Ans). The expression ans is then displayed in the editing line and represents the result of the previous calculation. You can perform mathematical operations on this result.

1.3. Using any result in the calculation history

To copy a previous result to the calculation editing bar, use the arrow keys to select the result you want to use (exact or approximate), then press (OK). The result is then displayed in the editing bar at the bottom of the screen.

1.4. Using the expression of a calculation already performed in the calculation history

You can copy the expression of a calculation that has already been performed to the calculation editing bar. To do so, select the expression of this calculation using

the directional arrows. Then press (OK), the expression of the calculation is then displayed in the edit bar at the bottom of the screen.

1.5. Deleting a line in the history

To delete a line in the history, use the arrow keys to select an item from this line and press (DEL).

To delete the entire history, select any item in the history using the arrow keys and use the **clear** function ((shift) then (DEL)).

2. Performing calculations with complex numbers

2.1. Choosing the complex format of the results

Your results can be displayed in rectangular or polar form. Make this setting in the Settings application.

In rectangular form, the calculation of $\sqrt{-1}$ will give the result i. In polar form, the calculation of $\sqrt{-1}$ will give the result $e^{1.570797*i}$.

> In the polar form, the angle in the exponential is always given in radians, even if the calculator is set in degrees mode.

2.2. Calculation of an expression with complex numbers

You can perform calculations with complex numbers as well as with real numbers. Your complex numbers can be typed in rectangular or polar form.

For example: if you type $i+e^{i*\frac{\pi}{2}}$, the result will be $2i$ if you are in rectangular mode and $2e^{1.570796*i}$ if you are in polar mode.

2.3. Absolute value, argument, real part, imaginary part, conjugate

You can calculate these values by using the shortcuts available in the **Complex numbers** section of the **Toolbox** menu to which you have access when you press the (Toolbox) key.

You can also manually type the functions used to calculate these values. In the following list are the syntaxes of the corresponding functions :

- Absolute value : `abs(z)`
- Argument : `arg(z)`

- Real part : `re(z)`
- Imaginary part : `im(z)`
- Conjugate : `conj(z)`

3. Performing calculations with matrices

3.1. Typing a matrix using the keyboard

To type a matrix in the editing bar at the bottom of the screen, use the brackets `[` and `]`, accessible by pressing (shift) then (exp) or (ln).

For example, type `[[1,0][0,1]]` to type the size 2 identity matrix :

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

When you press (OK), you can see your matrix displayed with the correct formatting in the calculation history.

It is useful to store matrices in variables (**M1**, **M2**, ..., **M9**). To do so, type your matrix then use the function **sto→** (by pressing (shift) then (pow)). Then type the name of the variable you want and press (EXE). For example, to store the size 2 identity matrix in variable M1, write `[[1.0][0.1]] → M1` and press (EXE).

3.2. Performing calculations

You can perform calculations between several matrices:

- Addition of two matrices: `M1+M2`
- Subtraction of two matrices: `M1-M2`
- Multiplication of two matrices (matrix product) : `M1*M2`
- Division of two matrices (inverse multiplication) : `M1/M2` (corresponds to $M1 * M2^{-1}$)

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

- Multiplication of a matrix by a scalar: `4*M1`
- Power of a matrix: `M1^5`

3.3. Inverse, determinant, transpose, trace, size

You can calculate these values by using the shortcuts available in the **Matrix** section of the **Toolbox** menu to which you have access when you press the (Toolbox) key.

You can also manually type the functions used to calculate these values. In the following list are the syntaxes of the corresponding functions:

- Inverse : `inverse(M)`
- Determinant : `det(M)`
- Transpose : `transpose(M)`
- Trace : `trace(M)`
- Size : `dim(M)`

2. Functions

1. Getting started

1.1. Drawing the graph of a function

1. When you enter the **Functions** application, select the cell to the right of the name of the function you want to plot.
2. Then type the expression of the function you want to plot. The function editing field appears at the bottom of the screen. To use the variable x within the expression of the function, press the (x,n,t) key.
3. Confirm by pressing (OK).
4. Then select the **Plot Graph** button at the bottom of the screen or the **Graph** tab at the top of the screen.
5. Confirm by pressing (OK).

You are now in the **Graph** tab and your graph is plotted. You can move the cursor on the curve using the directional arrows and read the coordinates of the point at the bottom of the screen.

> To open the options menu of the curve on which the cursor is located, press (OK).

1.2. Displaying the table of values

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

- First option: from the **Functions** tab

  1. If you are in the **Functions** tab, select the **Display values** button at the bottom of the screen.
  2. Confirm by pressing (OK).

  The value table is then displayed.

- Second option: from any tab

  1. Select the **Table** tab at the top of the screen.
  2. Confirm by pressing (OK).

The value table is then displayed.

2. Using the Functions tab

2.1. Adding a function to the list

You can add up to 4 functions in the list.

1. Select the **Add function** cell at the bottom of the function list.
2. Confirm by pressing (OK).

A new function appears in the list. You can directly type its expression with the keyboard.

2.2. Editing the expression of a function

You can change the expression of a function in the list by highlighting it and pressing (OK).

The function editing field is then displayed at the bottom of the screen.

2.3. Enabling or disabling a function in the list

A disabled function appears in gray in the function list. You can still edit its expression but its graph and table of values will not be shown in the **Graph** and **Table** tabs.

1. To deactivate a function, select the name of the function in the list.
2. Confirm by pressing (OK) to open the options menu for this function.
3. Select the **Turn on/off** option and press (OK) to toggle the status of the function.
4. Return to the function list by pressing (BACK).

Do the same if you want to change the status of a function from **Off** to **On**.

2.4. Deleting the expression of a function

1. Select the expression of the function you want to delete.
2. Press the (DEL) key.

The expression of the function has been deleted. You can enter a new expression.

2.5. Removing a function from the list

You can permanently remove a function from the list. However, the first function

in the list cannot be deleted.

1. Select the name of the function to be removed from the function list.
2. Confirm by pressing (OK) to open the options menu for this function.
3. Select the option **Delete function** and confirm.

The function disappears from the list.

> You can also delete a function from the list by selecting the name of the function to delete and pressing (DEL).

3. Using the Graph tab

3.1. Moving the cursor in the graph window

You can move the cursor using the four directional arrows:

- (Left arrow) / (Right arrow): Move the cursor on the curve to the right or left.
- (Up arrow) / (Down arrow): Move the cursor to a curve above or below the curve you are on.

3.2. Adjusting the display window

To access the display window settings, select one of the options under the **Graph** tab and press (OK).
You can choose between three options: **Axes**, **Zoom** and **Preadjustment**.

> When you are in the graph display window, you can press the (+) and (-) keys to zoom in/out.

3.2.1. Axes

In **Axes**, you can enter the values of **Xmin** and **Xmax** that define the width of your display window.

I f **Yauto** is activated, the height of your display window will be automatically calculated to display all points of the curve between **Xmin** and **Xmax**. Otherwise, manually enter your **Ymin** and **Ymax** values.

Confirm by selecting the **Confirm** button and pressing (OK).

3.2.2. Zoom

Select **Zoom** to access an interactive display window setting:

- (Left arrow) / (Up arrow) / (Right arrow) / (Down arrow): move the window
- (+) / (-): zoom in/zoom out

3.2.3. Preadjustment

The **Preadjustment** menu offers you 4 predefined display windows:

- **Trigonometrical**: window adapted to the representation of the different trigonometric functions
- **Integer**: window in which the abscissa are integers
- **Orthonormal**: window displaying an orthonormal coordinate system
- **Basic settings**: reset the display window

3.3. Moving the cursor to a given abscissa point

1. When the cursor is on the curve of the function for which you are looking for a particular abscissa, press (OK).
2. The plot options menu opens, select **Go to** and confirm.
3. Enter the abscissa 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.

3.4. Displaying the value of the derivative number

You can display the value of the derivative number in the banner at the bottom of the screen.

1. When the cursor is on any curve, press (OK).
2. The plot options menu opens. Select **Derivative** then press (OK) to toggle the switch to the active state.
3. Press (BACK) to return to the graph display window. The value of the derivative number appears in the legend at the bottom of the screen.

Do the same if you want to disable the display of the derivative number.

3.5. The Calculate menu

The Calculate menu allows you to identify intersection points, minima and maxima, zeros, calculate integrals and draw tangents with their equation.

1. When the cursor is located on a particular curve, press (OK).
2. The plot options menu opens. Select **Calculate** and press (OK).

This takes you to the menu **Calculate**.

3.5.1. Intersection

The cursor automatically moves to a point where the curve intersects with another curve. To jump from intersection point to intersection point within the window, use the directional arrows.

3.5.2. Maximum / Minimum

The cursor automatically moves to a local maximum / minimum of the function. To jump from maximum / minimum to maximum / minimum within the window, use the directional arrows.

3.5.3. Zeros

The cursor automatically moves to a point where the function vanishes. To jump from zero to zero inside the window, use the directional arrows.

3.5.4. Tangent

You observe the tangent to the curve at a point. Its equation is given in the legend banner at the bottom of the screen. You can use the directional arrows to draw other tangents.

3.5.5. Integral

1. At the bottom of the display window, you are asked to select the lower bound. To do this, use the (Left arrow) and (Right arrow) keys to position the cursor on the lower bound. Confirm with (OK). You can also directly type the value of x with the keyboard.
2. Now select the upper bound in the same way. Confirm by pressing (OK). You can return to the previous step by pressing (BACK). You are then asked to select the lower bound again.
3. The value of the integral you want to calculate is shown in the display bar at the bottom of the screen. To calculate a new integral, press (BACK). To exit the **Integral** mode, press (OK).

4. Using the Table tab

4.1. Modifying the interval in the table of values

You can automatically fill in the table of values with values of x in any interval of your choice. There are two ways to do this.

- First option

    1. Select **Set the interval** in the **Table** tab and confirm by pressing (OK).
    2. You get to the settings to specify the range of values of x\$. Enter the values of **X start** and **X end** with the numeric keys of the keyboard then the step value between each x value.
    3. Select the **Confirm** button and press (OK). The new table now displays the interval you have just specified.

- The second option

    1. Select the **x** cell at the top of the first column of the table and press (OK).
    2. The options menu for the **x** column opens. Select **Set the interval** and press (OK).
    3. You get to the settings to specify the range of values of x\$. Enter the values of **X start** and **X end** with the numeric keys of the keyboard then the step value between each x value.
    4. Select the **Confirm** button and press (OK). The new table now displays the interval you have just specified.

4.2. Typing values of x into the table

When you select a cell from the first column of the table (**Column x**), you can manually type a value of x\$ using the numerical keys on the keyboard. Once you have entered your value in the cell, confirm by pressing (OK).

You can delete a row from the table by selecting it and pressing (DEL).

4.3. Deleting all table values

1. Select the **x** cell at the top of the first column of the table and press (OK).
2. Select **Clear column** and press (OK).
3. An empty value table appears on the screen. You can now enter values in the **x** column manually or automatically.

4.4. Displaying the derivative function values

You can display the column of the derivative function in the table.

1. Select the name of the function and press (OK).
2. Select **Derivative function column** and press (OK). You have just activated the display of the derivative function column.
3. Press (BACK) to return to the table. The derivative function column appears next to the function you selected.

To hide the column of the derivative function, do the same or select the name of the derivative function and press (OK) to open the options of this column and no longer display it.

3. Python

The version of Python available on your NumWorks calculator is MicroPython 1.9.4, compatible with Python 3.4.

1. Scripts

1.1. The script list

When you enter the application, you will see the list of saved scripts. When you first use the application, three scripts are defined as examples: `factorial.py`, `mandelbrot.py` and `polynomial.py`.

1.2. Adding and removing a script from the list

You can add up to 8 scripts in the list.

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

A new script appears in the list. You can then enter a name for this script.

To delete a script, select the settings icon next to the script name and press (OK). Choose **Delete script** and press (OK).

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.

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 algorithms inside.

To help you write, press (Toolbox). A menu will open and show some shortcuts to make the 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 (var) key to display the list of functions defined in your scripts as well as the global variables.

1.5. 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.

2. The shell

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

The triple arrows `>>>` prompts you to enter a command.

You can use the shortcuts on the (Toolbox) menu to make text entry easier. You will also find in the menu of the (var) key the list of functions you have defined in your scripts.

3. Modules

The modules present in this version of Python are the `math`, `cmath`, `random` and `kandinsky` modules.

3.1. The math module

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

Function	Description
`e`	The constant `e=2.718281828459045`

Function	Description
`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 `ln2(x)` for $\frac{ln(x)}{ln(2)}$
`log10(x)`	Base-10 logarithm, type `ln10(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

Function	Description
`copysign(x,y)`	Returns `x`with the sign of `y`, for instance `copysign(3,-1)=-3`
`fabs(x)`	Absolute value, `fabs(x)` returns $\lvert x \rvert$
`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 $10 = 0.625 \times 2^4$
`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 infinity
`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, $lgamma(x) = ln(gamma(x))$

3.2. The cmath module

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

Function	Description
`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

3.3. The random module

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

Function	Description
`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[`

Function	Description
`uniform(a,b)`	Returns a random floating point number in `[a,b]`

3.4. The kandinsky module

Here is the complete description of the `kandinsky` module. You can get this list on your calculator by pressing (Toolbox) and going to **Modules** then **kandinky**.

Function	Description
`color(r,g,b)`	Defines the color from the values of `r`,`g`,`b`
`get_pixel(x,y)`	Returns the pixel `x`,`y` color
`set_pixel(x,y,color)`	Colors the pixel `x`,`y` of the `color` color
`draw_string(text,x,y)`	Displays `text` from the pixel `x`,`y`

4. Toolbox and var keys

4.1. The var key

The menu of the (var) key lists all the functions defined in your scripts (containing no errors) as well as the global variables.

4.2. The Toolbox key

The (Toolbox) key menu contains four sections for the faster editing of your scripts.

Section	Description
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` and `kandinsky` modules.

Section	Description
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`.

4. Statistics

1. Getting started

1.1. Typing your data in the table

When you enter the **Statistics** app, you must type your data in a two-column table. You can add up to 3 data tables.

- In the first column (**Values**), enter the values of your statistical data.
- In the second column (**Sizes**), enter the frequencies/sizes associated with each value in your dataset, i. e. the number of occurrences of each value.

> When you fill in the first column, the second column is automatically filled in with the value 1. This means that each of the values in your statistical data appears only once in the set. Change the sizes values in the second column if the values in your statistical set appear more than once.

Like, for example:
Let's consider the following statistical data: 1, 1, 1, 2, 3, 3, 4, 5, 5.
To enter this statistical data in the table, proceed as follows.

Values V1	Sizes N1
1	3
2	1
3	2
4	1
5	2

> You can also enter frequencies in the **Sizes** column.

1.2. Plotting data as a histogram

Once you have typed your data into the table in the **Data** tab, you can plot it as a histogram.

1. Select the **Histogram** tab at the top of the screen.
2. Confirm by pressing (OK).

You then see the histogram that displays your data.

1.3. Plotting data as a box plot

Once you have typed your data into the table in the **Data** tab, you can plot it as a box plot.

1. Select the **Box** tab at the top of the screen.
2. Confirm by pressing (OK).

You then see the box plot that displays your data.

1.4. Displaying statistical variables

Once you have typed your data into the table in the **Data** tab, you can display the statistical variables: mean, standard deviation, median,...

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

You then see the table of statistical variables.

2. Using the Data tab

2.1. Delete a value from the data table

You can delete a row from the table by selecting a cell in that row and pressing (DEL).

You can change the content of a cell by selecting it and typing a new value with the keyboard.

2.2. Clearing a column of the table

You can delete all the values in a column of the table.

1. Select the name of the column you want to clear. Confirm by pressing (OK).
2. The column options menu opens. Select **Clear column** and confirm with (OK).

Clearing the **Values** column also clears the **Sizes** column.

Clearing the **Sizes** column fills this column with the value **1**.

2.3. Generate a list with a formula

You can create a column of the data table using a formula involving another column.

1. Select the name of the column you want to fill. Confirm by pressing (OK).
2. The column options menu opens. Select **Fill with formula** and confirm with (OK).
3. Type your formula using the name of another column. For example, if you want column V2 to be filled with the values of V1 divided by 2, write `V1/2` in the text field at the bottom of the screen. Then press **OK**.

To enter a capital letter, press **shift** then **alpha** then the letter to display.

3. Using the Histogram tab

3.1. Moving the cursor in the histogram

When you are in the **Histogram** tab, you can read the numbers and frequencies in the bar at the bottom of the screen for each rectangle. The intervals represented by the rectangles are also displayed.

To move the selection to another rectangle in the histogram, use the (Left arrow) and (Right arrow) keys.

To move to another data set, use the (Up arrow) and (Down arrow) keys.

3.2. Setting histogram parameters

You can change the width of the histogram rectangles (bin width) and the start value of the data set.

1. Press (OK).
2. The histogram settings menu opens. Enter the values for the width of rectangles and the start of the set. Confirm by selecting the **Validate** button and pressing the (OK) key.

4. Using the Box tab

In the **Box** tab, you can read the statistical variables below the box plot:

- Minimum
- First quartile
- Median
- Third quartile
- Maximum

To move the cursor, use the Left arrow and Right arrow keys.

To move to another data set, use the Up arrow and Down arrow keys.

5. Using the Stats tab

The **Stats** tab displays the statistical variables calculated using the data in the **Data** tab:

- Total size
- Minimum
- Maximum
- Range
- Mean
- Standard deviation
- Variance
- First quartile
- Third quartile
- Median
- Interquartile range
- Sum
- Sum of squares
- Sample standard deviation

5. Probability

This app lets you study different probability distributions such as Binomial, Normal or Exponential. Input the distribution's parameters and get the corresponding probabilities. It is organized in 3 steps:

1. Choice of probability distribution: select the probability distribution you want to perform your probability calculations, the normal distribution for example.
2. Choice of the parameters: type the values of the parameters of the probability density function, standard deviation and mean for example.
3. Calculate probabilities: define your bounds and calculate the corresponding probability or perform the inverse by typing a probability value to calculate the value of the corresponding bound.

Once you have made a choice and moved to the next step, you can return to the previous step by pressing (BACK).

1. First step: choosing the probability distribution

Select the probability distribution you want with the directional arrows. Then confirm by pressing (OK) to go to the next step.

You have the choice between 3 continuous distributions and 2 discrete distributions.

Continuous distributions:

- Uniform distribution
- Exponential distribution
- Normal distribution

Discrete distributions:

- Binomial distribution
- Poisson distribution

2. Second step: choosing the parameters

Type the value of the parameter(s) then select the **Next** button and press (OK) to go to the next step.

At the bottom of the screen, you will see a description of the requested parameters.

In the table below, the parameters requested for each distribution are reminded.

Probability distribution	Requested parameters	What value to enter
Binomial	(n, p) : number of trials and success probability	(natural number, real number in $[0, 1]$)
Uniform	(a, b): bounds of the interval	(real number, real number)
Exponential	λ: parameter	non-negative real number
Normal	(μ, σ): mean and standard deviation	(positive real number, non-negative real number)
Poisson	λ :parameter	non-negative real number

3. Third step: calculating probabilities

3.1. Calculating a probability

1. Select the bound in which you want to enter your value.
2. Type the value.
3. Confirm by pressing (OK).

You can now read the result of the probability calculation.

3.2. 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 only concerns discrete distributions.

To do so, follow the instructions below.

1. Select the **Bound type** icon at the top left of the screen and press (OK).
2. A drop-down menu opens. Choose the type of bounds you want and confirm by pressing (OK).

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

3.3. Calculating the inverse

You can calculate a in $P(a \leq X) = p$ from a given p probability value.

1. Select the field in which the probability value is located.
2. Type your value.
3. Confirm by pressing (OK).

The calculator will display the value of a.

6. Equations

This app lets you solve equations and linear systems. The solutions are given in an exact or approximated form according to the equation.

1. Solve an equation

1.1. Enter an equation

When you open the application, press **OK** to add an equation. A pop-up opens to suggest equation templates that you can then modify. If you do not wish to use a template, choose **Empty**.

Enter your equation in the text field at the bottom of the screen. You can use any lowercase letter as unknown: press **alpha** then a letter to display it or simply press the **x,n,t** key to display the letter x.

Confirm by pressing **OK** once you have entered your equation.

To display the = sign, press **shift** and then press **pi**. If you validate without writing a sign = in your equation, it will be automatically added.

1.2. Solutions

To get the solutions of the equation, select the **Solve equation** button at the bottom of the screen and press **OK**.

1.2.1. Quadratic equations

If the input equation is a quadratic equation, the solutions **x0** and **x1** are automatically given in an exact form.

The table also displays the value of the discriminant.

1.2.2. General case

Generally, solutions are computed numerically and their value is often approximated.

When you press the button **Solve the equation**, the application then asks you to set an interval in which to search for the solution.

Set the values of **Xmin** and **Xmax** and press the button **Solve the equation**.

If there are too many solutions, the calculator only displays the first ten.

2. Solving a system of equations

2.1. Enter a system of equations

To enter a system, simply proceed as before. When you add a second equation, the application displays the equations as a system.

You can use any lowercase letter as unknown again.

Up to 6 equations can be added.

2.2. Solutions

The application solves linear systems with real or complex coefficients.

To get the solutions, select the **Solve the system** button at the bottom of the screen and press **OK**.

The application gives the solutions in exact form. It also indicates if there is an infinity of solutions or if there is no solution.

7. Sequences

1. Getting started

1.1. Drawing the graph of a sequence

1. When you enter the **Sequence** application, select the **Add sequence** cell and confirm by pressing (OK).
2. Choose the type of expression you want 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).
3. Then type the expression of the sequence you want to plot. The sequence editing field appears at the bottom of the screen. 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 (Toolbox). In this case, you must indicate the value of the first term of the sequence.
4. Confirm by pressing (OK).
5. Then select the **Plot Graph** button at the bottom of the screen or the **Graph** tab at the top of the screen.
6. Confirm by pressing (OK).

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

> To open the options menu of the graph on which the cursor is located, press (OK).

1.2. Displaying the table of values

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

- First option: from the **Sequences** tab

    1. If you are in the **Sequences** tab, select the **Display values** button at the bottom of the screen.
    2. Confirm by pressing (OK).

The value table is then displayed.

- Second option: from any tab

  1. Select the **Table** tab at the top of the screen.
  2. Confirm by pressing (OK).

  The value table is then displayed.

2. Using the Sequences tab

2.1. Adding a sequence to the list

You can add up to 2 sequences in the list.

1. Select the **Add sequence** cell at the bottom of the list.
2. Confirm by pressing (OK).

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

2.2. Editing the expression of a sequence

You can change the expression of a sequence in the list by highlighting it and pressing (OK).

The sequence editing field is then displayed at the bottom of the screen.

2.3. Enabling or disabling a sequence in the list

A disabled sequence appears in gray in the list. You can still edit its expression but its graph and table of values will not be shown in the **Graph** and **Table** tabs.

1. To deactivate a sequence, select the name of the sequence in the list.
2. Confirm by pressing (OK) to open the options menu for this sequence.
3. Select the **Turn on/off** option and press (OK) to toggle the status of the sequence.
4. Return to the sequence list by pressing (BACK).

Do the same if you want to change the status of a sequence from **Off** to **On**.

2.4. Deleting the expression of a sequence

1. Select the expression of the sequence you want to delete.
2. Press the (DEL) key.

The expression of the sequence has been deleted. You can enter a new expression.

2.5. Removing a sequence from the list

You can permanently remove a sequence from the list.

1. Select the name of the sequence to be removed from the sequence list.
2. Confirm by pressing (OK) to open the options menu for this sequence.
3. Select the option **Delete sequence** and confirm.

The sequence disappears from the list.

> You can also delete a sequence from the list by selecting the name of the sequence to delete and pressing (DEL).

2.6. Changing the type of the sequence

You can choose the type of expression of a sequence: 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).

1. Select the name of the sequence to be removed from the sequence list.
2. Confirm by pressing (OK) to open the options menu for this sequence.
3. Select the option **Sequence type** and press (OK).
4. Choose the type of expression you want and confirm by pressing (OK).

The type of the sequence has been changed. If you chose to define the sequence with a recursive expression, you will have to provide the first term.

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

2.7. Typing the expression of a recursive sequence

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

To do so, you can press (Toolbox) when editing the expression and select the term you need. You can also directly enter the term you want: type `u (n+1)` for u_{n+1} and `u (n)` for u_n.

With 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.

2.8. Changing the first term index

1. Select the name of the sequence to be removed from the sequence list.
2. Confirm by pressing (OK) to open the options menu for this sequence.
3. Select the line **First term index** and type a value.
4. Press (OK) and (Back) to return to the **Sequences** tab.

3. Using the Graph tab

3.1. Moving the cursor in the graph window

You can move the cursor using the four directional arrows:

- (Left arrow) / (Right arrow): Move the cursor to the right or left.
- (Up arrow) / (Down arrow): Move the cursor to a sequence above or below the sequence you are on.

3.2. Adjusting the display window

To access the display window settings, select one of the options under the **Graph** tab and press (OK).
You can choose between three options: **Axes**, **Zoom** and **Preadjustment**.

> When you are in the graph display window, you can press the (+) and (-) keys to zoom in/out.

3.2.1. Axes

In **Axes**, you can enter the values of **Xmin** and **Xmax** that define the width of your display window.

I f **Yauto** is activated, the height of your display window will be automatically calculated to display all points of the sequence between **Xmin** and **Xmax**. Otherwise, manually enter your **Ymin** and **Ymax** values.

Confirm by selecting the **Confirm** button and pressing (OK).

3.2.2. Zoom

Select **Zoom** to access an interactive display window setting:

- (Left arrow) / (Up arrow) / (Right arrow) / (Down arrow): move the window
- (+) / (-): zoom in/zoom out

3.2.3. Preadjustment

The **Preadjustment** menu offers you 4 predefined display windows:

- **Trigonometrical**: window adapted to the representation of the different trigonometric functions
- **Integer**: window in which the abscissa are integers
- **Orthonormal**: window displaying an orthonormal coordinate system
- **Basic settings**: reset the display window

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.

3.4. Effectuer le calcul de la somme des termes d'une suite

1. When the cursor is located on a particular sequence, press (OK).
2. The plot options menu opens. Select **Sum of terms** and press (OK).
3. At the bottom of the display window, you are asked to select the first term. To do so, use the (Left arrow) and (Right arrow) keys to position the cursor on the first term. Confirm with (OK). You can also directly type the value of n with the keyboard.
4. Now select the last term in the same way. Confirm by pressing (OK). You can return to the previous step by pressing (BACK). You are then asked to select the first term again.
5. The value of the sum you want to calculate is shown in the display bar at the bottom of the screen. To calculate a new sum, press (BACK). To exit the **Sum of terms** mode, press (OK).

4. Using the Table tab

4.1. Modifying the interval in the table of values

You can automatically fill in the table of values with values of n in any interval of your choice. There are two ways to do this.

- First option

    1. Select **Set the interval** in the **Table** tab and confirm by pressing (OK).
    2. You get to the settings to specify the range of values of x. Enter the

values of **N start** and **N end** with the numeric keys of the keyboard then the step value between each n value.
3. Select the **Confirm** button and press (OK). The new table now displays the interval you have just specified.

- The second option

1. Select the **n** cell at the top of the first column of the table and press (OK).
2. The options menu for the **n** column opens. Select **Set the interval** and press (OK).
3. You get to the settings to specify the range of values of x\$. Enter the values of **N start** and **N end** with the numeric keys of the keyboard then the step value between each n value.
4. Select the **Confirm** button and press (OK). The new table now displays the interval you have just specified.

4.2. Typing values of n into the table

When you select a cell from the first column of the table (**Column n**), you can manually type a value of n\$ using the numerical keys on the keyboard. Once you have entered your value in the cell, confirm by pressing (OK).

You can delete a row from the table by selecting it and pressing (DEL).

4.3. Deleting all table values

1. Select the **n** cell at the top of the first column of the table and press (OK).
2. Select **Clear column** and press (OK).
3. An empty value table appears on the screen. You can now enter values in the **n** column manually or automatically.

8. Regression

1. Getting started

1.1. Typing your data in the table

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

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

1.2. Computing the linear regression

Once you have entered your data in the table, you can plot a linear regression.

1. Select the **Graph** tab at the top of the screen.
2. Confirm by pressing (OK).

You then see the points that represent your data as well as the regression line that fits the model equation $y = ax + b$\$. The a and b coefficients are displayed in the banner at the bottom of the screen.

1.3. Displaying statistical variables

Once you have typed your data into the table in the **Data** tab, you can display the statistical variables: mean, standard deviation, median,...

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

You then see the table of statistical variables.

2. Using the Data tab

2.1. Delete a value from the data table

You can delete a row from the table by selecting a cell in that row and pressing (DEL).

You can change the content of a cell by selecting it and typing a new value with the keyboard.

2.2. Clearing a column of the table

You can delete all the values in a column of the table.

1. Select the name of the column you want to clear. Confirm by pressing (OK).
2. The column options menu opens. Select **Clear column** and confirm with (OK).

> Clearing the x_i column also clears the y_i column.
> Clearing the y_i column fills this column with the value 0.

2.3. Generate a list with a formula

You can create a column of the data table using a formula involving another column.

1. Select the name of the column you want to fill. Confirm by pressing (OK).
2. The column options menu opens. Select **Fill with formula** and confirm with (OK).
3. Type your formula using the name of another column. For example, if you want column X2 to be filled with the values of X1 divided by 2, write `X1/2` in the text field at the bottom of the screen. Then press **OK**.

To enter a capital letter, press **shift** then **alpha** then the letter to display.

3. Using the Graph tab

3.1. Moving the cursor in the graph window

You can move the cursor using the four directional arrows:

- (Left arrow) / (Right arrow): move the cursor on the line to the right or left or from point to point.
- (Up arrow) / (Down arrow): move the cursor from the data points to the regression line or move to another data set.

3.2. Predict a value of X or Y

You can look for a specific point on the regression line knowing its abscissa or ordinate: that is, you can predict a value of X given Y and a value of Y given X.

1. Move the cursor to the regression line and press (OK).
2. The regression line menu opens. Select **Prediction given X** if you know the value of X and **Prediction given Y** if you know the value of Y. Confirm by pressing (OK).
3. Type your value, then select the **Validate** button and press (OK).

The cursor has moved to the desired point. You can read the coordinates of this point at the bottom of the screen.

3.3. Adjusting the display window

To access the display window settings, select one of the options under the **Graph** tab and press (OK).
You can choose between three options: **Axes**, **Zoom** and **Preadjustment**.

> When you are in the graph display window, you can press the (+) and (-) keys to zoom in/out.

3.3.1. Axes

In **Axes**, you can enter the values of **Xmin** and **Xmax** that define the width of your display window.

I f **Yauto** is activated, the height of your display window will be automatically calculated to display all points of the curve between **Xmin** and **Xmax**. Otherwise, manually enter your **Ymin** and **Ymax** values.

Confirm by selecting the **Confirm** button and pressing (OK).

3.3.2. Zoom

Select **Zoom** to access an interactive display window setting:

- (Left arrow) / (Up arrow) / (Right arrow) / (Down arrow): move the window
- (+) / (-): zoom in/zoom out

3.3.3. Preadjustment

The **Preadjustment** menu offers you 3 predefined display windows:

- **Integer**: window in which the abscissa are integers
- **Orthonormal**: window displaying an orthonormal coordinate system
- **Basic settings**: reset the display window

4. Using the Stats tab

The **Stats** tab displays the statistical variables calculated using the data in the **Data** tab:

- Mean of x_i values 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
- Number of data points
- Covariance
- Sum of $x_i \times y_i$
- Slope a and y-intercept b of the regression line
- Correlation coefficient r
- Coefficient of determination r^2

9. Settings

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.

Similarly 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.

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

2. Result format

If you choose **Auto**, 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.

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.

3. Writing format

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

4. Complex format

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**.

5. Brightness

You can adjust the brightness of the screen using the directional arrows.

6. Language

To change the calculator language. You can choose between **English**, **French**, **Spanish**, **German** and **Portuguese**.

7. Exam mode

7.1. Activating the exam mode

Select **Exam Mode** in the application **Settings** then press (OK).

A **Activate Exam Mode** button appears. Press (OK) to activate the exam 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 exam mode.

7.2. What happens when you activate the exam mode?

Enabling the exam mode deletes all recorded data: calculation history, variables, function list, statistical series, Python scripts,...

When the exam mode is active, a symbol appears in the yellow band at the top of the screen to indicate it and the LED on the front edge of the calculator flashes red.

7.3. Deactivating the exam mode

You can only exit the exam mode by connecting the calculator to a computer via a USB cable. As soon as you connect the machine, a message appears asking you if you want to exit the exam mode. Choose **Confirm** and press (OK).

You are no longer in exam mode: the symbol **Exam mode** disappears from the display and the LED stops flashing red.

8. About

This screen gives you access to the software version number that is installed on your calculator as well as the serial number of your device.

10. Variables

You can store numbers or matrices in variables for reuse in future calculations. All variables are listed in the menu that appears when you press the (var) key on the calculator.

1. Numbers: A...Z

The numeric variables available in the calculator are capital letters from A to Z.

To store a number in a variable, type the number to store then insert the arrow **sto** (by pressing (shift) then (pow)) followed by the desired letter. For example to store **5** in B type : `5→B`. Then press (EXE) to confirm.

Be sure to use capital letters for variables. To make a capital letter press (shift) then (alpha) then press the key with the desired letter.

2. Matrices: M1...M9

The matrix variables available in the calculator are the following: $M1$, $M2$, ..., $M9$.

To store a matrix in a variable, type the matrix to store then insert the arrow **sto** (by pressing (shift) then (pow)) followed by the desired variable. For example to store $\begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$ in $M2$ type: `[[1,0][0,1]]→M`. Then press (EXE) to confirm.

Be sure to use a capital M for matrix variables. To make a capital letter press (shift) then (alpha) then press the key with the desired letter.

3. The var key

When editing text, you can press (var) at any time to open the **Variables** menu. This menu allows you to access the different variables stored in the memory.

Press (OK) on the desired variable to insert it in your calculation.

Press (DEL) to clear the selected variable: the numbers are set to zero while the matrices are cleared.

11. Toolbox

At any time when editing a calculation or expression, you can press (Toolbox). A catalogue of functions will open to help you make more specific calculations.

The **Toolbox** catalog is divided into several thematic sub-sections: Calculation, Complex numbers, Combinatorics, ... Choose the calculation you want to perform and press (OK). Complete the space between the parentheses with the arguments you need for each function.

The first three functions in the **Toolbox** catalogue are: **Absolute value**, **n-th root** and **Logarithm to base a**.

Function	Description
`abs(x)`	Calculates the absolute value of the argument you enter in parentheses. `abs(-4.5)` gives the value of $\lvert -4.5 \rvert$, 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 may not be an integer.
`log(x,a)`	Calculates the logarithm to base a. You must enter a and x in parentheses. `log(x,a)` gives the value of $\log_a(x)$.

1. Calculation

Function	Description
`diff(f(x),a)`	Calculates the derivative of a function at a point. Be careful to define the function using the x variable. `diff(f(x),a)` gives the value of *[Math Processing Error]*. For example, to calculate the derivative of a square root at 5: `diff(sqrt(x),5)`.

Function	Description
`int(f(x),a,b)`	Calculates the integral of a function between two bounds. Be careful to define the function using the *[Math Processing Error]* variable. `int(f(x),a,b)` gives the value of *[Math Processing Error]*. For example, to calculate the integral of the square root between 0 and 5: `int(sqrt(x),0,5)`.
`sum(f(n),nmin,nmax)`	Calculates the sums of terms in n. Be careful to define the terms with the variable n. `sum(f(n),nmin,nmax)` gives the value of $\sum_{n=n_{min}}^{n_{max}} f(n)$.
`product(f(n),nmin,nmax)`	Calculates the products of terms in n. Be careful to define the terms with the variable n. `product(f(n),nmin,nmax)` gives the value of $\prod_{n=n_{min}}^{n_{max}} f(n)$.

2. Complex numbers

Function	Description
`abs(x)`	Absolute value of a complex number. `abs(2+3i)` gives the value of $\lvert 2+3i \rvert$.
`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 instance, `re(2+3i)` returns 2.
`im(z)`	Imaginary part of a complex number. For instance, `im(2+3i)` returns 3.
`conj(z)`	Conjugate of a complex number. `conj(2+3i)` returns the conjugate of $2+3i$, that $2-3i$.

3. Combinatorics

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

4. Arithmetic

Function	Description
`gcd(p,q)`	Greatest Common Divisor of two integers. For instance, `gcd(55,11)` returns 11.
`lcm(p,q)`	Least Common Multiple of two integers. For instance, `lcm(13,2)` returns 26.
`factor(n)`	Integer factorization of n. For instance, `factor(24)` returns $2^3 \times 3$.
`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.

5. Matrix

Function	Description
`inverse(M)`	Inverse of the matrix M. For instance, `inverse([[0.25,0][0,0.25]])` returns $\begin{bmatrix}4 & 0\\0 & 4\end{bmatrix}$.
`det(M)`	Determinant of the matrix M. For instance, `det([[1,2][3,4]])` returns -2.
`transpose(M)`	Transpose of the matrix M. For instance, `transpose([[1,2][3,4]])` returns $\begin{bmatrix}1 & 3\\2 & 4\end{bmatrix}$.
`trace(M)`	Trace of the matrix M. For instance, `trace([[1,2][3,4]])` returns 5.
`dim(M)`	Size of the matrix M. For instance, `dim([[1,2][3,4]])` returns `[2,2]`.

6. Random and approximation

Function	Description
`random()`	Generates a random number between 0 and 1.
`randint(a,b)`	Generates a random integer a and b.
`floor(x)`	Floor function. For instance, `floor(5.8)` returns 5.
`frac(x)`	Fractional part. For instance, `frac(5.8)` returns 0.8.
`ceil(x)`	Ceiling function. For instance, `ceil(5.8)` returns 6.
`round(x,n)`	Rounds a number to n digits after the decimal point. For instance `round(8.6576,2)` returns 8.66.

7. Hyperbolic trigonometry

Function	Description
`cosh(x)`	Hyperbolic cosine.

Function	Description
`sinh(x)`	Hyperbolic sine.
`tanh(x)`	Hyperbolic tangent.
`acosh(x)`	Inverse hyperbolic cosine.
`asinh(x)`	Inverse hyperbolic sine.
`atanh(x)`	Inverse hyperbolic tangent.

8. Prediction interval

Function	Description
`prediction95(p,n)`	Prediction interval 95%. `prediction95(p,n)` returns $\left[p-1.96\frac{\sqrt{p(1-p)}}{\sqrt{n}};p+1.96\frac{\sqrt{p(1-p)}}{\sqrt{n}}\right]$.
`prediction(p,n)`	Approximation of the prediction interval. `prediction(p,n)` returns $\left[p-\frac{1}{\sqrt{n}};p+\frac{1}{\sqrt{n}}\right]$.
`confidence(f,n)`	95% confidence interval. `confidence(f,n)` returns $\left[f-\frac{1}{\sqrt{n}};f+\frac{1}{\sqrt{n}}\right]$.