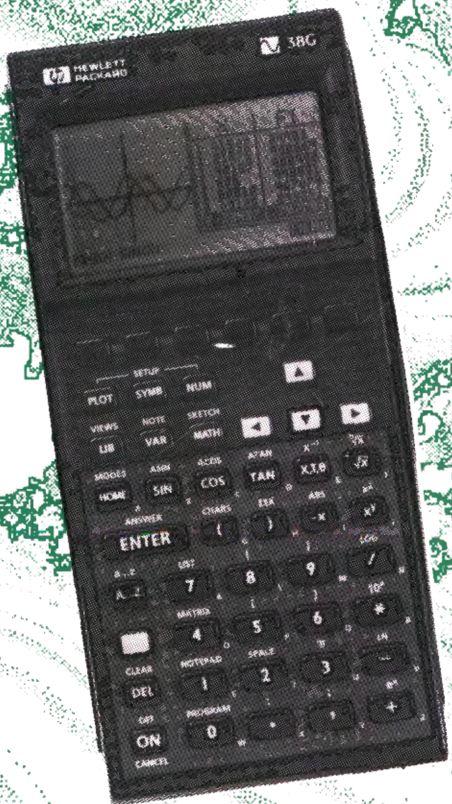
Mastering the HP38G GRAPHICS CALCULATOR

A Guide for Students and Teachers



by C. Croft

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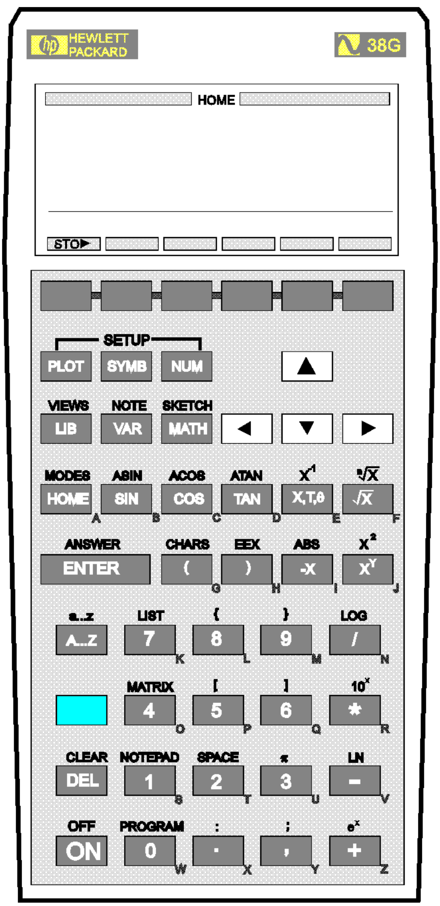
the
HP38G
Graphical Calculator

A Student Handbook



Mastering the HP38G

A Student Handbook

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Warnings!

Introduction

This booklet is intended to help you to master your HP38G calculator. The heart of this calculator is a very sophisticated computer, having more capabilities than any university mainframe computer of the ‘70s, so you should not expect to come to grips with its full capabilities in one or even two sessions. However, if you persevere with this booklet you will find that, in time, you are using the calculator with efficiency and confidence.

The majority of readers will probably only have used a Scientific calculator before so I have tried to make all explanations and examples as complete as possible. Those who are already familiar with another brand or type, may find that a quick skim of the majority of pages is sufficient, followed by a detailed reading of the Appendices & sections entitled “Tips and Tricks” which appear in various places.

Many of you may have parents who wonder (or may indeed be wondering yourself) what the impact of these calculators may be on the Mathematics curriculum - the topics taught and even more, the way they will be taught. The impact of these calculators will probably be far greater than has been the impact of computers during the last 10 years, because of their greater accessibility and portability and, in comparison with the computers available even 5 years ago, their power and capabilities. The inventiveness and flexibility of teachers of Mathematics will be stretched to the limit as we gradually change the face of Mathematics teaching in the light of these machines. For those who are concerned with the impact of a graphical calculator on the ‘fundamentals’ of Mathematics, it should be recalled that the same fears were held for Scientific calculators when they were introduced into the syllabus in the late ‘70s. History has shown that these fears were for the most part groundless. Students in the ‘90s are learning Mathematics in Years 11 and 12 that students of the ‘70s did not cover until their University years. In particular, the Scientific calculator proved to be a great boon to students of middle to lower ability in Mathematics, relieving them most of the burden of tedious calculations and leaving them far more time to concentrate on coming to grips with the concepts.

While not intended to fully replace the Owner’s Manual supplied with the calculator, the Owner’s Manual is certainly not the clearest and most explanatory of documents! This booklet is intended to fill in the holes, and also to provide a series of tips, both small and large, that will make your operation smother and more confident.

You have chosen one of the best calculators on the market. The HP38G is not only powerful but genuinely easy to use. Congratulations, and happy computing.

How to use this Manual

In attempting to design this manual to cover the full use of the HP38G calculator I have included explanations which will be useful to anyone from a student who is just beginning to use algebra, to one who is learning advanced calculus, and also to a teacher who is already familiar with some other brand of graphic calculator.

This also means, however, that readers may encounter one of two difficulties. Firstly, the information in here will be beyond the needs of some readers and secondly, the explanations may be too detailed (slow) for more advanced users.

For students who don't yet need the more advanced capabilities, suggestions on what parts of the manual to read are given below. The suggestions are based on the Mathematics curriculum in Western Australia, but if you live somewhere else (why?) you should be able to adapt them to your own system without too much difficulty. For more advanced users, it is suggested that you read the sections on the Function, Sequence, Statistics and Solve aplets, and also read the 'Tips and Tricks' sections which follow many chapters.

There is also a chapter of fully worked examples at the end of the manual which use a great many of the capabilities of the calculator.

Year 8
Some topics covered include…

> *Solving linear equations, graphing linear equations and possibly simple quadratics, examining number patterns, expanding brackets, factorisation involving removal of a single factor, calculations involving powers (x^2 , x^3 ,...), square roots, cube roots, order of operations, positives and negatives, scientific notation, simple indices.*

Suggestions…

> Read about the Function aplet in full, ignoring any bits that don't make sense. Don't worry about the explanation of the '*FCN*' menu but make sure you know how the '*Zoom*' menu, the **VIEWS** button, and **PLOT SETUP** work. Learn to 'Build Your Own' in the **NUM** view because it let's you find values for rules easily (i.e. if $y = 2x + 3$, find y if x=4). Learn to use the **HOME** view for routine calculations and how to use the calculator's memories. Read about the Solve aplet and using it to solve equations. In the **MATHS** menu, read about the functions ROUND, TRUNCATE and POLYFORM. Make sure you know how to save and transfer aplets. Learn about the Sketch view and the Notes catalogue for a bit of fun.

Year 9

Some topics covered include…

> *Solving complex linear equations and simple quadratic equations, factorisation of quadratics, use of formulae, indices, percentages, simultaneous linear equations graphically and algebraically, trigonometry, statistical graphs and measures of central tendency, simple probability.*

Suggestions…

> Cover all of the material mentioned in the Year 8 section on the previous page. Also read the explanation of the '*FCN*' menu in order to know how to find the intercepts and turning point of a quadratic, and to know how to find intersections of graphs when solving simultaneously.
>
> In the **MATHS** menu, read about the Trig functions and π, the functions ISOLATEand QUAD, the | ('where') function, RANDOM and POLYROOT.

Year 10

Some topics covered include…

> *Solving complex linear and non-linear simultaneous equations, and trig, exponential & complex quadratic equations, factorisation of any quadratic, use and re-arrangement of formulae, complex indices, 3D trigonometry, statistical graphs (univariate & bivariate), measures of central tendency and spread, time series data, absolute value and greatest integer functions, matrices.*

Suggestions…

> Cover all of the material mentioned in the Year 8 and Year 9 sections on this and the previous page. Also read the explanation of the '*FCN*' menu in order to know how to find the intercepts of graphs and intersections of graphs when solving simultaneously. Read the suggestions on how to deal with graphs whose shape you don't know in advance. In the **MATHS** menu, read functions CEILING, ABS and FLOOR, FNROOT, POLYCOEF, and POLYEVAL. Read the section covering the Matrices catalogue and the functions DET, IDENTMAT, INVERSE, and TRN.

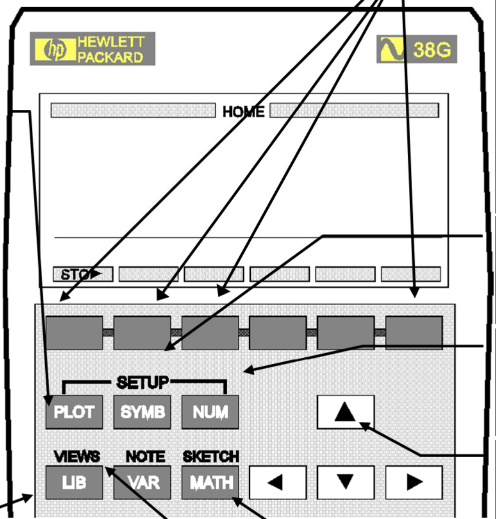
Year 11 and 12

Topics covered here will vary according to which course students undertake. It is suggested that students read the whole manual, and also re-read it at intervals as more material is covered in their courses, making more of the manual relevant. Make sure that you read the last chapter of worked examples.

Where's the ON button?

Let's begin by looking at the fundamentals - the layout of the keyboard and which are the important keys that are used frequently. The sketch below shows most of the important keys, with the exception of the **HOME** key. These are the ones which control the operation of the calculator - the others are just used to do calculations once the important keys have set up the environment to do it in.

The PLOT key swaps to the graph view.



These six keys are flexible, changing their function as you do different things. The shaded bar at the bottom of the screen labels them. Always check this bar to see what special functions are available in the current situation.

The **SYMB** key nearly always takes you to a view in which you can enter equations.

The **NUM** key gives you a tabular view of your function, sequence or data.

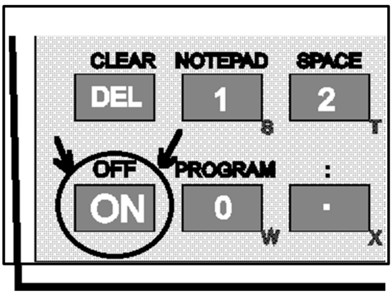
These are the cursor (or arrow) keys. They let you move around within a window.

The **MATH** key gives you access (via a series of menus) to all the mathematical functions you could ever wish for! See pages 126-171

The **LIB** key is the king of them all! This is the key that allows you to chose which aplet you wish to work in.
What's an aplet? Read on.

The VIEWS key gives a different menu in each aplet. It can be very useful, and is always worth checking out.

So - where's the ON button? Here….

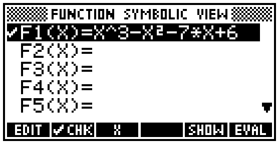


Examples of the effects of each of these keys are shown on the next page, and on the pages that follow.

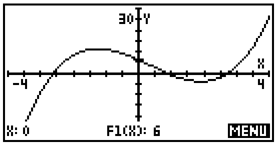
Some Examples

Shown below are snapshots of some typical screens you might see when you press each of the keys shown on page 9. *Exactly what you see depends on which aplet (see next page) is active at the time.* The aplet in use below is the Function aplet, which is used to graph and analyse functions. Notice how the functions listed at the bottom of the screen change in each different view. They relate to the blank programmable keys underneath the screen and their use changes from view to view.

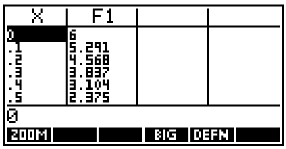
The **SYMB** key:
(set up to graph
$y = x^3 - x^2 - 7x + 6$)



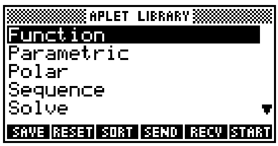
The **PLOT** key:
(after graphing it)



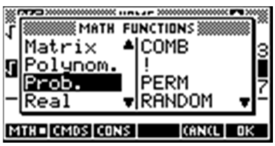
The **NUM** key:
(showing a tabular view
of the same function.)



The **LIB** key:
(used to choose which
aplet is the active one.)



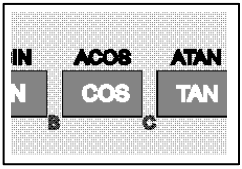
The MATH key:
(showing the Probability
section of the menu.)



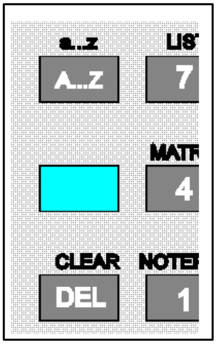
Finding Buttons & Notation Conventions

There are three types of keys/buttons that are used on the HP38G.

The first type are the normal ones that you see on any calculator - the ones that you see in front of you when you look at the calculator. Most of them, of course, have two or more functions.

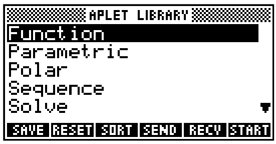


Take for example the **COS** button shown left. If you simply press the button as is, you will get the **COS** function. However if you look at the left side of the calculator, under the **ENTER** key, you will see two keys (the **A..Z** and the **BLUE** keys) that change the function of the button, like the **2ndf** and **INV** keys do on other brands of calculator.

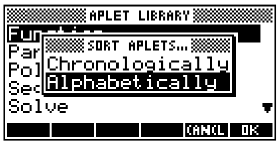


The **BLUE** key is the one that gives you the second function for each button. In the case of the **COS** button, the second function is **ACOS** (arc-**COS** or inverse **COS**). Most buttons have a second function that is obtained via the **BLUE** key. When I want you to use one of these buttons that needs to have the **BLUE** key pressed first I often won't say so. It seems to me that you're intelligent enough to work out for yourself when the **BLUE** key needs to be pressed.

All references to keys that appear on the normal keyboard, whether they need the **BLUE** key or not, are in **boldface**.



The second type of key is the row of blank keys directly under the screen. These keys change their function depending on what you are doing at the time. The easiest way to see this is to turn the calculator on and press the **LIB** key. As you can see in the snapshot on the right, the functions on the programmable keys are listed at the bottom of the screen. All you have to do to use them is to hit the blank button under the definition that you want to use.



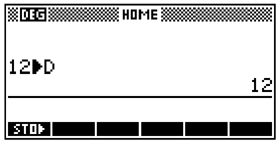
All references to keys of this type are shown in quotes and italics. For example, if I want you to press the button under the SORT label it would be written as '*Sort*'. Do it now and you'll see the screen shown on the right. Notice that the programmable keys have now changed function. Press the one under '*Cancel*'.

Sometimes pressing a key pops up a menu on the screen as you just saw. You use the up/down arrow keys to move the highlight through the menu and make choices by pressing the ENTER key. Choices that are listed in a menu will also usually be written in the same way using italics. As an example, I might say to hit '*Sort*' and choose '*Chronologically*'. By the way, the manual you get with your calculator uses a different convention to this. They write the programmable keys as {{SORT}} and the normal keys as (LIB).

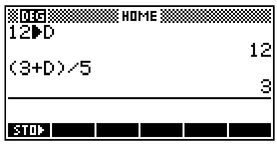
The third way a key can be used is to get letters of the alphabet. This is not so that you can write letters to your friends (although you can do that with the Notepad) but so that you can use pronumerals like X and Y or A and B. The key above the BLUE key labelled A..Z is used to type in letters of the alphabet. The full range of letters is there if you look for them. Lower case letters are obtained by pressing the BLUE key before the A..Z key. If you want to type in more than just a single letter, hold down the A..Z key.

Try this…

If you haven't already, '*Cancel*' out of the menu from the previous screen. Press the HOME key to see the screen on the right. Yours may not be blank like mine but that doesn't matter.



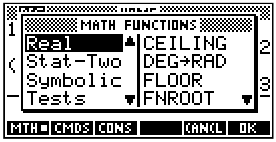
Press 12 and then press the programmable key labeled 'STO➢'. Now press the A..Z key and then the alphabetic D key (on the TAN button). Finally, press the ENTER key. Your screen should look like mine on the right. You have now stored the value 12 into memory D. Each alpha key can be used as a memory.



You can also use these memories in calculations. Type in the following (not forgetting the A..Z button before the D)…. (3+D)/5 ENTER
The calculator will use the value of 12 stored earlier in D to evaluate the expression (see right). In case you haven't worked it out for yourself, the / key is the divide button and the * key is the multiply button.

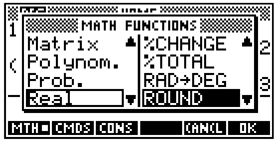
More information on memories and detailed information on the HOME view in general is given on pages 12 - 26.

The calculator also comes with a huge number of mathematical functions that are very useful. They can all be obtained via menus through the **MATH** key. Try pressing the **MATH** button now and you should find your screen looks like the snapshot on the right.

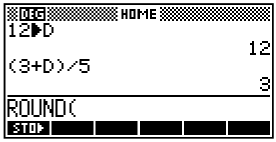


The **MATH** menu is covered in detail on pages 126 - 171 but we will have a brief look now.

The left side of the menu lists the categories of functions. As you use the up/down arrows to scroll through the topics, you'll see the list on the right change. Move down through the left menu until you reach '*Prob.*' (short for Probability) and then one step more and you'll find yourself back at '*Real*'. Now hit the right arrow button and your highlight will move into the right hand menu. Move the highlight down through this menu until you reach '*Round*' (see above). Press **ENTER**.

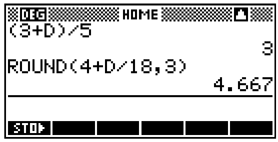


You should now be back **HOME**, with the word **ROUND(** entered in the display as shown right. You can also achieve the same effect by using **A..Z** to type the word in letter by letter.



Now type in: **4+D/18,3)** **ENTER**
(the comma key is next to the + key on the keyboard)

As you can see, the effect was to round off the answer of 4·666666.. to 3 decimal places.



There are shortcuts for obtaining things from the **MATH** menu that are covered later (see page 126).

Everything revolves around Aplets!

The designers of this calculator decided that it was impossible to arrange matters so that such a small number of keys and such a small screen could hold all the things needed for everything that you might want to do with the calculator. Instead they provided a set of "Aplets" for you to use, which effectively means that this is not just one calculator but six (or more), changing character and capabilities as you change aplets.

The best way to think of these aplets is as "environments" within which you can work. Although these environments seem dissimilar when you first start to use them, they all have things in common, such as that the **PLOT** key produces graphs, the **SYMB** key puts you into a screen used to enter equations & rules, and the **NUM** key displays the information in tabular form.

There are six standard aplets available via the **LIB** key. More can be created by you or down loaded from the Internet (see pages 104 and 111) The standard aplets are, in alphabetical order:

The Function aplet
Provides f(x) style graphs, calculus functions etc. It will not only graph but find intercepts, intersections, areas and turning points.

The Parametric aplet
x(t), y(t) style graphs used in Year 11/12. Ever wondered how the ABC logo is produced? Find out when you explore this aplet later.

The Polar aplet
r(θ) style graphs are explored in Year 11/12. Quite apart from their mathematical use, they produce some really lovely patterns!

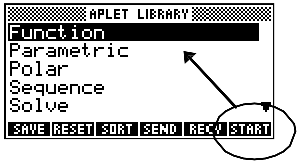
The Sequence aplet
Handles sequences such as $T_n = 2T_{n-1} + 3$; $T_1 = 2$ or $T_n = 2^{n-1}$. Allows you to explore Fibonacci's sequence to your heart's content. Never heard of it? Well, read on.

The Solve aplet
Solves equations for you! Give it an equation such as $A = 2\pi r(r + h)$ and it will solve for any variable if you tell it the values of the other two.

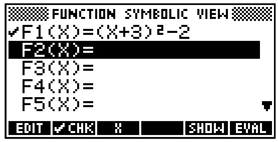
The Statistics aplet
Handles stats data and graphs really well. Data entry is easy, as is editing. Gives you not only the mean but the median and IQR as well. Draws histograms and box & whisker graphs, as well as analysing bivariate data in many different ways.

The *Function* aplet is probably the easiest to understand and also the one you will use most often, so we will have a very quick look at this aplet.

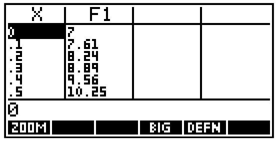
The **LIB** key is used to list all the aplets and to start one up.



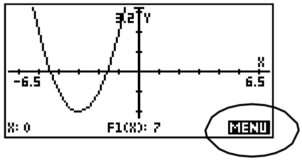
The **SYMB** view is used to enter equations…. It can store up to ten functions. Room for more can be made by making copies of the Function aplet (see 104 - 106)



The **NUM**eric view shows the function in table form…



The **PLOT** view is used to display the function as a graph…



The '*Menu*' button gives access to a number of other useful tools allowing further analysis of the function and its graph.

Although these views are superficially different in other aplets, the basic idea is similar.

Having said that aplets are best thought of as "working environments", it is equally true that aplets are essentially programs, with the standard six simply being built into the calculator. This is a programmable calculator, having its own programming language and able to perform quite sophisticated tasks.

Unless you particularly want to learn about the programming language, there is no reason why you should worry about it. The standard six aplets will cover most, if not all, of your requirements.

However one of the great strengths of the HP38G is its ability to "download" additional aplets (programs) from other HP38G's, from a PC or Mac and even from the Internet. Once aplets are downloaded from the Internet to the PC or Mac a "Connectivity Kit" is available from Hewlett-Packard (and dealers) which allows you to connect a cable from the PC or Mac to your calculator and then transfer the aplets to it.

Once an aplet is on any one calculator, transferring it to another takes only seconds using the built in Infra-red link at the top of each calculator. This is exactly like the remote control of a VCR, and allows two calculators to talk to each other. In the interests of exam security the distance over which they can talk is limited to about 9 to 10cm.

Aplets are available to do many Mathematical tasks such as Bivariate Analysis, Time Series Analysis, exploration of graphs and even some tasks called for in Physics and Chemistry. There are currently only a few Web sites available with aplets but this should increase with time.

The Hewlett-Packard site is the best and is found at…

http://hpcvbbs.external.hp.com:80/calculators/hp38g/aplets/index.html

If you have access to the Web you might wish to check this site out to see the list of aplets and get a feel for their capabilities even though there's no point downloading them without a Connectivity Kit.

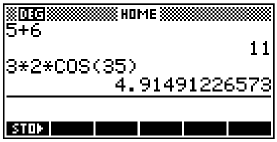
It may not be worth the expense (about $60) for you to buy one of these Connectivity Kits yourself. If your school has decided to specify that you buy the HP38G then they may well have bought at least one kit themselves. They can then download any aplets they want to use into the teacher's calculator, who will then download them into yours via the infra-red link.

The topic of aplets is discussed in more detail in the chapter entitled "Using, copying & creating aplets on the HP38G".

The HOME view

In addition to these aplets, there is also the HOME view, which is independent of all the others. This is accessed via the HOME key (which is just below the LIB key) and is the view in which you will do your routine calculations such as working out 5% of $85, or finding √35. The HOME view is the one of the views that you will often use, so we will explore that view first.

The HOME View and a General Overview



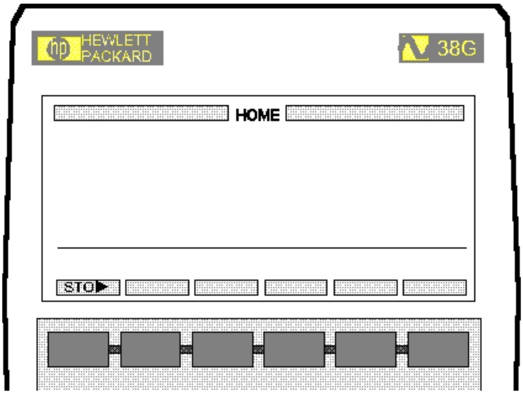
This is the **HOME** base for the calculator. All other aplets can be accessed from it to varying degrees, and all mathematical functions are available in this view. Calculations performed can range from the simple to the complex. You should learn to use this view as efficiently as possible, since a great deal of your work will be done here.

We will explore the **HOME** view and the general use of the calculator in the order:

1. Exploring the Keyboard.
2. Fractions on the HP38G
3. The History.
4. Storing & Retrieving Memories.
5. Referring to other aplets from the **HOME** view.
6. A Brief Look at the **MATH** Menu.

Exploring the Keyboard

It is worth looking over the keys on the calculator to familiarise yourself with the mathematical functions available. If we examine them group by group, you will see that they tend to fall into two categories - those which are specific to the use of aplets, and those which are commonly used in mathematical calculations.

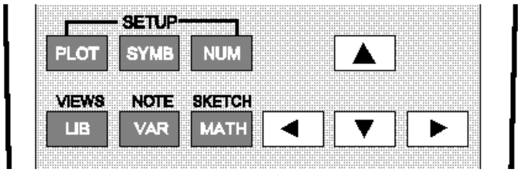


The first row of blank keys are usually aplet related. The reason they have no label is that their meaning is redefined in different situations - they are the ‘programmable keys’. The current meaning of each key is listed in the row of boxes at the bottom of the screen.

In the **HOME** view shown above, the only key that has been given a function is the far left one. It has the function labeled **STO➢**, and is used to store values in memory (more later). Shown on the right is a snapshot of the **LIB** view, in which all the keys have definitions.

Note that it is worth developing the habit of checking the screen to see if any of those keys have been given meanings. In many views, the programmable keys have been set up with useful shortcuts and functions.

The next two rows of keys are mainly aplet related, so we'll deal with them as a group.

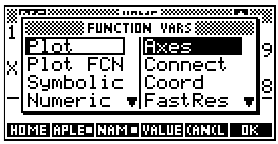


The arrow keys on the right are used in a variety of different views, usually to move the highlight or the cursor (a small cross) around on the screen.

The LIB key is used to choose between the various different aplets available. Everything in the HP38G tends to revolve around aplets, which you can think of either as miniature programs or as environments within which you can work. The HP38G comes with six standard aplets - Function, Sequence, Solve, Statistics, Parametric and Polar. Which one you want to work in is chosen via the LIB key.

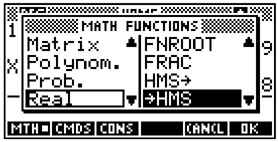
In addition to these six, *which are covered in great detail in the chapters following this,* many more aplets are available from the Internet (probably via your teacher) which have been written by other programmers. Once these are downloaded into your calculator they can also be accessed via the LIB key. For more detail on aplets, see the brief summary later in this section, or the chapter entitled "Creating Your Own Aplets".

The PLOT, SYMB and NUM keys are used within aplets to move from view to view - for example, within the Function aplet, the PLOT view shows the graph, the SYMB view shows the equations and the NUM view shows the equations in tabular (table-like) format.



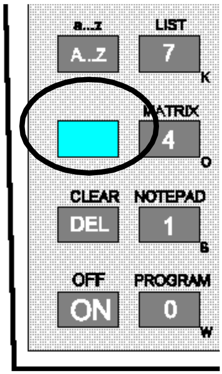
The VAR key is used (mainly by programmers) to access all the different variables stored by the calculator. Shown right are two views of the VAR screen, the first from the HOME list showing the graphic variables (memories) G1, G2…. and the next from the APLET list showing some of the variables in the PLOT controlling set. *The* VAR *key is not normally one that you need access to*, and you probably did not follow much of this 'explanation'. Don't worry. The key is really used only by those programmers who want to produce more complex aplets of their own and is discussed in more detail elsewhere.

The **MATH** key provides access to a library of mathematical functions. Some of the more common ones have keys of their own, but there is a limit to the number of keys that one can put on a calculator before the user gets too frustrated at having to search for every key needed. Hence the **MATH** key.



The **MATH** menu lists all those functions that would not fit onto the keyboard. Shown in the screen snapshot right is a small selection of the total list. For a listing of almost all the functions, together with examples of their use, see the chapter entitled “The MATHS Menu” starting on page 126.

On each of the keys discussed so far you will see another function written in blue (aqua) above the button. As with most calculators, the HP38G gets twice the action out of every key by having a second function for each one.

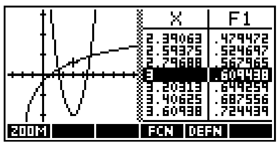


This second function is accessed via the **BLUE** key on the left side of the calculator. Although this manual will sometimes tell you explicitly to press this key, in most cases it will be assumed that you are capable of working out for yourself when it is necessary to press it.

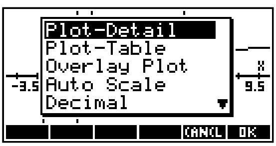
The **SETUP** keys (above **PLOT**, **SYMB** and **NUM**) are used to ‘set up’ their respective views. For example, the **PLOT SETUP** screen controls things like axes, labels etc. Their use changes in different aplets, so for more information see the explanations in the chapters dealing with the various aplets, particularly with the Function aplet.

The **VIEWS** key pops up a menu from which you can choose various options. This menu is provided for two purposes…

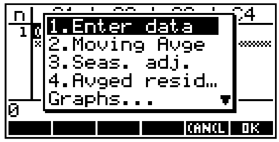
Firstly, within the standard aplets (Function, Sequence, Solve etc.) it provides a list of special views available to enhance the **PLOT** view.



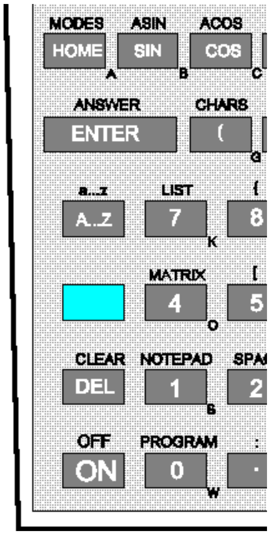
For example while the standard **PLOT** screen just provides a graph, the **VIEWS** menu allows you to use a split screen such as shown above right. More information is given on this use of the **VIEWS** menu in the chapter dealing with the Function aplet. Part of the standard **VIEWS** menu is shown left.



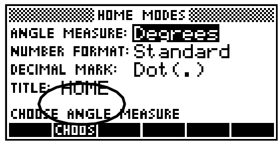
In addition to this first use, the **VIEWS** key also has a much more important role when using aplets which have been downloaded from the Internet (perhaps via your teacher). When a programmer writes an additional aplet for the HP38G, he or she will usually need to provide a menu from which you can control and use it. This menu is always tied to the **VIEWS** key and replaces the menu that is normally found on the key. For example, the snapshot shown right is of a **VIEWS** menu taken from an aplet designed to analyse and graph Time Series data.



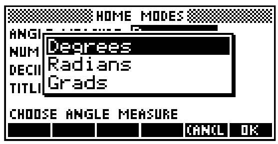
Information on the use of the **SKETCH** and **NOTE** keys can be found in the chapters entitled "Using the Sketchpad with the HP38G" and "Using the Notepad Catalogue with the HP38G". As a quick summary, any aplet (including the standard six) has a note and a sketch associated with it. For the standard six these will usually be blank unless you have added to them yourself. The main use for them comes with aplets downloaded from the Internet. The instructions for using the aplet are usually included with the aplet in note form, sometimes with an accompanying sketch.



The next group of keys is shown on the left. The **HOME** key allows you to change into the **HOME** view from wherever you are. Above it is the **MODES** key, accessed by pressing **BLUE** first.



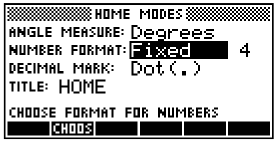
The **MODES** view (see right) controls the numeric format used in displaying numbers and angles in all aplets. At the bottom of the screen you will see that one of the programmable keys has been given the function '*Choose*'. Pressing this key pops up a menu of choices from which you can select the option which suits you.



If you don't want to use the menu, then pressing the '+' key repeatedly (instead of '*Choos*') will cycle through the choices without a menu. This can be a lot faster if there are only one or two choices.

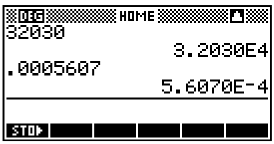
The options for 'Number format:' are shown on the right. **Standard** is probably best in most cases, although it can be a little annoying to constantly have 12 significant figures displayed.

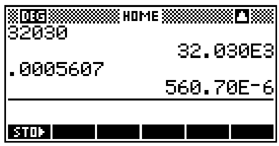
Using Fixed, Scientific and Engineering formats all need you to also specify how many decimal places should be displayed. The screenshot on the right shows the setting of Fixed 4, which rounds everything off to 4 decimal places. You can of course change the 4 to any other number you want.



A setting of Scientific notation ensures that any results are displayed in scientific notation. Of course, the calculator's idea of scientific notation may not be the same as yours. Since the calculator has no way of displaying powers as superscripts, a result of $3\cdot 203\times10^4$ has to be displayed as 3.203E4. The alternative of Engineering notation is very similar to Scientific, except that powers are always displayed as multiples of 3. This is done to allow easy conversion in the Metric system, which also works in multiples of 1000.

The screens below show the same numbers displayed as Fixed 4, Scientific 4 and Engineering 4.



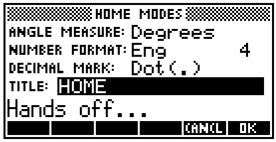


A quick tip… when you '*Zoom*' in (or out) on a graph an you have labels switched on for the axes, you end up with axes whose numeric labels are horrible decimals. This can be fixed either by changing the values in **PLOT SETUP** to better ones, or by having previously set the Number Format to Fixed 2. Changing to Fixed 2 afterwards will not help, since the setting only affects numbers drawn from then on. If you see the problem start to develop (the axes are drawn first) then just hit the '*Pause*' button, change to Fixed 2 and then hit the **PLOT** button again.

The setting of Fraction 4 is deceptive in some important ways and is discussed in more detail on pages 19 - 21.

The next alternative of 'Decimal Mark:' controls the character which is used as a decimal point. In many countries, especially the Asian ones, a comma is used instead of a decimal point. If you opt to use a comma rather than a full stop then any places where a comma would normally be used (such as in listing sets) will swap to using a full stop.

The final option of 'Title:' controls the title which is displayed at the top of the **HOME** page. If you move the highlight onto that line you might like to try typing in a new title. The **A..Z** key under the **ENTER** key is used to obtain alphabetical characters, while pressing **BLUE** first gives a lower case letter. The alphabet can be found in red on each of the keys, starting with '**A**' on the **HOME** key. If you want spaces in the title, use the space found on the '**2**' key (pressing **BLUE** first).

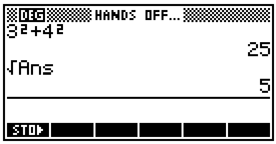


Moving back to our tour of the keyboard, the next key is the **ENTER** key. This is used as an all purpose "I've finished - do your thing!" signal to the calculator. In situations where you would normally press the '**=**' key on most calculators, press the **ENTER** key instead.

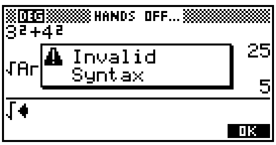
Above this key is the **ANSWER** key. This can be used to retrieve the final value of the last calculation done. An example of this is shown right.

Having a key like this becomes more important in a D.A.L. calculator (Direct Algebraic Logic). In the old style calculators, an expression like $\sqrt{3^2+4^2}$ could be evaluated by pressing [3] [x^2] [+] [4] [x^2] [=] [√] [=] because even though the expression is *written* as $\sqrt{25}$ the old calculators required you to enter it as $25\sqrt{\ }$. With the new calculators this doesn't work (try it!) because they require you to enter it in the same order as it is written. On a D.A.L. calculator like the HP38G you have to put the previous answer *after* the √. The equivalent set of keystrokes on a D.A.L. style calculator is:

[3] [x^2] [+] [4] [x^2] [ENTER] [√] [BLUE] [ANSWER] [ENTER]

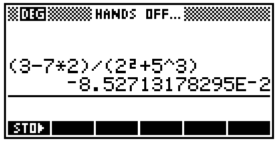


This is shown in the snapshot right.

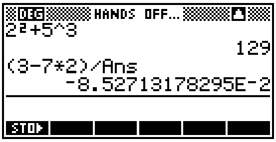


Pressing the √ key with nothing after it will simply produce the error message shown left, because the calculator is saying "find the square root of what?".

If you are not terribly confident about using brackets, then the ANSWER key can be quite useful. For example, you could calculate the value of $\dfrac{3 - 7 \times 2}{2^2 + 5^3}$ by using brackets…

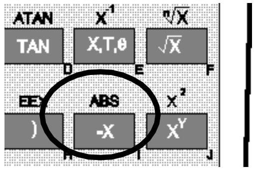


…. or you could use the ANSWER key.



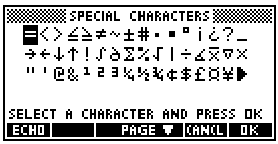
An alternative to using the **ANSWER** key is to use the History facility along with the '*Copy*' function. This is discussed later.

Another example of the influence that D.A.L. style thinking has on the result is the provision of a 'negative' key (shown right).

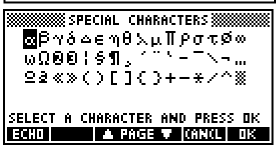


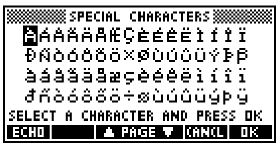
If you want to calculate the value of (say) –2 – (–9) then you *must* use the negative key before the 2 and the 9 rather than the subtract key.
If you press the [–] key before the 2 instead of the [-x] key, then the calculator will enter instead: **Ans - 2**!

The reason this happens is that a subtract cannot start a 'sentence' in mathematics, while a negative can. Since the subtract can't come first, the calculator decides that you must have intended to *subtract from the previous answer*. Hence the sudden appearance of an **Ans**.



The next key to be examined is the **CHARS** key. This key is used to access all of the many characters that are used occasionally but not often enough to bother putting on the keyboard. Pressing **BLUE CHARS** will pop up the screen on the right. One of the programmable keys is set to be a '*Page Down*' key, and will give access to two more pages of characters.





These special characters are obtained by pressing the programmable key labeled '*Echo*'. You can press '*Echo*' as many times as you need to in order to obtain multiple characters. When you have as many as you need, press the '*Ok*' button.

The next key is the DEL key. This serves as a backspace key when typing in formulae or calculations, erasing the last character typed. If you have used the left/right arrow keys to move around within a line of typing, then the DEL key will delete the character above the flashing cursor. Another use for the DEL key is to restore factory settings. For example, if you move back into the MODES screen and move the highlight down onto the Title, then pressing the DEL key will restore the word HOME. The CLEAR key above DEL can be thought of as a kind of 'super delete' key. For example, where pressing DEL would erase one formula only, CLEAR will erase the whole set of ten. Pressing CLEAR in the MODES view would restore factory settings to all the entries.

The remaining buttons of LIST, MATRIX, NOTEPAD and PROGRAM have special chapters of their own.

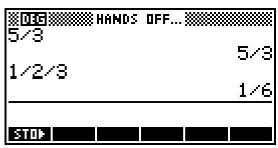
Fractions on the HP38G

Earlier in this section we examined the use of the MODES view, and the meaning of Number Format. We discussed the use of the settings Fixed, Scientific and Engineering, but left Fraction for later. The final setting of Fraction is a little deceptive and has a few traps that lie in wait for the unwary.

Most calculators have a fraction key, often labeled $\boxed{a\,{}^{b}\!/_{c}}$, that allows you to input (say) $1\frac{2}{3}$ as 1¬2¬3 or something similar. What these calculators usually won't do is allow you to mix fractions and decimals. If you type in something like $1\frac{2}{3}$ + 3· 7 then you will receive an a decimal result - the calculator will not attempt to convert the 3· 7 into a fraction. The reason for this is that while some decimals like 0.25 are easy to convert to a fraction, others, such as recurring ones, are not so easy. Hence most calculator designers opt for the easy way of switching to a decimal answer in any mixture of fractions and decimals.

The makers of the HP38G have taken a ***very*** different approach. Once you select Fraction mode, *all numbers become fractions - including any decimals.* If you are only going to be using fractions from that point on, then this will not cause a problem as long as you bear the following two points in mind….

The first point is that there seems to be no provision for inputting mixed fractions such as $1\frac{2}{3}$. Fractions are entered using the divide key $\boxed{/}$ and, while the calculator is quite happy with improper fractions such as 5/3, it (correctly) interprets 1/2/3 as (1/2)/3 (one half divided by 3) and gives a result of 1/6 !

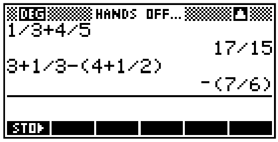


The solution to this problem is simply to enter mixed fractions as (1+2/3). While the brackets are often not strictly necessary it is a good idea to include them anyway or "Order of Operations" problems may occur, such as $1\frac{2}{3} * \frac{1}{5}$ being interpreted as 1+(2/3*1/5) rather than as (1+2/3)*1/5.

Some examples are… (using Fraction 4 or higher)

1. $\frac{1}{3}+\frac{4}{5}=\frac{17}{15}$

2. $3\frac{1}{3}-4\frac{1}{2}=-1\frac{1}{6}$

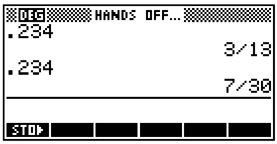


The second important point involves a drawback of the approach taken by the HP38G, and lies in the method used to convert decimals to fractions.

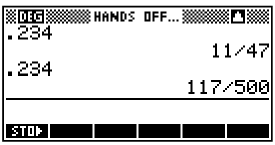
The method the HP38G uses is basically to generate (internally and unseen by you) a series of continued fractions which are *approximations* to the decimal you typed in. The final fractional approximation chosen for use is the first one found which is 'sufficiently close' to the decimal. The trap lies in what constitutes 'sufficiently close', and this is determined by the '4' in Fraction 4. *Very roughly*, the calculator will use the first fraction it finds in its process of approximation which matches the decimal to that
number of significant digits. The process is actually more complex than this, but it will do for an approximation.

For example, a setting in the **MODES** view of…

Fraction 1 changes 0.234 to $\frac{3}{13}$
which is actually 0.2307692…
(matching to at least 1 sig. fig.)



Fraction 2 changes 0.234 to $\frac{7}{30}$
which is actually 0.2333333…
(matching to at least 2 sig. fig.)

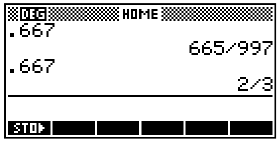


Fraction 3 changes 0.234 to $\frac{11}{47}$
which is actually 0.2340425…
(matching to at least 3 sig. fig.)

Fraction 4 changes 0.234 to $\frac{117}{500}\left(\text{or } \frac{234}{100}\right)$ which is exactly 0.234

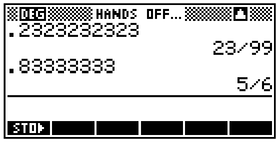
Basically, the value of 'n' in 'Fraction n' affects the degree of precision used in converting the decimal to a fraction.

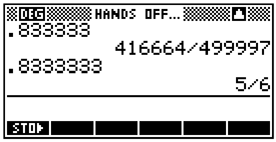
This can be useful *if you understand what is happening*. As you can see in the screenshot right, a setting of Fraction 4 produces a strange (but actually fairly accurate) result for 0.667, while changing to a setting of Fraction 2 will give a result of 2/3. In other words, what makes this approach taken by the HP38G useful is that it is often capable of producing results which may be strictly less accurate but are probably closer to what was intended by the 0.667 in the first place.



If you are wanting to use this facility to convert decimals to fractions, here are some tips…

- if you are converting a recurring decimal, set to about Fraction 6 and ensure that you include more than 6 decimal places in the number you enter. As you can see in the second screenshot, not including enough decimal places does not produce good results!

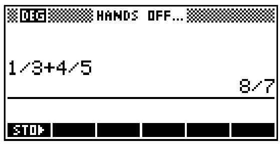




- if you are converting an exact decimal to a fraction, then set to a Fraction value at least 2 more than the number of decimal places in the value entered. Both examples right were done at Fraction 6.

Forgetting the current setting of Fraction can produce some unfortunate effects. For example, at Fraction 2, the value of 123.456 becomes 123, with the 0.456 dropped entirely! Beware!

This need for a correct setting of Fraction n *extends even to working purely with fractions*. One of the earlier examples at the top of the previous page was 1/3 + 4/5 = 17/15. If you use a setting of only Fraction 2 to perform this, you will find to your amazement that 1/3 + 4/5 = 8/7 ! The reason is that the 1/3 and 4/5 were converted to decimals and added to give 1.133333…. This was converted back to a fraction (needing to match only to 2 sig. fig.) to give 8/7 (which is 1.1428..).

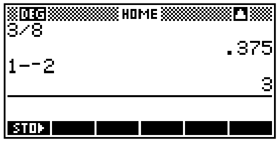


In conclusion, while it is not suggested that you entirely dismiss the use of the Fraction format, it is important that you understand and remember its limitations.

The History

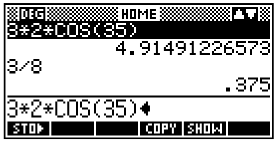
The **HOME** page maintains a record of all your calculations called the History. You can re-use any of the calculations or their results in subsequent calculations.

Try this for yourself. Type in a series of about eight calculations, pressing the **ENTER** key after each one to tell the calculator to perform the calculation. You will now be looking at a screen similar to the one on the right.



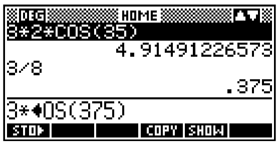
If you now press the up arrow key, a highlighted bar will move up the screen. When you reach the top of the screen the previous calculations will scroll into view.

You may have noticed that as soon as the highlight appeared so did two labels at the bottom of the screen. If you now press the unmarked button under '*Copy*' (there is a row of them under the screen) you will find that the highlighted calculation will be copied on the edit line. This is shown in the screen shot on the right.



At this point you can use the left and right arrows and the **DEL** key to edit the calculation by removing some of the characters and/or adding to it.

For example, in the screenshot below right, the calculation of 3*2*COS(35) has been edited to 3*COS(375).



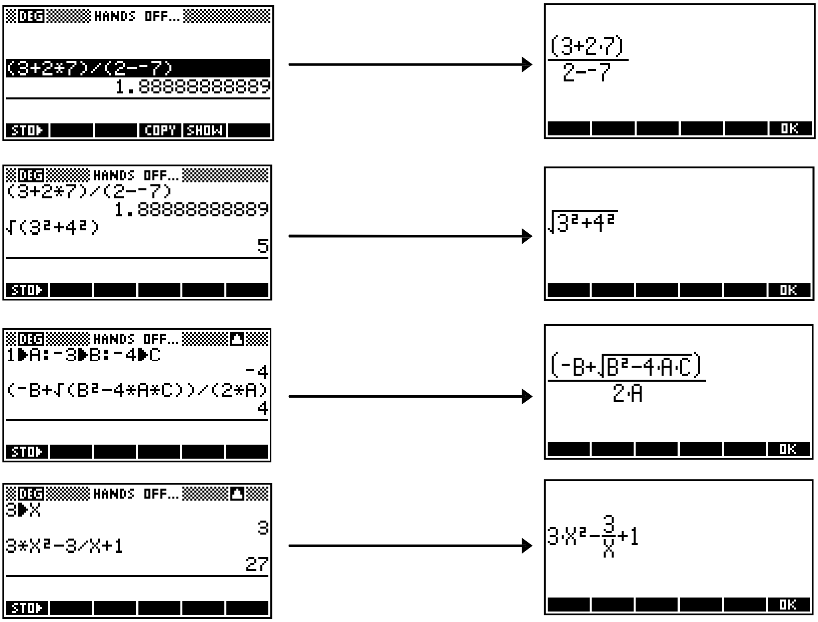
Pressing enter will now cause this new calculation to be performed.

Some tips…

- Pressing **ON** instead of **ENTER** will erase the whole line.
- Pressing **BLUE CLEAR** erases the whole history. This is worth doing regularly, since the history uses memory that may be needed for other things.
- You can '*Copy*' pieces and results from any number of different lines in building your new expression.

Next to the '*Copy*' key you will see another programmable key labeled '*Show*'. This key will display an expression the way you would write it on the page rather than in the somewhat difficult to read style that is forced on the calculator when it must show the whole expression on one line.

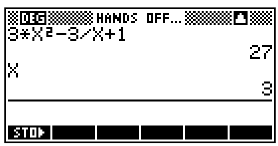
Some examples…



Storing and Retrieving Memories

Each of the alphabetic characters shown in red on the keys can function as a memory. Some examples of this are shown in the third and fourth examples above where the values of 1, -3 and -4 are stored into A, B and C and the value of 3 is stored into X. All of this 'storing' of values is done with the 'STO➤' key, which is one of the programmable keys listed at the bottom of the screen in the **HOME** view. There are ways listed in the official manual of obtaining even more memories than these 26 alphabetic ones (such as storing as a list) but 26 is enough for most people.

Once a value is stored into the appropriate memory, it can be used in any calculation simply by typing the letter into the place where you would normally use the value. Just typing the letter and pressing **ENTER** will display the contents of that memory (see right).

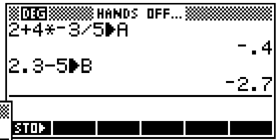


There is an advantage to storing results in memories, particularly if they are long decimals, or if you're going to be re-using the result a number of times.

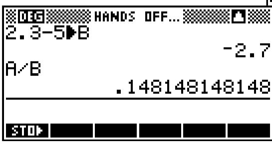
As an example, we will perform the calculation of $\dfrac{2+\dfrac{4\times(-3)}{5}}{2\cdot 3-5}$. We will do this in two stages, calculating the top and bottom of the fraction and storing the results in memories.

Firstly the top of the fraction, storing the result in memory **A**…

Now the bottom, storing in **B** ….



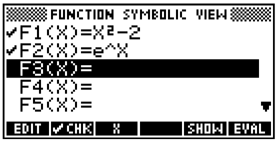
And then finally the result…



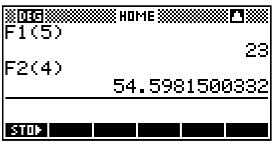
Referring to other aplets from the HOME view.

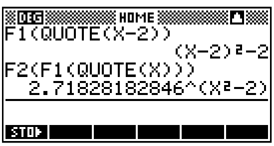
Once functions or sequences have been defined in other aplets, they can be referenced in the HOME view.

e.g.1 Suppose we use the Function aplet to define F1(X)=X²-2 and F2(X)=e^X as shown right.



These functions now become accessible not only from within the **HOME** view but also within any other aplet also. This is shown by the screen shots below.

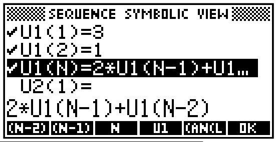




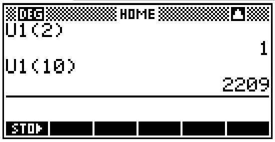
The way the results are shown will (of course) depend on your settings in the **MODES** view.
Even algebraic references can be made, as shown left. The reason for the QUOTE(X-2) rather than just X-2, is that using X-2 would tell the calculator to use the value currently stored in memory X, while QUOTE() tells it to use the symbol. The QUOTE function is available through the **MATH** menu under Symbolic.

This type of work is actually *far* more easily done in the Function aplet, where QUOTE is not needed and the '*Eval*' key does a more efficient job. See pages 38.

e.g.2 Suppose we use the Sequence aplet to define a sequence with $T_1 = 3$, $T_2 = 1$ and $T_{n+1} = 2T_n + T_{n-1}$.



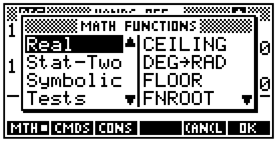
In the HOME view, the sequence values can be referred to as easily as the function values in the previous example.



Shown in the chapter on the Sequence aplet is an example of referring to a sequence from within the Solve aplet.

A Brief Look at the MATH Menu

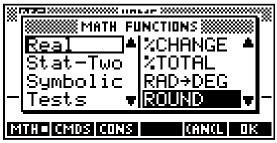
The **MATH** menu holds all the functions that are not used often enough to be worth a button of their own. There is a *huge* supply of functions available, many of them extremely powerful. When you press the **MATH** button you will see the pop up screen shown right. The left hand menu is a list of topics.



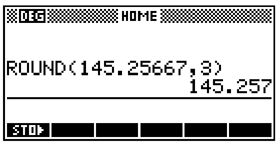
Scroll through the topics until you find the one you want, then use the right arrow button to move into the list of functions for that topic.

For example:

The function **ROUND** will round off to a specified number of decimal places.



E.g. round off 145.25667 to 3 decimal places.



- Press the **MATH** button & move immediately right (→) into the Real group of functions.
- Press the '**R**' key (the * button) to move to the first of the functions beginning with 'R', then move down one more function to **ROUND**. Press **ENTER.**
- Now finish off the command and press **ENTER** again to see the result.

Summary

1. The up/down arrow key moves the history highlight through the record of previous calculations. When the highlight is visible, the '*Copy*' key can be used to retrieve any earlier results for editing using the left/right arrow keys and the DEL key.

2. Care must be taken to ensure the your idea of order of operations agrees with the calculator's.
   For example: $(-5)^2$ must be entered as $(-5)^2$ rather than as -5^2
   $\sqrt{5+4}$ must be entered as √(5+4) rather than √5+4
   $\frac{2+4}{3-7}$ must be entered as (2+4)/(3-7) rather than 2+4/3-7.

1. The ANSWER key can be used to retrieve the results of the calculation immediately preceding the one you're working on. E.g. √(5+Ans)

2. The DEL key can be used to erase single lines in the history. The BLUE CLEAR key will delete the entire history. Regular clearing will ensure that memory is not taken up with material that is not required.

3. The '*Show*' key will rewrite a line of calculation as you would see it on the page.

4. The MODES view can be used to set the format in which numbers are displayed on the HOME page, and to choose the angle measure which is to be used. ***The* Fraction *mode is dangerous to use if you don't understand it.***

5. Numbers are stored in memory using the programmable key labeled STO ➤. The stored values can then be used by simply putting the letter in the expression in place of the number.

> For more information on the complete set of mathematical functions available in the HOME view (and everywhere else for that matter) see the chapter entitled '***The MATH menu'***.

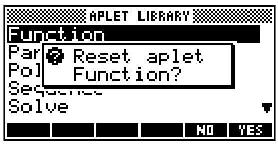
The Function Aplet

The Function aplet is probably the one that you will use most of all.
It allows you to:

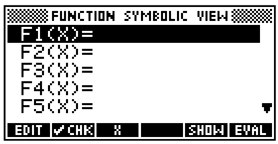
- graph equations.
- find intercepts.
- find turning points (maxima/minima)
- find areas under curves.
- find areas between curves.
- find gradients.
- find derivatives algebraically.
- find integrals algebraically.
- evaluate functions at particular values.
- graph and also evaluate algebraically expressions such as f(g(x)) or f(x+2).

The first step for any aplet is to choose it in the Aplet Library. Press the **LIB** key and you will see something similar to the screen on the right. Use the arrow keys to move the highlight up or down until the Function aplet is selected. Now, looking at the list of programmable functions at the bottom of the screen, you should see labels of '*Start*' and '*Reset*'.

Press the key under '*Reset*' first. You'll see the message shown right - press the '*Yes*' button. The reason for doing this is to clear out any functions that you may have put in there while playing around, and so to ensure that what you see will be the same as the screen snapshots shown to you.



Now press the '*Start*' key. When you do, your screen should change so that it appears like the one on the right. Notice the screen title so that you will know where you are (if you didn't already). This is called the **SYMB** (Symbolic) view.



Note: Pressing **ENTER** here would have had the same effect. Whenever there is an obvious choice (such as here, or if the only choices were '*Cancel*' or '*Ok*') then pressing **ENTER** will usually produce the desired effect.

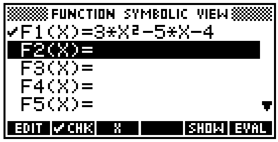
Whenever you enter an aplet, one of the keys which usually changes its function is the key labelled X,T,θ. As its label suggests, it supplies an X, or a T, or a θ, depending on which aplet you are in.

Let's use that key to produce a graph of a quadratic $y = 3x^2 - 5x - 4$.

Using the up/down arrows, move the cursor (if necessary) to the line F1(X) = . Type in:

3 | X,T,θ. | BLUE | X^2 | - | 5 | X,T,θ. | - | 4 | ENTER

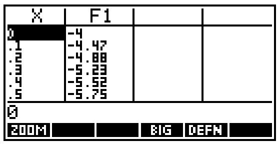
This will produce the screen shown on the right. Notice the tick next to the function. The tick is to signify that this function is to be graphed, so that if you had (say) five functions entered but only wanted numbers 1, 3 and 4 graphed, you could simply ensure that only F1(X), F3(X) and F4(X) were ticked.



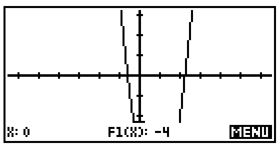
The key that turns the tick on and off is one of the screen keys - the one labelled with the '✓*CHK*'. In case you're wondering, the CHK is short for 'Check', because the Americans call 'Tick' marks 'Check' marks.

Try turning the tick on and off for function F1(X). Remember, the highlight has to be on the function before the tick can be changed. Make sure it's on when finished.

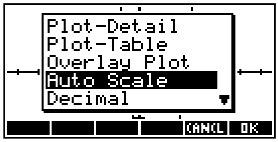
If you now press the **NUM** key, you will see the screen on the right. It shows the calculated function values for F1(X), starting at zero and increasing in steps of 0.1 Make sure the highlight is in the X column, and then press **4 ENTER**. You will find that the numbers will now start at 4 instead of zero. It is also possible to change the step size via the '*Zoom*' button, which can be convenient at times, particularly for trig functions. This will be covered later (see page 51).



Now try pressing the **PLOT** key. The graph you'll see will not be a terribly useful one (see right) because the axes will not be set up correctly. We'll look next at how to do this.

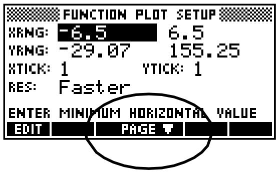


One of the easiest ways to set up the axes properly for a function whose shape is not known in advance is to let the calculator suggest a suitable scale. This is done using the 'AutoScale' option in the **VIEWS** menu (see pages 46 - 51 for more information on the **VIEWS** menu. Also see page 50 for a way that offers advantages over this method but is not as quick).



Press the **BLUE** key and then the **VIEWS** key (it's above the **PLOT** key). Use the arrow keys to scroll down to 'AutoScale' and press **ENTER**. The calculator will adjust the y axis in an attempt to fit as much of the graph on to the screen as possible given the x axis you have chosen. The drawback is that it doesn't choose 'nice' scales such as we would choose (going up in 0.2's or 5's or 40's etc.) so we really need to tidy up its choice a little. If you look at the y axis in particular, you'll see that the tick marks are so close together that it looks like a solid line!

This tidying is done in the **PLOT SETUP** view. If you look at the **PLOT, SYMB** and **NUM** keys you will see the word '**SETUP**' above them. The **SETUP** view for each of these keys is obtained via the **BLUE** key.



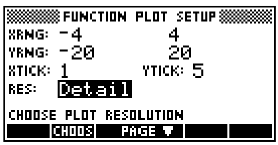
If you press **BLUE** then **PLOT SETUP** you will see the view on the right.

There are two pages to this view (see the '*Page* ∇'key at the bottom of the screen). The first page is used to set axes.

Move the highlight to 'XRng:' and type in **-4**. (see box below)

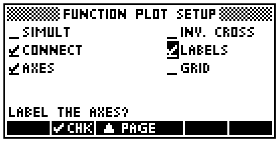
> **NOTE**: <u>Don't</u> use the subtract key to input a negative. You MUST use the key labelled **-x** which is in the same row as the **ENTER** key.

Type in **4** for the other 'XRng:' value, then **-20** and **20** for the 'YRng:' values. When you've done this, move the highlight to 'Ytick:' and change it to **5**.

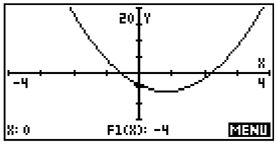


Move the highlight to 'Res:' (short for 'Resolution') and press the '*Choos*' key. You will see that you have a choice of 'Faster' or 'More Detail'. Choose 'More Detail'. Your view should now look like the snapshot on the right.

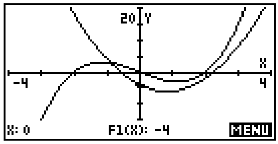
Now press the '*Page* ∇' key. You will now be looking at the screen shown right. Using the arrow keys to move the highlight, make sure that your CHKs match the ones in my snapshot. (See the next page for an explanation of all those ticks.)



Now press **PLOT** again. Perfect!

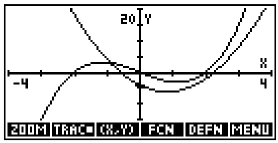


The next stage of our exploration works better if we have two graphs on the screen, so press the **SYMB** key, enter the function $F2(x) = x*(x-2)*(x+2)$ exactly as you see it (minus the 'F2(X)=' part of course). Make sure both functions are ticked, then press the **PLOT** button. Your display should now look like…



If you look at the programmable key list at the bottom of the screen you will see only a single entry, labelled '*Menu*'.

If you press the button under it, your screen will change to look like the one on the right.

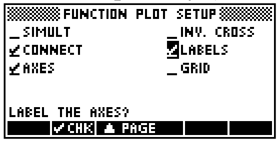


Press it again and the screen will clear completely. The same button will bring the list of functions back again too.

See page 50 for a good method of quickly graphing a function whose appearance you do not know in advance. Note: You may find that you won't follow it properly until you read the pages in between.

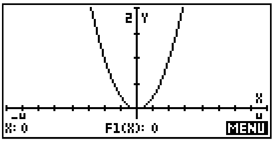
We'll look at each of these functions on the menu bar in turn, but not in the order they appear on the screen. Before we do, let's go back and have a look at the meaning of the CHKs (ticks) on the second page of **PLOT SETUP**.

The first tick '*Simult*' controls whether each graph is drawn separately (one after the other) or whether they are all drawn at the same time (from left to right on the screen). Drawing the graphs simultaneously saves quite a bit of time, but makes it difficult to tell which graph is which when drawing multiple graphs.

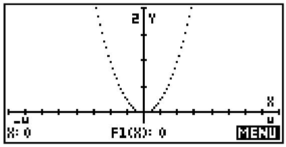


The second tick '*Conect*' controls whether the separate dots that make up a graph are connected with lines or left as dots.

Eg.



vs…

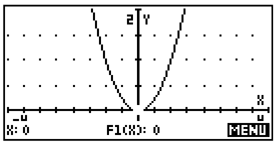


If your graph is discontinuous, for example as a piecewise defined function might be (see page 45), then you might choose to unCHK '*Connect*'.

The third tick '*Axes*' controls whether axes are drawn. The fourth '*Inv.Cross*' controls the appearance of the cursor cross that can be moved by the arrow keys. It is best if you try this one yourself to see the effect.

The fourth tick '*Labels*' controls whether labels (X, Y and numbers) are put on the axes. The only time this causes problems is if the scale is odd, causing the ticks to have many decimal places. See page 51 for an example of a trig graph that was a problem until the labels were changed to be only 4 d.p.

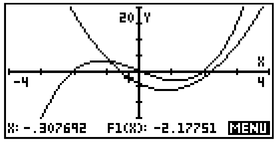
The fifth and last tick '*Grid*' causes a grid of dots to be drawn on the screen (see right).



The Menu Bar functions

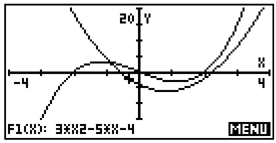
Trace

'*Trace*' is quite a useful tool. The dot next to the word means that it is currently switched on. You can press the button underneath to switch it off, but leave it on for now. With '*Trace*' switched on, press the left arrow 5 or 6 times. You will see a very small cross (or cursor) move along the F1(X) function. The up/down arrow moves the cursor from function to function. Try moving the cursor to F2(X), and then press the button labelled '*(x,y)*'. You will find that the co-ordinates of the cursor will appear at the bottom of the screen, changing as you move the it. Unfortunately, the jumps in x values as you move the cursor are not usually a useful size. It is possible to reset the axes so that each pixel (each left/right jump) is 0.1 exactly using the **VIEWS** button and then choosing **Decimal** (see page 50), but this resets the scales to $-6\cdot5 \le x \le 6\cdot5$ on the x axis and to $-3\cdot 2 \le y \le 3\cdot 2$ on the y axis, which may not be what is best to display the graph.



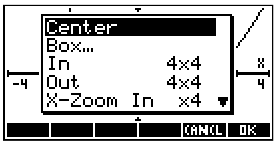
Defn

Press the **MENU** key to bring the function list back and then press the button labelled '*DEFN*' (short for '*Definition*'). You will find that the equation is now listed at the bottom of the screen. The up/down arrows will move the cursor from F1(X) to F2(X), with the definition changing as it does so. This is extremely useful if you have multiple functions displayed.

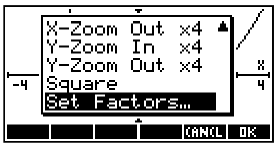


The Zoom functions

The next menu key we'll examine is '*Zoom*'. Pressing the button under '*Zoom*' pops up a new menu, shown right.



The menu is longer than will show in one screen height, so I've included two screen shots to show the whole menu.

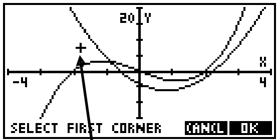


The list which follows covers the purpose of each of these options…

'*Center*' This redraws the graph with the same scale for each axis but centred around the current position of the cursor. If you have a 'nice' scale, this will preserve it, while showing perhaps a more interesting section of graph.

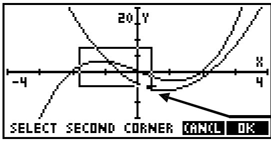
'*In/Out*' These two options zoom in or out by adjusting the scales by the factor shown. The default factor is 4x4 but this can be adjusted through the '*Set Zoom Factor*' option later in the menu. I find the most useful settings are either 5x5 or 2x2.

'*Box…*' This is the most useful of the '*Zoom*' commands. When you choose this option a message will appear at the bottom of the screen asking you to 'Select first corner'. If you use the arrow keys to move the cursor to one corner of a rectangle containing the part of the graph you want to zoom into and then press **ENTER**, the message will change to 'Select second corner'. As you move the cursor this time to a position at the diagonally opposite corner of a box, the box will appear on the screen.



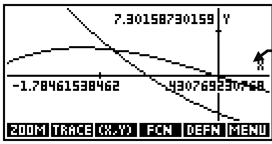
The cursor positioned at one corner of a box.

Pressing '*Ok*' expands the box to fill the screen.



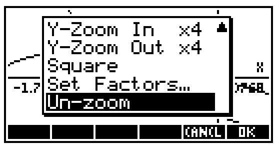
…and at the other corner.

You'll notice that the scale has been disrupted so that the labels are no longer very helpful. A quick switch into **PLOT SETUP** would allow you to choose better end points for the axes.



…and finally the result.

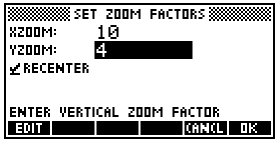
Rather than doing that however, try looking at the '*Zoom*' menu again. If you scroll down right to the end of it, you will find an option that was not there before - '*UnZoom*'. If you choose this option, the screen will go back to the way it was before you did the '*Zoom*'. If you see that the graph is going wrong while it is forming, you can press '*Pause*' and then '*UnZoom*'.



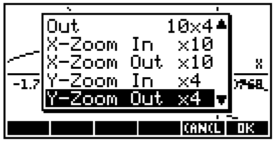
This is worth remembering!

‘*X-Zoom In/Out x4’* and ‘*Y-Zoom In/Out x4*’

These two options allow you to zoom in (or out) by a factor of 4 on either axis.



The factors can be set using the ‘*Set Factors…*’ option, which gives you access to the view shown above right. Changing the x factor to 10, is reflected in the ‘*Zoom*’ menu as you can see in the second screen snapshot. You will also see a CHK mark next to an option called ‘Recenter’. If this is CHKed then the graph will be redrawn with the current position of the cursor as its centre.

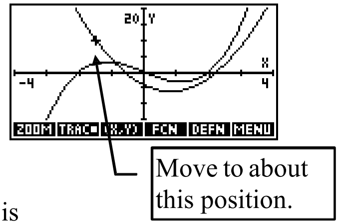


‘*Square*’

This option changes the vertical scale to match the horizontal scale.

The FCN Function menu

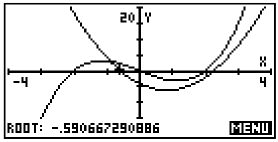
Before continuing, set the axes back to the way we set them on page 29 using **PLOT SETUP**. Then, looking at the menu functions again, you will see that the only one we have not yet examined is the one labelled ‘*FCN*’. This button pops up the Function Tools menu.



Before you use this button, move the cursor so that it is in roughly the position shown above right. You’ll also need to have ‘*Trace*’ switched on. Remember the up/down arrows move from function to function.

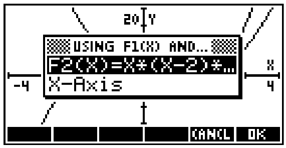
Now press the ‘*FCN*’ button. As you can see on the right, this button gives you access to a number of useful tools. If you move the highlight to ‘*Root*’ (as shown) and press **ENTER** (or ‘*Ok*’) then the cursor will jump to the nearest x intercept for the function it is on, starting its movement at the current position. Try it.

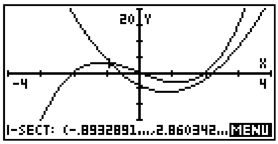
Notice the message at the bottom of the screen (see right) giving the value of the root that was found. To find the other root, you would need to move the cursor so that it is closer to the other root than to the present one. In this case, since it's a quadratic, that means moving it past the turning point.



NOTE: Those familiar with the Newton-Raphson iteration, and other similar iterative methods of finding roots will realise that I am over simplifying when I use the word "closer". For our purposes here however, it will suffice.

The next function tool in the '*FCN*' menu is '*Intersection*'. If you choose this option, then you will be presented with a choice similar to the one in the screen shown right. Exactly what is in the menu depends on how many functions you have showing. In the case shown here we only have two, so the choice is of finding the intersection of F1(X), which is the one the cursor is on, with either the X axis, or the other function F2(X). The results for F2(X) are shown right. Notice that the cursor jumps to the point of intersection.

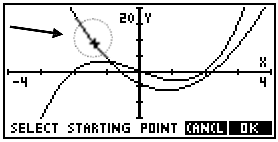




The next tool is '*Slope'*. This gives the numerical value of the derivative at the point of the cursor. This can be of somewhat limited value if your scale is not chosen so that the cursor movement jumps are on 'nice' values (see next paragraph). See page 50 for an explanation of how to arrange 'nice' choices of axes.

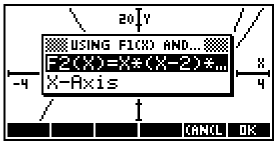
For example, if I wanted to find the derivative at the point x = 2, then the best I can do in the present scale is to choose a value close to this. The best ways to handle this is either to rescale the axes using the **VIEWS - Decimal** menu which sets the scales so that the cursor jumps in increments of 0.1 and then zoom (see page 50) or to use the **HOME** view as shown in the screen on the right. Note that F1(X) has to be defined in the function aplet first, or else typed out in full inside the brackets!

Note: For more information on using the **HOME** view to calculate values of derivatives and integrals, see the "Tips and Tricks - Functions & Calculus" section at the end of this Function aplet chapter (see pages 38,39,42 - 44).



Another useful tool provided in the '*FCN*' menu is the '*Area…*' tool. Before we begin to use it, make sure that *Trace*' is switched on, and that the cursor is on the function F1(X) - the quadratic. The '*Area…*' tool is somewhat similar to the Box Zoom in that it requires you to indicate the start and end points of the area to be calculated. If you now choose '*FCN*' and then '*Area…*' you will see the message shown on the right, asking you to choose a starting point. Move the cursor to a position somewhere near the position shown in the snapshot and then press the '*Ok*' button.

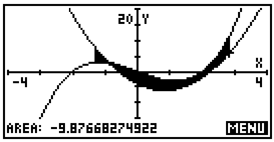
When you do this, another menu will appear, asking you to indicate which area you wish to calculate. In this case there are only two choices - between F1(X) and the X axis and or between F1(X) and F2(X). If we had defined more functions in the **SYMB** view then this menu would of course be longer. If you choose the function F2(X), then the graphs will reappear, with a message requesting that you choose an end point.



As you move the cursor along the graph F1(X), the area will be shaded by the calculator. When you reach the end point you are looking for, press the '*Ok*' button and the area will be calculated as

$$\int_{1st\ pt.}^{2nd\ pt.} F1(x) - F2(x)dx$$

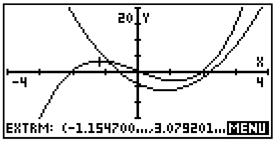
This is shown right.



As with the '*Slope*' tool, this can be of somewhat limited use because of the difficulty in specifying the endpoints precisely if the scale is not chosen carefully. See pages 50 for details on how to set up a more useable scale. It is often simplest to define F1(X) and F2(X) and then to change into the **HOME** view and type in the calculation ∫ (a,b,F1(X)-F2(X),X) replacing a and b with the endpoints of the integral desired. (See pages 42 - 44 for more details on this.)

> Note: When you use the '*Area…*' tool, the shading remains on the screen. The simplest way to get rid of it is to force a redrawing of the screen by doing a zoom, pausing it immediately and then un-zooming.

The final item is the '*Extremum*' tool. This is used to find relative maxima and minima for the graphs. Make sure that '*Trace*' is switched on and that the cursor is positioned on F2(X) in the vicinity of the left hand maximum (turning point). Now choose '*Extremum*' from the '*FCN*' menu. You should find that the cursor will, after a slight delay, jump (see right) to the position of the maximum at approximately (-1·15, 3·08). The value given is accurate and does not depend on your having chosen a 'nice' scale.



The cursor will probably not be positioned precisely at the point found, so don't expect that you can now (for example) use the '*FCN*' menu to find the area from the extremum to the y axis. Because the cursor is usually slightly off the extreme point you area won't be correct. See pages 173,174 for a neat way to accomplish this type of problem in the HOME page.

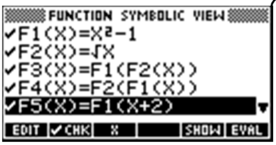
Tips and Tricks - Functions & Calculus.

Note: See also the 'Tips and Tricks' after the Solve aplet.

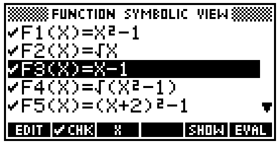
Composite functions

The Function aplet is capable of dealing algebraically with composite functions such as $f(x + 2)$ or $f(g(x))$ in its **SYMB** view. The *'Eval'* and *'Show'* buttons are particularly helpful with this. For example, if we define $F1(x) = x^2 - 1$ and $F2(x) = \sqrt{x}$, then we can use those definitions in our defining of F3, F4…

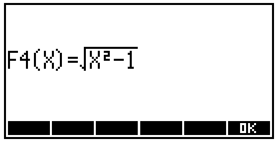
eg.



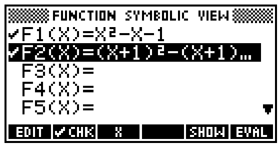
The highlight is now positioned on each of these in turn, and the *'Eval'* button pressed.



The result of each '*Eval*' is shown in the upper right hand screen shot.



Notice that the calculator is smart enough to realize in F3(X) that $\left(\sqrt{x}\right)^2 - 1$ is the same as $x - 1$. There is a limit to this however. If you define $F1(x) = x^2 - x - 1$ and then $F2(x) = F1(x + 1)$, then the *'Eval'* routine will not simplify $\left(x + 1\right)^2 - \left(x + 1\right) - 1$ to $x^2 + x - 1$.



These functions can of course all be graphed. The speed of graphing is *considerably* slowed if it is not *Eval*uated first.

Using functions in the HOME view

Once functions have been defined in the **SYMB** view of the Function aplet, they can be reused in the **HOME** view (and indeed in any other aplet!). For example suppose you needed to find some exact points (x = 0, 1, 2 and 3) for a graph of

$f(x) = \dfrac{2x}{(x-2)}$ when doing a hand sketch of it.

Type its definition into the Function aplet **SYMB** view, switch to the **HOME** view and then simply type F1(0) and press **ENTER**. The function will be evaluated for x = 0. Similar results can be obtained for F1(1), F1(2) and F1(3). Note the error message for x = 2 when a divide by zero is attempted.

Differentiating

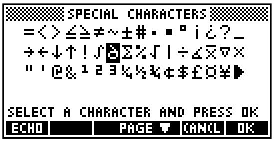
There are a number of different approaches that can be taken to differentiating, some of which are best done in the HOME view and some in the SYMB view of the Function aplet.

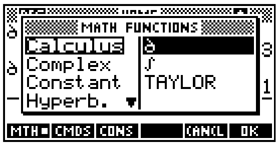
The syntax of the differentiation function is:

> $\delta X($*function*$)$,
>
> where *function* is defined in terms of X.

The function can either be defined in the SYMB view of the Function aplet, or typed in on the spot. The δ symbol is obtained either through the MATH button in the **Calculus** section, or via the **CHARS** button (above the left bracket). The variable name (X in this case) can be any other alphabetic character depending on what you used in your function.

i.e.

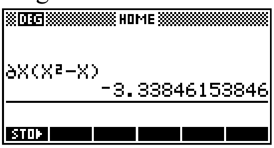




Although it may seem more involved, the MATH button is actually the simpler.

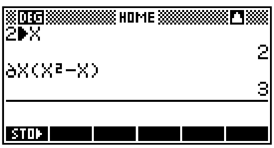
The MATH menus can be found quite quickly by hitting the alphabetic key that corresponds to the first letter of the menu you want. Hitting MATH then the **C** key (on the **COS** button - no need to hit **A..Z** first) will take you straight to the relevant **Calculus** menu. (Hitting **C** twice would take you to the **Complex** menu.)

If you use this function in the HOME view you will not receive the result you expect. Eg.



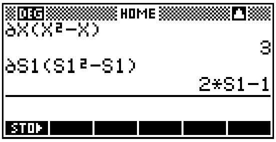
The reason for this is that the result you see is the derivative of $x^2 - x$ evaluated at whatever value of x happens to be currently in memory.

This can be seen more clearly if we store a specific value into the memory X beforehand…



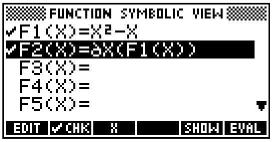
The value of 3 which results is the value of the derivative $2x - 1$ at the value of $x = 2$.

But what of algebraic differentiation? It is possible to do this in the **HOME** view using what is termed a "formal variable" of S1. (..or S2 - S9)
Eg.

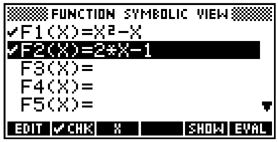


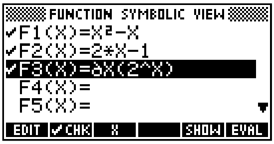
The drawback of this is simply the awkwardness of having to work with S1's rather than with X's.

An easier method is to do this in the **SYMB** view of the Function aplet. In this view the earlier method of using X produces the result we desired. Either define your function as F1 and its derivative as F2 (see the first snapshot below), or else type in the whole expression on one line (see the second snapshot). As you can see the calculator's algebraic abilities do not extend to differentiating $f(x) = 2^x$ as $f'(x) = \ln(2).2^x$, but at least it is numerically correct.
Eg.



press *'Eval'*

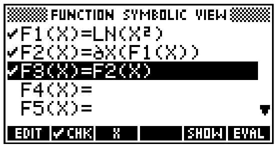




press *'Eval'*

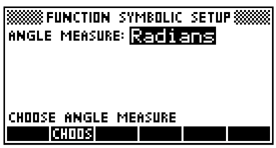
(and *'Show'*)

Doing your differentiation in the Function aplet offers the additional advantage of being able to graph the result.



One additional trick which is worth remembering is to set up the SYMB view as shown right. When you press the '*Eval*' button, the derivative replaces whatever was typed there, which can be inconvenient if you have to differentiate more than one function and therefore have to retype ∂X(F1(X)) every time. Pressing '*Eval*' on the F3 function instead means that you only need retype 'F2(X)'.

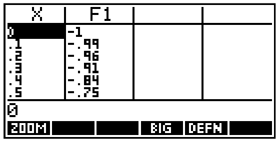
Trig Functions



The only time that the **SYMB SETUP** view is used in the Function aplet is when the function is a trigonometric one. Ensure that the 'Angle Measure' is set to the right type. Pressing the + key will cycle through the three possible types, or use the menu popped up when you press the '*Choose*' button. See page 51 for an example of graphing a trig function and using the **VIEWS** menu to get a good scale.

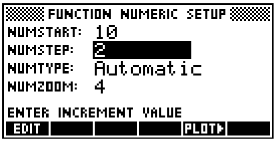
The NUMeric view revisited

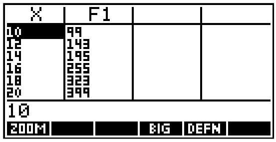
We saw earlier that the **NUM** view gives a tabular view of the function. It is possible to manipulate this view through the **NUM SETUP** view.



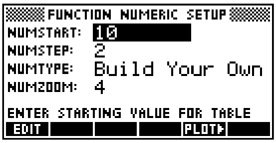
Firstly, one can change the start value and the step size that is to be shown.

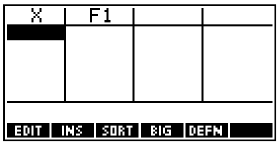
Eg. Values of 10 and 2, rather than the usual 0 and 0.1, give:





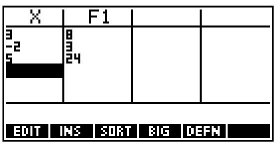
You may also have noticed an entry called ‘NumType’ with the value of ‘Automatic’. The alternative to ‘Automatic’ is ‘Build Your Own’ (obtained by moving the cursor to ‘NumType’ and pressing the + button. Switching back to the **NUM** view after this will show an empty table, waiting for you to enter your own values for X.





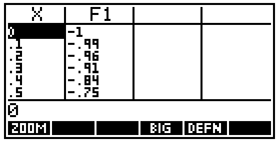
Typing in the values of (for example): **3 (ENTER) -2 (ENTER)** & **5 (ENTER)**
Don’t forget to use the **-x** button to put in the negative!

gives…



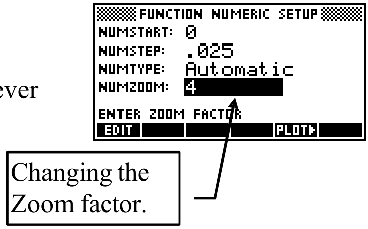
…with the function values being calculated as you input the X values. This can be quite useful if you are wanting to evaluate the behaviour of a function at selected points.

If you now switch back to '*Automatic*' (via **PLOT SETUP**), you will see a '*Zoom*' button at the bottom left of the screen. This can be quite useful as a fast way to reset the scale.



Pressing the '*Zoom*' button pops up the menu on the right. The first option of '*In*' causes the step size to decrease from 0.1 to 0.025. This is a factor of 4 and is changable via the **NUM SETUP** view. I find a zoom factor setting of 2 or 5 to be more useful.

The second option of '*Out*' causes the opposite effect, changing the step size upwards by whatever the Zoom Factor is set to.



The '*Decimal*' option is the normal one. It changes from whatever is showing back to the step size of 0.1 The '*Integer*' option on the other hand, changes the scale so that the step size is 1 (i.e. an <u>integer</u> scale).

The '*Trig*' option changes the scale so that the step size is $\frac{\pi}{24}$ or 15° exactly. This will obviously be of use when dealing with trigonometric functions.

Integration

The situation for integration is very similar to that of differentiation *(the explanation for which I will assume you have already read)*. The difference is that although using the **HOME** page still requires the use of a "formal variable" S1, the results are *far* better than they are in the Function aplet.

The syntax of the integration function is:

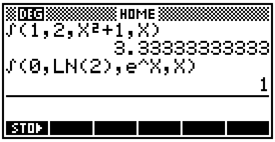
$$\int(a, b, function, X),$$

where a and b are the limits of integration and *function* is defined in terms of X.

Some examples of this follow, together with an example of why the Function aplet is not good to use in this case.

The $\int$ symbol is again obtainable either via the **MATH** or the **CHARS** buttons, with the **MATH** button being marginally easier.

Let's look first at the definite integral…



The screen left shows $\int_1^2 x^2 + 1\, dx = 3.3333\ldots$

followed by $\int_0^{\ln 2} e^x\, dx = 1$.

It may help you to remember the syntax of the differentiation and integration functions if you realise that they are filled in with values in exactly the same way that they are spoken.

Eg. $\int_1^2 x^2 + 1\, dx$ is read as:

"the integral from 1 to 2 of $x^2 + 1$ dx "

& entered:

$\int$ (1, 2, $X^2 + 1$, X) (without the spaces!)

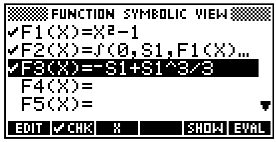
A similar tack has been taken with the differentiation function, so that:

$\frac{d}{dx}\left[X^2\right]$, which is read as "the derivative with respect to X of X^2"

is entered as: $\partial X\left(X^2\right)$

Algebraic integration is also possible, in the following fashions:

(i) If done in the **SYMB** view of the Function aplet, then the results are exactly what we would hope for, excepting only the absence of a constant of integration ‘c’.

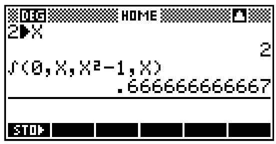


The screenshot right shows the results of defining F1(X)=X²-1 and then F2(X)=∫(0,S1,X²-1,X), together with the results of the same thing after pressing the ‘*Eval*’ button (placed in F3 only for convenience of viewing). All that one need do now is simply read ‘-S1+S1^3/3’ as $-x+\frac{x^3}{3}$ or, better yet, as it should be $\frac{x^3}{3}-x+c$

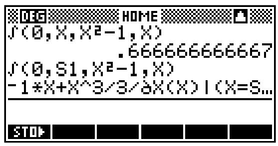
> ***Note***: If you intend to integrate a number of functions then it is annoying to have to re-type F2 each time. Instead, define F1(X) as the function, F2(X)=∫(0,X,F1(A),A) and finally F3(X)=F2(S1). If you do this then you can press ‘Eval’ on the F3 function and not have to re-type F2(X).

(ii) If done in the **HOME** view, with X as the variable of integration, then the results, as they were for differentiation are not good.

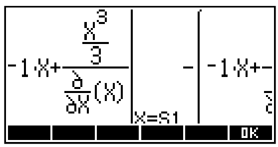
i.e. $\int x^2-1\,dx$ which would normally become $\frac{x^3}{3}-x+c$ is instead interpreted as a definite integral if entered as ∫(1,X,X²-1,X). This means that it is evaluated with an upper limit of whatever happens to be in the X memory at the time. This is shown in the screenshot on the right.



The solution might be to use the “formal variable” S1 which we encountered earlier.



The results of this are shown right, together with the ‘*Show*’ version of the answer given. The reason for the mess is that the calculator assumes that X itself is a function of another variable and integrates accordingly, doing a ‘partial integration’ which.



There are also limits to what the calculator can integrate. If you try to evaluate $\int \sin^2 x.\cos x\,dx$ using the calculator, it will not be able to do it.

Piecewise defined functions

It is possible to graph piecewise defined functions using the Function aplet, although it is neither terribly convenient, nor totally satisfactory.

For example: $f(x)=\begin{cases} x^2-2 & ; x \le 1 \\ 3-x & ; x > 1 \end{cases}$

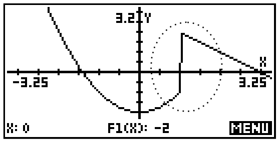
If you enter the function into the **SYMB** view as:

F1(X) = (X ≤ 1) * (X^2 - 2) + (X > 1) * (3 - X)

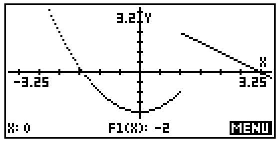
or as F1(X)= IFTE(X ≤ 1, X^2 - 2, 3 - X)

(obtaining the ≤ and > signs through the **CHARS** key)

…then you will find that the result is reasonably satisfactory with one exception. Unfortunately, the '*Connect*' option on page two of the **PLOT SETUP** menu causes the graph to be drawn connected at x = 1 when it should be discontinuous.



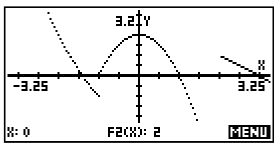
Switching off the '*Connect*' option removes this problem but leaves the graph drawn as a series of dots rather than as a connected shape. It also doesn't treat the endpoints of the graph properly. Many prefer the second graph even though it is not as good as it could be.



The reason why this method works is that the ($x \le 1$) and the ($x > 1$) expressions are evaluated as being either true (which for computers has a value of 1) or false (which has a value of 0). Thus for values of x such as -3 or 0, where ($x \le 1$) is true and ($x > 1$) is false, then F(x) becomes F1(X) = 1*(X^2 - 2) + 0*(3 - X) which is simply F1(X) = X^2 - 2 (as required). The IFTE function is not documented in the manual and stands for "IF Then Else" ie. IF (X ≤ 1) Then X^2 - 2 Else 3 - X

Graphing piecewise defined functions whose definition has three or more parts is a little more complex. The inequalities have to be more specific as to which part of the rule governs each part of the axis. The trick is to ensure that only one of the inequalities can be true for any given section of the x axis.

For example: $f(x)=\begin{cases} x^2-2 & ; x \le 1 \\ -2x^2+2 & ; -1 < x < 2 \\ 3-x & ; x > 1 \end{cases}$



…would need to be graphed as:

F1(X)=(X≤–1)*(X^2-2)+((X>-1)AND(X≤ 2))*(-2X^2+2)+(X>2)*(3-X)

or as F1(X)=IFTE(X≤–1, X^2-2, IFTE(X≤ 2, -2X^2+2, 3-X))

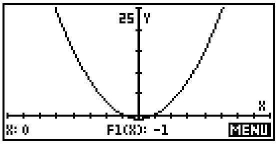
The VIEWS menu

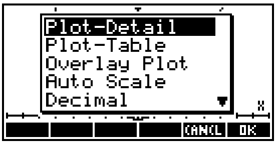
In addition to the views of **PLOT, SYMB** and **NUM** (together with their associated **SETUP** views), there is another button which we have so far only used fleetingly to Autoscale… the **VIEWS** button.

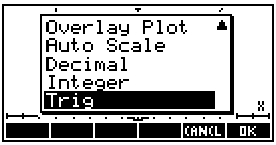
> Note: The contents of the **VIEWS** menu changes according to which aplet you are currently using. The Function aplet contents are covered here. You will find that the others differ in only small ways. Aplets downloaded from the Internet will usually have radically different **VIEWS** menus, which have been created by the person who wrote the program for the aplet.

The **VIEWS** button (located above **LIB,** so you will need to press **BLUE** first) pops up a menu that can be extremely useful. We have already seen the use of the '*AutoScale*' option (see page 29). The other options are also very useful.

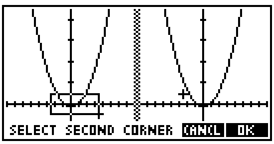
Shown on the right is the graph of $F1(X) = X^2 - 1$. If we press the **VIEWS** button, the menu shown below will pop up. Two views are shown so that all the options can be seen.





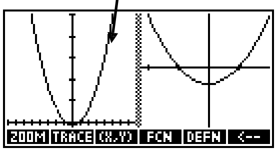


Choosing '*Plot-Detail*' from the menu, splits the screen into two halves and re-plots the graph in each half. The right hand side can now be used for any of the '*Zoom*' functions without affecting the left screen.

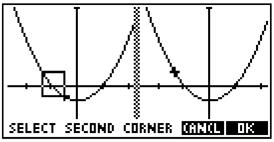


All the normal function tools are available.

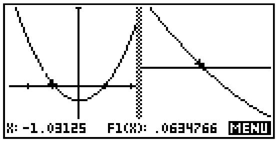
For example a '*Box…*' zoom gives the graph on the right allowing easy comparison of 'before' and 'after' views..



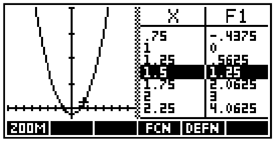
We can now use the left graph again to zoom in on another defining F1(X) and F2(X) section of interest, or alternatively, press the button under the '←' label. This switches the right hand graph onto the left screen, allowing you to zoom in even closer if the first zoom was insufficient.



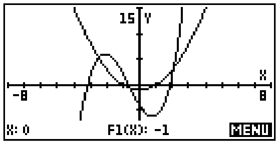
Using '*Trace*' or any of the other tools then allows you to find or examine points of interest, and any of the normal '*FCN*' tools such as '*Area…*' or '*Extremum*' can be used in this split screen.

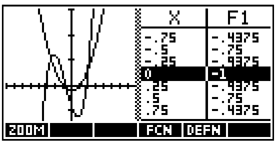


The next item on the **VIEWS** menu is '*Plot-Table*'. This option plots the graph on the left, with the Numeric view on the right half screen. Using the left/right arrow keys moves the cursor in both the graph and the numeric windows. The jump size of the scale in the window is set to $1/32$ *nd* of the scale in the full window. My x axis was set to $-8 \leq x \leq 8$ which results in the fairly useful scale shown. With only one function showing, hitting the up or down arrows simply centres the current value in the table. If more than one function is CHKed, then up/down switches between them.

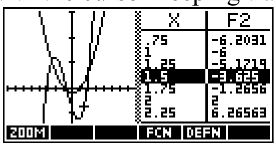


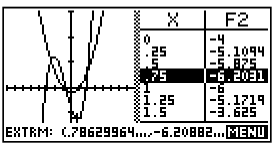
Let us switch now to a graph of the two functions $F1(X) = X^2 - 1$ and $F2(X) = X^3 + 2X^2 - 5X - 4$. This shown in full on the right.





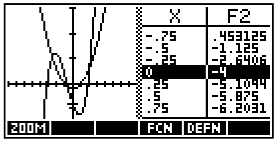
Changing to a '*Plot-Table*' gives the result shown left. As you can see, the scale has been preserved unchanged, although without labels, and the table on the right has a scale of 0·25. Looking at the table heading you will see that it currently shows the function F1(X). The left/right arrow keys move within that function, with the cursor keeping track. Hitting the up/down arrows now not only centres the table highlight but, more importantly switches from F1(X) to F2(X).





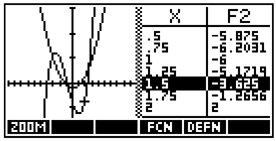
What makes this view even more useful is that the table keeps its 'nice' scale even while the usual '*FCN*' tools are being used. As you can see in the screenshot left, the table automatically repositioned to show the closest value to that of the extremum found.

The '*Area…*' tool is also available in this view and, more importantly, *when the cursor is moved it follows the scale in the table.* You will recall that the problem with using the '*Area…*' tool was that the cursor did not usually land on the values that were required. However in this view, unlike the normal PLOT view, it is possible to find the integral from (say) 0·75 to 1·5 visually instead of having to do it in the HOME view. Let's try it first to find the value of the slope of F2(X) at the point X=1·5.

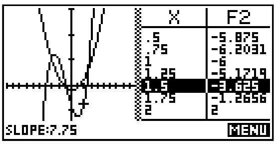


The method is the same as it is in the PLOT view.

Start with the view shown above right. This has F1(X) and F2(X) as given on the previous page, with the scale set in PLOT SETUP to $-8 \le X \le 8$ and $-10 \le Y \le 15$ and YTick set to 5. Choose '*Plot-Table*' from the VIEWS menu and you should see the screenshot above right.

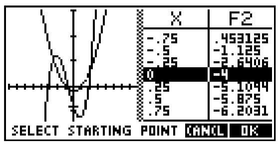


Use the up/down arrows if necessary to ensure that the table shows F2 not F1. Use the left/right arrows to move the highlight in the table to 1.5 and then choose '*Slope*' from the '*FCN*' menu.

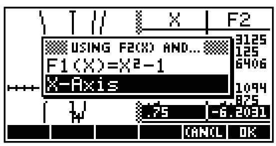


You should find that you obtain a slope of 7·75 as shown in the screenshot left.

Now let's try a similar method to find $\int_{0.75}^{1.5} F2(X)\, dX$

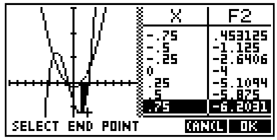


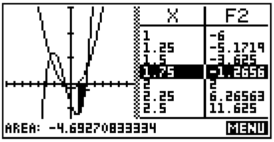
Use the '*FCN*' button again, but this time choose '*Area…*' and then position the cursor at 0·75 (see right), remembering that it is the left/right arrows that move within the table, not the up/down arrows.



Press '*Ok*' to choose 0·75, then choose '*X-Axis*' from the menu of choices that appears.

Next select the end point of the integral. Very unfortunately, the highlight in the table doesn't move with the cursor as it creates the shaded area. You must keep track in your mind of the cursor position, knowing that each press of the arrow key moves it by 0·25. This weakens an otherwise useful technique and is an oversight on Hewlett-Packard's side. Hopefully it will be fixed in the next model.



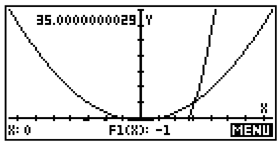


The consolation is that once the integral is calculated, the highlight moves to the end point you selected. At least then you can tell when you chose incorrectly (as I did left). Frankly, I don't think the job is worth doing this way, but it is there if you want to use it.

Another possibility from the **VIEWS** menu is '*Overlay Plot*'. This option can be used to add another graph over the top of an existing one, without the screen being blanked first as it usually is. As an example, if you have already graphed functions F1(X) through to F6(X) and then add another one in the **SYMB** view, then you don't really want to have to wait while all the earlier ones are redrawn. If you unCHK the earlier graphs and then Use '*Overlay Plot*' for the new one then the new one will be drawn over the top of the existing ones. Of course the results will not be good if you change the scale before overlaying!

The use of '*Auto Scale*' has already been seen earlier. It is a handy way to ensure that you get a good picture of the graph if you are not sure in advance what scale to choose. After using '*Auto Scale*' you can then use the **PLOT SETUP** view to adjust the results.

Auto Scale works by *using the X-axis range that is currently chosen in* **PLOT SETUP**, and adjusting the Y-axis range to include as much of the graph as possible. Unfortunately, the scale that is chosen is seldom a 'nice' one that goes up in 0·2 or 10 or 5.



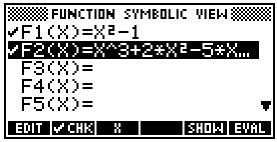
Another point to remember is that the '*Auto Scale*' is done only for the ***first*** CHKed graph. If there are other graphs and they don't fit the scale then they will not benefit. As you can see in the example shown right, the quadratic shows well but the second graph (a cubic) shows only an ascending section. Zooming out would be the only option here.

The next option of '*Decimal*' resets the scales so that each pixel (dot on the screen) is exactly 0·1. The result is an X scale of $-6{\cdot}5 \le X \le 6{\cdot}5$ and a Y scale of $-3{\cdot}2 \le Y \le 3{\cdot}2$. Although it may not give the best view of the function, the main advantage of this is that the (x,y) ordered pairs will be 'nice' values.

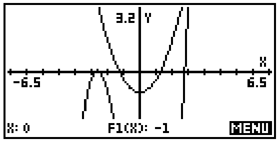
A program can be downloaded from my website (see page 124) which will automatically adjust your axes to the nearest set giving 'nice' values.

Here's a possible strategy (other than '*Auto Scale*') for graphing which works quite well and, more importantly, gives 'nice' scales…

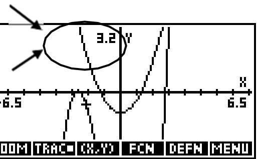
* Enter your graphs into the **SYMB** view.



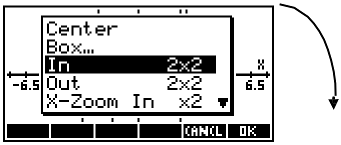
* Press **VIEWS** and choose '*Decimal*'. This will give you the ranges we discussed at the top of the page, probably not showing the graph to best advantage.



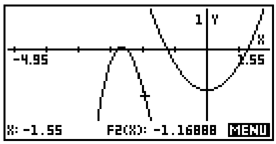
* Place the cursor so that it is in the centre of the area you are most interested in.



* Use the '*Zoom*' menu to adjust the view. You may choose first (as I did) to change the zoom factors to something other than 4x4, and to ensure that 'Recenter' is CHKed.

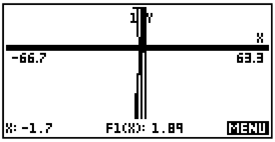


The advantage of doing it this way is that if you zoom in or out by a factor of 2 or 4 or 5, the cursor jumps will stay at (relatively) nice values.

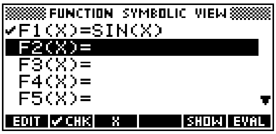


This means the problems with 'Area' and 'Slope' mentioned earlier don't apply. *In the case shown above right, the cursor moves in jumps of 0·05, which is good for most purposes*.

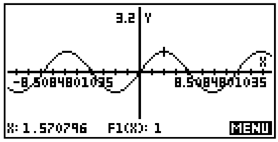
The next option on the **VIEWS** menu is '*Integer*'. This is similar to decimal, except that it sets the axes so that each pixel is 1 rather than 0.1. The result of this is usually rather horrible unless the graph is suited to this. For example, the graph on the right is the same functions as those in the screen shot immediately above.



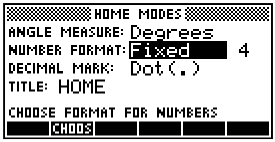
The final option of '*Trig*' is one that is very useful when graphing trig functions. It sets the scale on the axes so that each pixel (and so each cursor jump) is $\frac{\pi}{24}$ or 15º. This means that if you were graphing (say) $F1(X) = \sin(X)$ then 24 presses of the left or right arrows will move you through exactly π. If you zoom in or out from this, the jumps will still stay relatively 'nice', particularly since 24 has many factors. For example, with a zoom factor of 2, zooming in once would mean each pixel was now $\frac{\pi}{48}$ or 7·5º, while zooming out would give a pixel jump of $\frac{\pi}{12}$ or 30º.



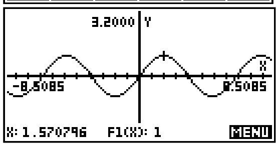
As you can see, the cursor is nicely at a value of $\frac{\pi}{2}$, although the labeling is not the best.



If you decide that you want better labels, change the numeric format to 'Fixed 4' in the **MODES** view, then use **VIEWS** '*Trig*' again to re-plot the graph.

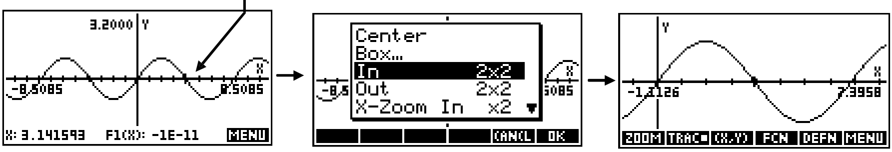


The result, as you can see, is much better. Two decimal places would also have given a good result.



Cursor at π. The graph should show F1(X)=0 but doesn't due to internal rounding errors (normal).

Suppose we are primarily interested in the first 2π of the graph. We move the cursor to π (the middle) and then zoom in. This example uses Zoom Factors set to 2x2 and with 'Recenter' CHKed.



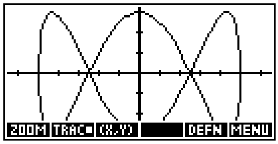
The Parametric Aplet

This aplet is used to graph functions where x and y are both functions of a third independent variable t. It is generally very similar to the Function aplet and so the space devoted to it here is limited mainly to the way it differs.

An example of a graph from this aplet is:

$$x(t) = 5\cos(t),$$
$$y(t) = 3\sin(3t); \quad 0 \le t \le 2\pi$$

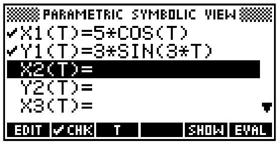
which gives:



Although it allows you to graph equations of this type, only some of the usual **PLOT** tools are present - as you can see in the screen shot above, the '*FCN*' button is not shown, meaning that none of its tools are available. Some thought about the nature of these equations will tell you why.

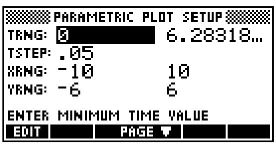
As we saw, the first step for any aplet is to choose it in the Aplet Library. Press the **LIB** key to view the Aplet Library and use the '*Reset*' button to wipe any existing functions.

As with the Function aplet, this aplet begins in the **SYMB** view by allowing you to enter functions, but Parametric functions are ***paired***. Each function consists of a function in T for X and another for Y.

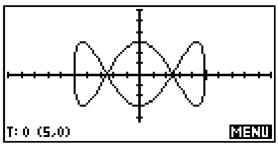


Looking at the **PLOT SETUP** view, you will see that we now have to enter a range for T as well as the usual ranges for X and Y. It is crucial to understand the different effects of the T range to that of the X and Y.

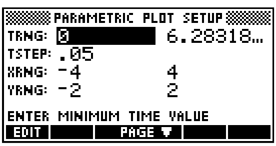
The X and Y ranges control the lengths of the axes. They determine how much of the function, when drawn, that you will be able to see. For example…



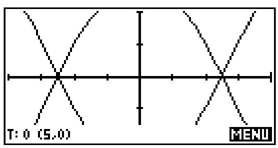
gives a graph of:



whereas..

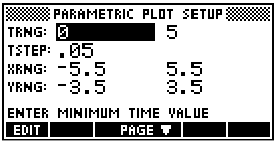


gives a graph of:

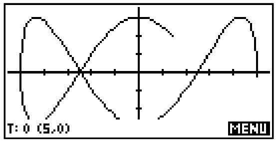


Notice that in both cases, '*Trace*' and '*(X,Y)*' are on and show the T value, followed by an ordered pair giving (x,y).

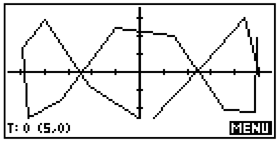
The effect of T on the other hand is to determine how much of the graph is drawn in the first place, not how much is displayed once drawn.



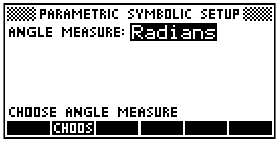
gives a graph of:



As you can see above, changing the T range from $0 \le t \le 2\pi$ to $0 \le t \le 5$ gives a graph that appears only partially drawn. What constitutes "fully drawn" depends, of course, on the function used.



TStep: controls the jump between successive values of T when evaluating the function for graphing. Any graph is always a series of straight lines, and making TStep: too large produces a graph which is not smooth (see right for TStep = 0.5 instead of 0.05). Decreasing TStep beyond a certain point will not smooth the graph further, only slowing down the graphing process.

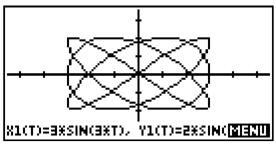


Since trig functions are often used in parametric equations, one should always be careful that the Angle Measure chosen in **SYMB SETUP** is correct.

The **NUM** view gives, as usual, a tabular view of the function. In this case there are three columns, since X1 and Y1 both derive from T. As with the Function aplet, it is possible to change the starting point and step size of the table, and also to change it into a 'Build Your Own' type of table (see page 41).

Interesting graphs are available through this aplet…

For example, try exploring variants of the graph of:



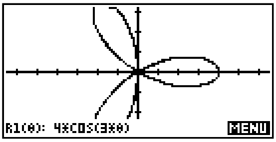
$$x(t) = 3\sin 3t$$
$$y(t) = 2\sin 4t$$

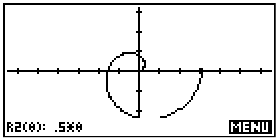
The Polar Aplet

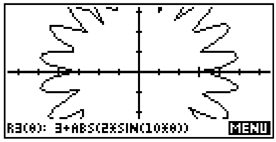
This aplet is used to graph functions where the radius r is a function of the angle θ (theta). As with the parametric aplet, it is very similar to the Function aplet and so the space devoted to it here is limited mainly to the way it differs.

Some examples of functions of this type, together with their graphs are:

$r = 4\cos(3\theta)$ $\quad$ $r = 0.5\theta$ $\quad$ $r = 3 + |2\sin(10\theta)|$

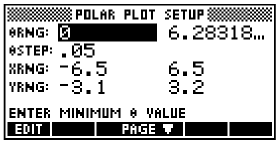






As with the Parametric aplet, looking at the **PLOT SETUP** view reveals that ranges must be specified not only for X and Y but for θ also.

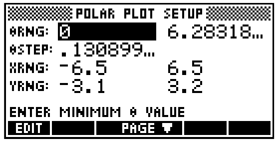
The values set for XRng and YRng control the length of the axes. The views used above were produce by using the **VIEWS - Decimal** option, but there is no real advantage in choosing this scale for the Polar aplet (where each pixel is 0·1 in both X and Y directions) since the movement of the cursor follows the increments set for θ in θStep regardless of the X and Y position.



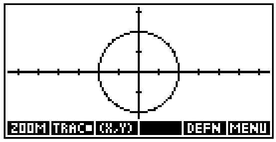
The values set for θRng and for θStep are the critical components in controlling the appearance of the graph. The values set for θRng control how much of the graph is drawn, while the values for XRng and YRng control how much of the graph is displayed on the screen once drawn. The value of θStep chosen controls how smooth the graph is, as did TStep in the Parametric aplet. Read the Parametric aplet (pages 52,53) for a more detailed discussion.

The values set for θRng in this instance were $0 \le \theta \le 2\pi$. This is the default value for θRng and usually gives you a reasonable idea of the appearance of the graph, allowing adjustment in **PLOT SETUP**.

As you will see if you try plotting these graphs yourself, this is too much for R1 ($\pi \le \theta \le 2\pi$ just re-plots the same graph for a second time), not really enough for R2 (I would have liked to see more of the spiral) and exactly correct for R3. The value of 0·05 set for θStep is a good compromise, although there is evidence in R3 that a smoother graph might result from using (say) 0·02.



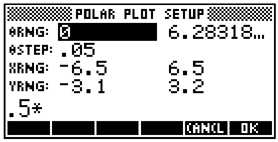
If you go into the Polar **PLOT SETUP** view (as above) and press the **CLEAR** button (above **DEL**), you will find that the view will reset to its default values set in the factory (as will happen in most other views). The value set for θStep is π/24. I feel that this setting results in graphs that are too 'chunky' and I usually change it to 0.05 even though it slows the graphing process down a little.



It is often important in the Polar aplet to have a set of axes that are 'square', so that graphs which are supposed to be circular do not look oval. Choosing the **Decimal** option from the **VIEWS** menu will give this 'square' appearance. If the resulting axes don't show enough of the function, then '*Zoom*' in or out. See page 50 for discussion of this method in the Function aplet.

Many of the ranges used for θRange involve π. The **π** key can help here.

Suppose we wish to use a θRange of $\frac{\pi}{2} \leq \theta \leq \frac{3\pi}{2}$.



Enter the **PLOT SETUP** view and then move the cursor to the left value of θRange and use the **π** key on the keyboard (on the **3** button) to type in **π / 2** and press **ENTER**.

The calculator will evaluate **π / 2** and enter the appropriate value into the minimum of θRange. Now move to the right hand maximum value and enter **3π / 2**. If you plot the function now, you will find that the θRange has been set appropriately.

The value of **π** can also be obtained through the Constants section of the MATH menu (see page 151) but this involves the use of far more key strokes.

The Sequence Aplet

This aplet is used to deal with sequences (and indirectly series) in both explicit or non-recursive form (where T_n is a function of n) and implicit (recursive or iterative) form (where T_n is a function of T_{n-1}).

Examples of these types of sequences
are: (explicit/non-recursive)

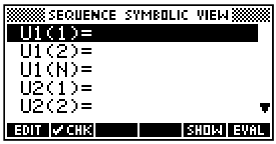
$$T_n = 3n - 1 \quad ..... \quad \{2,5,8,11,14,....\}$$
$$T_n = n^2 \quad ..... \quad \{1, 4, 9,16, 25,.\}$$
$$T_n = 2^n \quad ..... \quad \{2, 4,8,16, 32,..\}$$

(implicit/recursive)

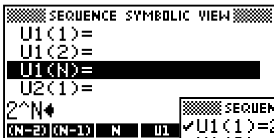
$$T_n = 2T_{n-1} - 1 \quad ; T_1 = 2 \quad ..... \quad \{2, 3,5, 9,17,...\}$$
$$T_n = 5 - T_{n-1} \quad ; T_1 = 2 \quad ..... \quad \{2, 3, 2, 3, 2, \}$$

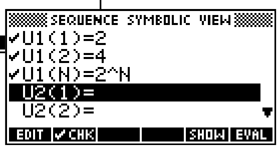
$$T_n = T_{n-1} + T_{n-2}\, ; T_1 = 1, T_2 = 1 \quad ..... \quad \{1,1, 2, 3,5,8..\}$$

As with most aplets, putting the Sequence aplet to use starts in the **SYMB** view with the entering of the formulae. The Sequence aplet uses the terminology U(N) rather than the more common T_n for its definitions, probably in order to avoid having to use subscripts which would not show up well on the screen. As is mathematically correct, all functions of this type are assumed to be defined for the positive integers only - for N = 1, 2, 3, 4..



Each definition has three entries - U1(1), U1(2) and U1(N) (see right). If the sequence is non- recursive then only the U1(N) entry need be filled in, with the entries for U1(1) and U1(2) being calculated automatically from the given definition.

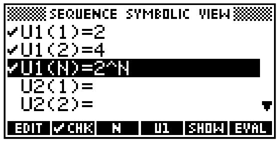




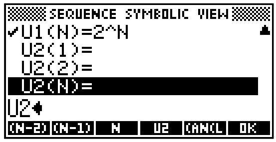
Let's start with a non-recursive sequence of $T_n = 2^n$. If you type it in as shown right (using the **X,T, θ** button to get N), press **ENTER** and then watch carefully, you will see the entries for U1(1) and U1(2) filled in automatically. CHK marks appear on all three, but CHKing or unCHKing any one does for all three.

There are a number of very convenient extra buttons provided at the bottom of the screen when entering sequences.

Two of these - U1 and N - are available as soon as the cursor moves onto the U(N) line (see right). Pressing either will enter the appropriate text into the sequence definition.



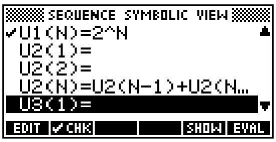
The rest (see right) become visible once you have begun entering the sequence definition. Suppose we enter the Fibonacci sequence into U2 by defining U2(N) = U2(N-1) + U2(N-2). Rather than having to type all of this we can use the buttons provided, pressing:



U2 then **(N-1)** then **+** then **U2** then **(N-2)**.

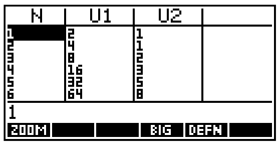
This is a <u>very</u> convenient feature, and worth remembering.

The result…

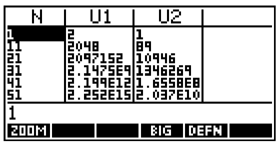


There is no CHK mark next to the definition yet, since the sequence is defined recursively and no values have yet been given for U2(1) and U2(2). Type in a value of 1 for both of these and then press the **NUM** button to switch to the Numeric view.

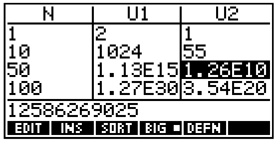
As you can see in the screenshot right, the Numeric view shows the values in the sequence as a table. If you move the highlight into the U1 and U2 columns, you can press the '*Defn*' button and see the sequence rule if you have forgotten it. You can experiment for yourself and see the result of pressing the '*Big*' button (see next page for an example). The '*Zoom*' button is also available as usual, but is not really much use.



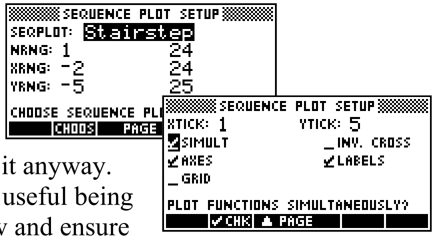
The **NUM SETUP** view offers more useful features. Change to that view now and change the NumStep value to 10. If you swap back then to the **NUM** view you will see (as right) that the sequence jumps in steps of 10. In case you don't realise…
2.1475E9 is 'computerese' for $2 \cdot 1475\times10^9$.



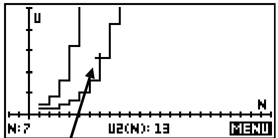
Now go back to the **NUM SETUP** view and change the 'Automatic' setting to 'Build Your Own' by moving the highlight to it and pressing the + key. Switch back to the **NUM** view and enter the values **1**, **10**, **50** and **100** into the N column. You will find that the values for those terms of each sequence will appear in the U1 and U2 columns almost immediately. In case you didn't realise, the reason for the larger text is that I have the '*Big*' button switched on.



Due to the type of problems one is usually trying to solve with sequences, the **PLOT** view is really not terribly useful in this aplet, but let's have a look at it anyway. Two types of plots are available, the more useful being 'Stairstep'. Change to the **PLOT SETUP** view and ensure that the setup view is the same as that shown above right. Now change to the **PLOT** view and you should see a graph similar to the one shown below right. The values shown at the bottom of the screen are produced by switching '*(x,y)*' on using the menu.



The second type of graph is the 'Cobweb'.



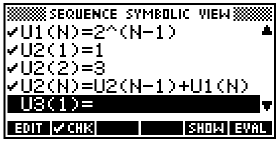
It will not be discussed here.
You can explore it yourself.

The U2(7) term is 13.

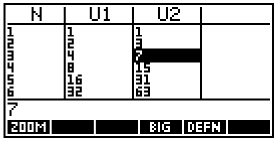
Tips and Tricks - Sequences & Series

Defining a Series using a sequence (Sum to n terms)

Defining a series (sum to n terms of a sequence) is fairly straightforward if one uses two sequences, the second being a running total of the first.

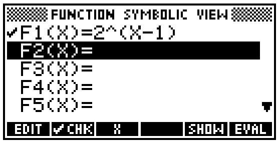


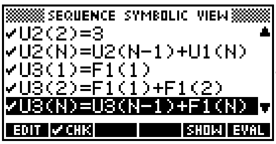
Suppose we define U1 as: $U1(N) = 2^{N-1}$; $N = 1,2,3...$ Then the sum to n terms of U1 can be defined in U2 by setting up its definition as shown in the screenshot right. Note the reference back to U1 in the definition of U2. You have to calculate the first two terms yourself, because for some reason the calculator won't allow a reference to another sequence in U(1) and U(2).



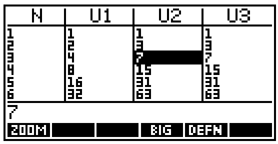
As you can see right, the result is entirely satisfactory. Once U2 is defined in this way you can change U1, needing only to adjust the values of U2(1) and U2(2).

An alternative is available if the definition of the sequence is one that is better or more easily done in the Function aplet. If you first define the sequence as a function in the Function aplet (see right) then the definition shown in U3 will produce the same result. You have to use the **A..Z** key to input the F's in the definitions.





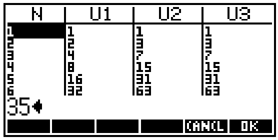
U2 & U3 give the same result.

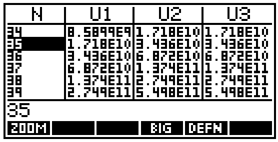


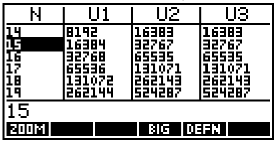
Solving Problems

Questions like "What term is the first to be greater than 10 000?" or "When does S_n first exceed 10 000?" can easily be answered in the Numeric view.

Simply move into the N column, make an inspired guess as to the term you require and type it in. For example, in answer to the first question, we estimate N=35. Typing it in and then pressing **ENTER**, we find that U1(35) [T_{35}] is far too large! By successive guesses, we find that T_{15} is the one we were seeking. The second problem is as easily solved in this way.

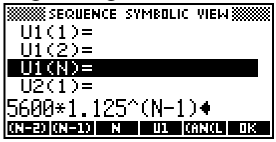




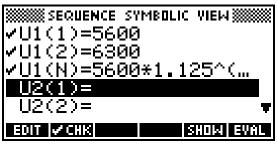


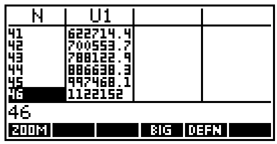
Population type problems are also easily dealt with in this way.

For example, "A population of mice numbers 5600 and is growing at a rate of 12.5% per month. How long will it be until it numbers more than one million?"



Pressing **CLEAR** (above **DEL**) clears out the existing expressions, and I can enter my formula. The two values of 5600 and 6300 are automatically calculated, and we make a mental note that the number of months is one less than the term number N (since 5600 is supposed to be <u>after</u> zero months). All we need do now is switch to the Numeric view to find, with some experimenting, that U1(46) is the first to exceed one million. Thus the answer is <u>45 months</u>.





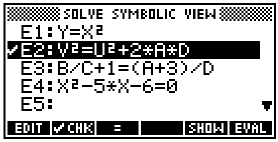
Note: It is also possible to answer these questions in the Solve aplet (read the pages which follow to learn how to use the Solve aplet first!).
For example if we use the Sequence aplet to define U1(N)=2^(N-1) as before, then we can change to the Solve aplet and enter into E1 the equation U1(N)=10000, change to the **NUM** view and press '*Solve*' and obtain an answer of 14·29. This means, of course that N=15 is the first term exceeding 10000. If you're wondering why we didn't suggest setting E1 to U1(N)>10000, the reason is that the Solve aplet doesn't seem to be able to deal with inequalities even though no error message is given if you try.

The Solve Aplet

This aplet may rival the Function aplet as your ‘most used’ tool. It solves equations and finds zeros of expressions involving not only many variables but even derivatives and integrals.

To ensure that we are using the same terminology, let's define our terms first.

An equation includes an = sign, and can be solved:

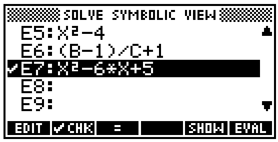


Note the = sign provided for convenience.

eg.
$$\left.\begin{array}{c} y = x^2 \\ v^2 = u^2 - 2ad \\ \dfrac{b}{c} + 1 = \dfrac{a+3}{d} \\ x^2 - 6x + 5 = 0 \end{array}\right\}$$
…are all equations.

An expression, on the other hand, does not contain an = sign. It can be evaluated or rearranged but not solved. When you enter an expression into the Solve aplet it internally tacks an “ = 0 ” onto the end so as to convert it into an equation which can be solved.

eg.
$$\left.\begin{array}{c} x^2 - 4 \\ \dfrac{b-1}{c} + 1 \\ x^2 - 6x + 5 \end{array}\right\}$$
…are all expressions.



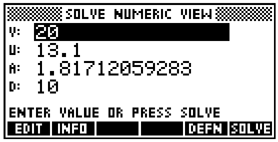
Let's start by looking at the equation $v^2 = u^2 - 2ad$. This equation gives the final velocity (v) of a body/particle as a function of the initial velocity (u), the acceleration acting on it (a) and the distance traveled (d).

Suppose you had the Physics problem:

> “What acceleration is needed to increase the speed of a car from 16·67 m/sec (60kph) to 27·78 m/sec (100kph) in a distance of 100m?”

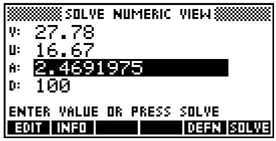
We’ll assume that you have already realised that this is the appropriate equation to use (you see: the calculator is never going to replace your brain!) and also that you have entered the equation into E2 (as above) and have made sure that it is CHKed (as above).

If you press the **NUM** key to change to the Numeric view, you will see something similar to the screen on the right. What values are showing on your screen will depend on what happens to be in the memories V, U, A and D at the time.

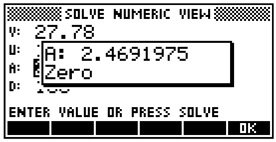


Move the highlight to V and enter the value 27·78, then to U and enter 16·67 and finally to D and enter 100.

Now move the highlight back to A (the value you're trying to find) and press the '*Solve*' button. You should find that you too obtain the answer to our problem of 2·47 m/sec^2.



When the '*Solve*' process has finished, you can obtain a (very bare!) report on it by pressing the '*Info*' button. The result in this case is not very informative as you can see. There is more about these messages at the end of this chapter.



Our first example was fairly simple because there was only one solution. When there is more than one possible answer you are required to supply an initial estimate or guess. The Solve aplet will then try to find a solution which is 'near' to the estimate.

For example… "*If* $f(x) = x^3 - 2x^2 - 5x + 2$ *find all values of x for which*

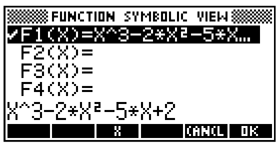
$$\textit{(i)}\ f(x) = 1$$

$$\textit{and} \quad \textit{(ii)}\ f'(x) = 2\text{ ''}$$

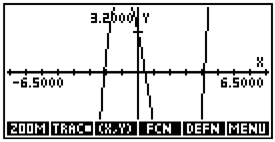
Although you may have a clear enough picture in your mind to be able to provide the Solve aplet with the estimates it needs, I'm going to assume that you (like me) would find it helpful to see a graph first.

While it is possible to do the whole process in the Solve aplet, using the Function aplet offers more advantages. The **PLOT** view in the Solve aplet does not work in a very intuitive way and I find it far easier to work first in the Function **PLOT** view, in addition to having access to all its tools.

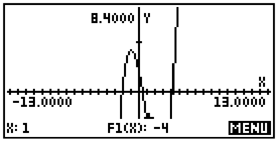
Change into the Function aplet and enter the function $f(x) = x^3 - 2x^2 - 5x + 2$ into the definition of F1(X).



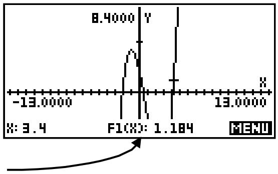
Use **VIEWS - Decimal** to get a quick idea of the function, then ‘*Zoom - Out 2x2*’ to expand the scale. **Note**: If your zoom factors are not set to 2x2 it is suggested that you change them first - the default of 4x4 is often too much.



The graph which results does not show the minimum but we don’t really need it for our problem. If needed we could move the cursor and then use ‘*Zoom - Centre*’ which would keep the convenient scale but reposition the axes.

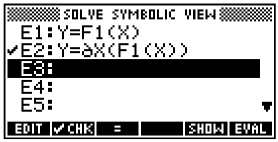


We can now use this graph to estimate values of x for which F1(X)=1. Press **MENU** and engage ‘*Trace*’ (if not already selected) and the ‘*(x,y)*’ tool.
Now move the cursor (in jumps of 0·2 for our present scale) until you find the three approximate locations where F1(X)=1. Suppose we find X = -1·6, 0·2 and 3·4.



From the graph it also seems to me that estimates of -1 and 3 will be close enough for Solve to use in finding where $f'(x) = 2$.

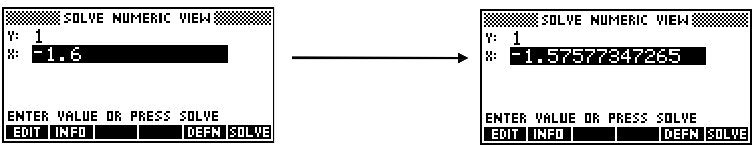
Now change back to the Solve aplet. Having already defined F1(X) we can reuse it in the Solve aplet.
Define: E1 to be Y=F1(X),
and then: E2 to be $Y = \partial X(F1(X))$
(in other words the derivative of F1(X) with respect to X)



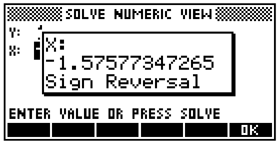
Note: Some reminders	- the = sign is one of the screen keys. - the derivative character ∂ is obtained through the **CHARS** key or through the **MATHS - Calculus** menu.

Now make sure that E1 is CHKed rather than E2 and then change into the **NUM**eric view. Enter a value of 1 into Y, move the highlight to X (if not already there) and enter our first estimate of -1·6. Press ‘*Solve*’.

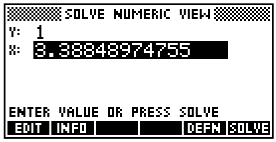
Before… and after…



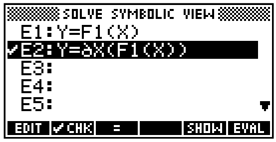
Now press the '*Info*' button. An answer of "Zero" or "Sign Reversal" means the solve process worked correctly. See page 66 for an explanation.



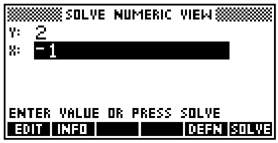
If you repeat this for the other two estimates, you will find solutions to part (i) of x = -1·5758, 0·1873 and 3·3885 (to 4 decimal places.).

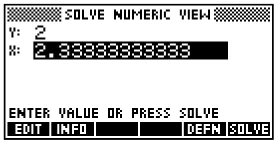


Change back to the **SYMB** view and change the CHK mark to E2. Then move to the **NUM** view again. This time we require $f'(x) = 2$, so set Y to 2.



Enter the estimate of -1 into X, ensure the highlight is still on X and then press '*Solve*'. You'll find that, after a longer delay due to the derivative calculations, the value will come up as still -1! Good estimate wasn't it! Don't forget, you should always press '*Info*' after each solve to verify its validity.





The other solution to part (ii) of x = 2·3333 can now be obtained if you enter the second estimate of 3.

Note:	The Solve aplet does not seem to be able to cope with inequalities. Although there is no error message when you use < or >, the answer it supplied when I tested it in a number of examples was incorrect. What is even worse is that they were reported in the Info messages as being correct!

The Solve aplet can also be used in conjunction with any of the functions available through the **MATHS** menu.

Example 1: "Find a such that $\int_2^a x^3 - x\,dx = 4$ "

Set E1 to: $\int\left(2, A, X^3 - X, X\right) = 4$

In the **NUM** view, set A to an initial guess of 3, and position the highlight on A (not X). Ignore X since it is not really involved except as a temporary variable during the integration. Press '*Solve*'. **Answer: X = 2·4495 (to 4 decimal places)**

Example 2: "Let X be a random variable, representing the heights of basketball players. If X is normally distributed, with $\mu = 184 \cdot 5$ and $\sigma^2 = 105$ then find the height above which only 5% of players should be found."

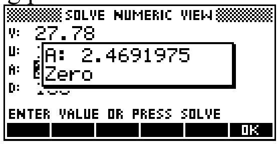
The MATH function for the Normal distribution is UTPN - Upper Tailed Normal Probability. In the Solve aplet, set E1 to: UTPN(184·5,105,X)=0·05.
Enter the **NUM** view and press '*Solve*'. **Answer: 201·35cm**

Further reading

There are many more ways in which the Solve aplet can be used in conjunction with the functions available in the **MATHS** menu. The **MATHS** menu is discussed in detail on pages 125 - 170, with worked examples often using the Solve aplet.

Info messages

When you press '*Info*' after a solve operation you will see a message similar to the one below right. Basically what happens in this solving process is that the calculator solves equations by transposing them so that they are equal to zero.



Thus: $v^2 = u^2 - 2ad$

becomes: $v^2 - u^2 + 2ad = 0$

which becomes: $(27 \cdot 78)^2 - (16 \cdot 67)^2 + 2 \times a \times 100 = 0$ when the values you supplied where substituted into it.

The calculator then proceeds to find a value of A which would make this zero, and it is reporting that it succeeded. Happy? An answer of 'Sign reversal' is also Ok, since normally one expects to find an answer of zero at the point where the equation changes from positive to negative (or vice versa). It's just saying that it couldn't get a *precisely* zero answer to 12 significant digits, only two answers minutely on either side of zero. The only time that you need to worry about this is when you receive any of the error messages. These are:

'Extremum' - it found a minimum, but could not reach zero. Try solving the equation $x^2 + 4 = 0$ (which has no real solutions) and you will see this message. The smallest value that $x^2 + 4$ can have is 4 at x = 0, so the answer supplied will be very close to this (such as 1·2E-9). Unless you check '*Info*' you won't realise that this is not actually a valid solution.

'Bad Guess' - the initial estimate you supplied was outside the domain of the function. For example, the equation involves a square root and you supplied a negative value as your initial guess.

'Constant?' - no solution was found. The value of the function was the same at every point tested (and it wasn't the value you wanted).

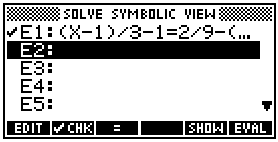
Tips and Tricks - Solve

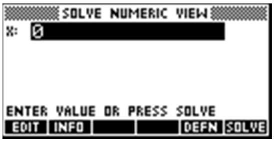
Easy problems

Have you ever thought “There has to be an easier way!” when confronted in a test with something like:

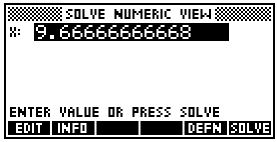
$$\frac{(x-1)}{3} - 1 = \frac{2}{9} - \frac{(3-x)}{4}$$

As long as you are sure that there is only one answer to a problem, as there is in this case, then solving it is simply a matter of entering the equation into the **SYMB** view and solving it.





Enter any value at all and ‘*Solve*’…

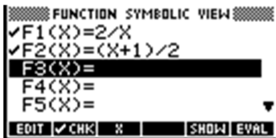


Harder problems

When you know or suspect that there is going to be more than one solution to a problem it is often advisable to graph the left and right sides as separate functions

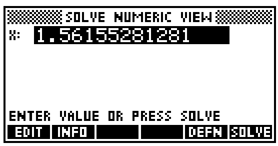
in the Function aplet first, in order to get estimates.

For example: $\frac{2}{x} = \frac{(x-1)}{3}$



When you plot these in the Function aplet (I used **VIEWS - Decimal**), you can see that the solutions are near -2 and 1·5. If we now switch to the Solve aplet and enter the equation (see right) we can use these as guesses.

This will give solutions of -2·56 and 1·56 (to 2 decimal places.).

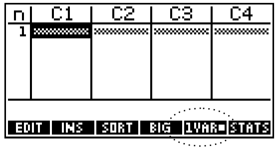


Of course your teacher may be insisting on an answer given as a surd, or on showing all working, but at least you’ll be able to check your answer!

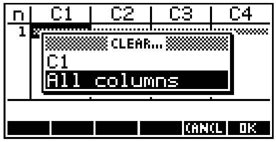
NOTE: Unfortunately it is not possible to use the Solve aplet for simultaneous equations. The aplet will only search for a solution to one variable at a time. See Matrices (pages 91 - 93,176) for techniques to handle these.

The Statistics Aplet - Univariate Data

One of the major strengths of the HP38G is the tools it provides for dealing with statistical data. Unlike the other aplets, the Statistics aplet begins in the **NUM**eric view which offers easy input and editing of values, while the **SYMB** view is reserved for specifying which columns contain data and which ones frequencies, as well as for indicating pairing of columns for bivariate data.



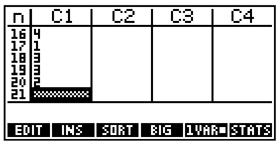
The HP38G treats univariate and bivariate data quite differently and those differences are reflected in the **SYMB** and **PLOT** views. Because of this we will split the Statistics chapter into two and deal with univariate data first. On the screen you will see a button labeled either '*2VAR*' or '*1Var*'. Pressing the button under this label changes from univariate (1VAR) to bivariate (2VAR) and back. Make sure the button is showing '*1VAR*' before proceeding.



If your **NUM** view already has some data in it, press **CLEAR** (above **DEL**) and choose '*All columns*'. The **DEL** key is used to delete individual pieces of data, rather than whole columns.

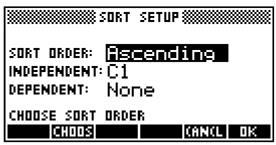
Let's use the following set of data and obtain all the usual statistics on it, as well as a histogram and a box & whisker graph.

{ 2, 3, 1, 0, -2, 3, 4, 2, 2, 0, 6, 2, 3, 1, 0, 4, 1, 3, 3, 2 }



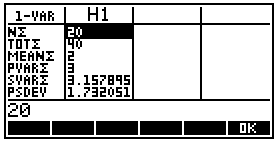
Move the highlight into column C1 and enter the data, pressing the **ENTER** key after each piece of data.

Looking at the bottom of the screen you will see a series of tools provided for you. '*Edit*' is not really worth bothering with. It is easier just to retype a number than to press '*Edit*' and then use the arrow keys and **DEL** to change it.

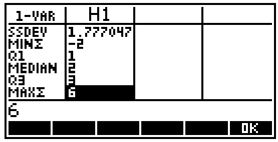


The key labeled '*Ins*' inserts space for a new number by shifting all the numbers down one space. '*Sort*' does exactly what it says… it sorts the data into ascending or descending order. The extra bits in the screen shot right are used with bivariate sorts and will be explained in that section of the notes. Press '*Cancel*' to stop the sort.

The ‘*Big*’ key does exactly the same thing as in any other aplet. The last key labeled ‘*Stats*’ is the really useful one.



Press the ‘*Stats*’ button and you will see the screen shown right. If you use the down arrow, you can scroll down and see the rest of the screen (shown below right).



NOTE: If you got an error message instead of these screens, change into the **SYMB** view, press **BLUE CLEAR** to get rid of any left over definitions, CHK the H1 row and finally change back to **NUM** view and try again. This is explained in more detail later.

As you can see in the screens above right, the HP38G gives not only the standard statistics that any scientific calculator would give, but also the minimum and maximum values, the median and the upper and lower quartile cut-offs. The mode is not given, but this is easily obtained from the histogram as we will see later.

The method the calculator uses to find the upper and lower quartiles is as follows: If N is even (eg. 12)…

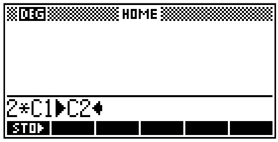
median = av. of 4 & 5 = 4·5
{ 1, 2, 2, 3, 4, 4, 5, 6, 6, 6, 7, 8 }
Q2 = median of upper half = 6
Q1 = median of lower half = 2·5

If N is odd (eg. 11)…

median = middle score = 4
{ 1, 2, 2, 3, 4, 4, 5, 6, 6, 6, 7 }
Q2 = median of upper half = 6 <u>excluding</u> median value
Q1 = median of lower half = 2 <u>excluding</u> median value

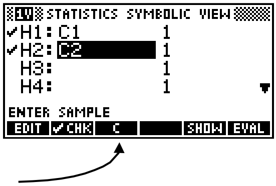
As you probably know, there is no standard way to find these Q1 and Q2 values. This is a fairly common method and is only likely to cause you problems if your teacher insists on another method which gives a different result.

Let's create a second column of data, and cheat by making all its values double the values in the first column. We can use the **HOME** view to avoid having to retype the values as follows…



* Change to the **HOME** view and type in: then press **ENTER**.
* Hit the **NUM** key to change back to the **NUM**eric view. You should find your new column created and ready.

If you now hit the '*Stats*' button, you will find that you still only see statistics for the first column (H1). The reason for this is that you have not set up the second column in the **SYMB** view.



Change into the **SYMB** view and change yours so that it looks like the one on the right. You must make sure that H2 is CHKed, because only CHKed columns will show on the '*Stats*' page.

Note that a programmable key is provided to give you the letter C without having to use the **A..Z** button.

If you check you will find that the stats are now available for both columns of data.

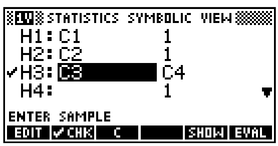
You may be wondering why the **SYMB** view is organised around H1, H2..H9 rather than simply around the columns C1, C2..C9. The reason is that it allows you to easily cope with a frequency table by setting up one column to represent values and another to represent the frequencies. If not using a frequency table, the frequencies are normally set, of course, to 1.

Let's set up columns C3 and C4 to represent the table below.

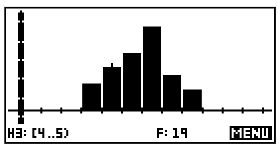
x_i	freq.
3	12
4	19
5	25
6	37
7	15
8	9

Enter the values 3, 4, 5, 6, 7 and 8 into C3 and then 12, 19, 25, 37, 15 and 9 into C4

Now set up your **SYMB** view to look like the one below. Make sure only H3 is CHKed.

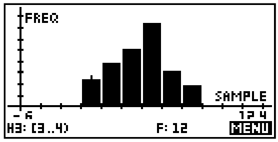


Only one histogram can be drawn at a time and if more than one is CHKed, only the first one is drawn.

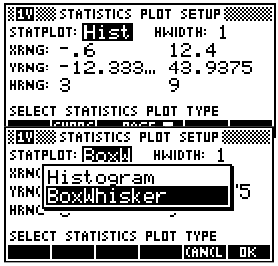


Now use **VIEWS** - ‘*Auto Scale*’ to plot the graph. You will find that it looks like the one on the right.

If you use the left/right arrows and look at the bottom of the screen you’ll see that the frequencies and ranges are listed. I found that I could tidy this graph up a little by going into **PLOT SETUP** and (on the second page) setting the YTick value to be 5 instead of 1. I also CHKed the ‘*Labels*’ option. The result is shown right.

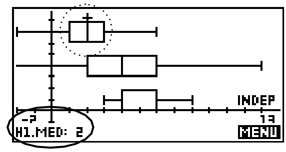


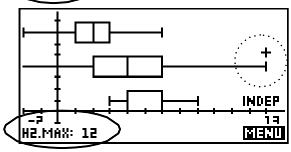
You probably noticed a lot of other options in the first page of **PLOT SETUP**. Their explanations follow.



The setting of ‘Statplot’ controls what type of graph is drawn. There two choices are ‘Hist’ (for histogram) or ‘BoxW’ (for Box and Whisker). Pressing the + key while ‘Statplot’ is highlighted will switch between these two, or you can hit the button under ‘*Choos*’ and pick from the menu that pops up.

Unlike histograms, it is possible to have more than one box and whisker graph plotted. This makes comparisons between data sets very easy. If you look for the cursor (circled) in the diagram shown right, you will see that when ‘*Trace*’ and ‘*(x,y)*’ are turned on (as they are by default) then information about the graph is given at the bottom of the screen. As usual the up/down arrows change from graph to graph, while the left/right arrows move within the graph.

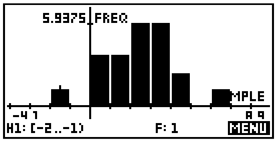




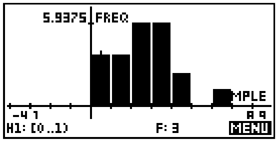
As an aside, pressing the ‘*Menu*’ button produces the normal tools of ‘*Zoom*’, ‘*Trace*’, ‘*(x,y)*’ and ‘*Defn*’. They all behave in the normal manner. The ‘*Defn*’ tool can be quite useful by displaying at the bottom of the screen information on which columns make up each graph if you lose track.

Looking again at the screen shot of page 1 of **PLOT SETUP** (second from the top of the page) you will see that there are three ranges. As with the Parametric and Polar aplets, XRange and YRange control how much of the graph is seen. If your histogram has frequencies of (say) up to 30 then you need to make sure your YRange reaches at least that value or the top of the histogram will be cut off. In the same way, if your data has a minimum value of -5 and a maximum of 35 then your XRange will need to be at least that size. Using **VIEWS** '*Auto Scale*' generally produces very satisfactory results.

The effect of HRange is rather odd. It controls what range of data is analysed in calculating the frequencies, and is normally set to be the maximum and minimum values for the data. For example H1 (shown right) has an HRange of -2 to 7. If I go into **PLOT SETUP** and change this to 0 to 7 then the graph loses the left hand column representing the value of -2.



This allows you to eliminate outliers from your graph quite easily. Eliminating them from your graph does not eliminate them from inclusion in the calculation of the values that appear in the '*Stats*' page. To do that you would need to use **DEL** in the **NUM** view to delete the actual data itself.



If you have a particular need to graph two histograms, the only way to do it would by using **VIEWS -** '*Plot Overlay*'. This would only be visually successful if the two did not overlap. Basically this is not advisable.

One final note concerns the grouped data. We saw earlier how to deal with data displayed in a frequency table, but did not deal with the case where the data was also grouped into intervals or classes.

For example:

data	yi
10 - 19	15
20 - 29	25
30 - 39	37
40 - 49	23
50 - 59	17

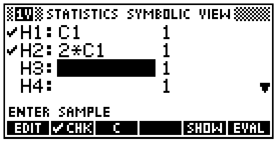
The HP38G does not provide a way for dealing with data of this form. Statistics for the data can be obtained by entering the mid-points of the intervals as the data values but these will of course only be approximations.

The graphical plot of this will then show a series of isolated columns (width one unit) at each mid-point, instead of columns extending the width of the intervals from 10 - 19, 20 - 29 etc.

Tips and Tricks - Univariate Statistics

New columns as functions of old

You have already seen the use of one trick when we created a new column C1 by storing 2*C1 into C2 using the HOME view. This can easily be extended to create new columns as functions of any number of others. For example, a set of data that you suspect is exponential could be straightened by storing LN(column) into a fresh column. Changes of scale and origin can be investigated in this way by storing (say) -2*C1 + 3 into C2. You can even combine columns such as storing C1 + C2 into C3.



If you don't particularly need the data to be actually stored as a fresh column, you can use the SYMB view to accomplish the same thing in a simpler way. For example, the SYMB view snapshot on the right would accomplish the same thing as storing 2*C1 into C2. A histogram of H2 would look the same as the one we produced earlier using the HOME view, and the '*Stats*' command would give exactly the same results. The advantage of this is that it takes much less memory if both columns need not be stored.

Simulating Random Variables

It is occasionally handy to be able to fake a set of data that simulates observations on random variables of various sorts. This can be done using a function from the MATHS menu called 'MAKELIST'.
(Covered in the section on the MATHS key, see pages 125 - 170)

The syntax is: MAKELIST(*expression, variable name, start , end, increment*)

where	*expression*	is the mathematical rule used to generate the numbers.
	variable name	is the letter (X, Y etc.) that is to be used in the expression (any other letters will be taken as constants).
	start	is the first value that *variable name* is be given.
	end	is the largest value that *variable name* is to take.
and	*increment*	is the amount that *variable name* should be incremented by.

For example: MAKELIST(X^2,X,1,10,2)

would produce { 1, 9, 25, 49, 81 } as X went from 1 to 3 to 5 to …

Example 1: Simulate 100 observations on a U[0,1] r.v. to be stored in C2.

In the **HOME** view type: MAKELIST(RANDOM,X,1,100,1)➢C2

Note: 1. The ➢ symbol is a programmable keys in the **HOME** view, appearing as 'STO➢' and read as 'store'.

2. The X is only a dummy variable here to count off the obs.

Example 2: Simulate 50 observations on a discrete uniform r.v. U[3,7]

In the **HOME** view type: MAKELIST(INT(5*RANDOM+3),X,1,50,1)➢C2

Example 3: Simulate 50 obs. on a Binomial r.v. with n = 20 and p = 0.75. In the **HOME** view type: MAKELIST(Σ(J=1,20,RANDOM<0·75),X,1,50,1)➢C2

Note: The Σ and the = can be found using the **CHARS** key.

Example 4: Simulate 100 obs. on a normal distribution with μ=80 and σ^2=50.

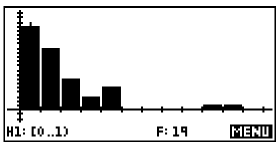
In the **HOME** view type: (ensure **MODES** is set to radian measure first)

MAKELIST(80+√50*(√(-2*LN(RANDOM))*sin(2*RANDOM)),X,1,100,1)➢C2

Example 5: Simulate 50 obs. on an exponential distribution with a mean of 2.

In the **HOME** view type: MAKELIST(-2*LN(1-RANDOM),1,50,1)➢C2

As an illustration, the result of this particular simulation is shown graphically on the right. Its mean turned out to be 2.067 (3 decimal places.). Yours will be different of course - after all, that's the point of using *random* numbers!



NOTE: Sometimes when dealing with large columns of data you will get an error message saying ‘Insufficient memory’.
Some steps to help are given below. Retry whatever you were doing after each step. Remember, the memory is not infinite!

1. Use BLUE CLEAR to delete the HOME history. If you’re using HOME to deal with large lists then it will use a lot of memory in a short time because the lists are stored in the history as well as being copied into the column you specified.
   You could just delete the lines showing the lists and leave the lines of complex typing if you’re going to re-use them later.

2. ‘*Reset*’ any aplets containing data which is no longer required.

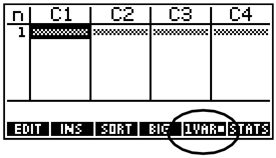
3. Hold down the ON key and simultaneously press the first and third programmable keys from the left. Hold down all three keys for about a second and then release. This does a low level memory clear out. It will not delete any programs or aplets that you have downloaded into the calculator, nor will it affect any Notes or Sketches that you may have stored.

4. Do the same as for step 3, except use the first and last programmable keys.
   WARNING! This resets the calculator to factory defaults and will delete the entire contents of your calculator, including any aplets you have saved. Only the standard six aplets will not be deleted, since they are permanently built in to the calculator, and their contents will be lost.

5. Sometimes the HP38G can lock up completely. This is very rare when running any of the standard six aplets, but can occur when running a ‘foreign’ aplet. If this happens, try pressing the ON button repeatedly. Next, try steps 3 and 4 above. If the calculator is still not responding then turn it over and look at the back. On the right hand side (of the calculator, not the cover) you will see a very small hole. Gently insert a wire (an unbent paper clip is ideal) into this hole and *gently* push the reset button hidden inside. Now turn the calculator back over and try turning it on again. If you still have no luck you will need to consult a service provider.

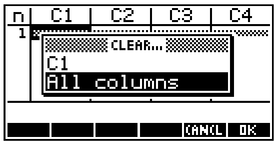
The Statistics Aplet - Bivariate Data

As I said in the Univariate section, one of the major strengths of the HP38G is the tools it provides for dealing with statistical data. Unlike the others, the Statistics aplet begins in the **NUM**eric view which offers easy input and editing of values, while the **SYMB** view is reserved for specifying which columns contain data and which frequencies, as well as for indicating pairing of columns for bivariate data.



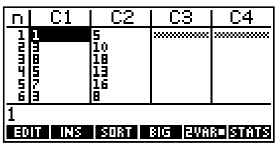
The HP38G treats univariate and bivariate data quite differently and those differences are reflected in the **SYMB** and **PLOT** views. Because of this we have split the Statistics chapter into two.

The previous section dealt with univariate data and we are now going to look at bivariate (paired) data. On the screen in the **NUM** view of the Statistics aplet you will see a button labeled as either '*2VAR*' or '*1Var*'. Pressing the button under this label changes from univariate (1VAR) to bivariate (2VAR) and back. Make sure the button is showing '*2VAR*' before proceeding.



If your **NUM** view already has some data in it, press **CLEAR** (above **DEL**) and choose '*All columns*'. The **DEL** key is used to delete individual pieces of data, rather than whole columns. One must be careful when doing this for Bivariate data. If your data pairs were in column 1 (C1) and column 2 (C2) then deleting a single piece of data from C1 without deleting its paired element in C2 would destroy the relationship between the two columns.

Let's use the set of data on the next page to illustrate the use of the features of the Bivariate aplets. We will obtain all the usual statistics on it, as well as drawing a scattergram.



Move the highlight into column C1 and enter the x_i data, pressing the **ENTER** key after each piece of data. Now do the same for the y_i data in C2.

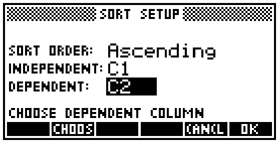
Looking at the bottom of the screen you will see a series of tools provided for you. '*Edit*' is not really worth bothering with. It is easier just to retype a number than to press '*Edit*' and then use the arrow keys and **DEL** to change it.

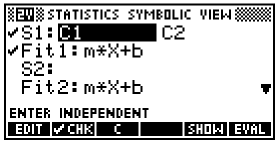
Note: You can enter the x_i and y_i data into both columns simultaneously if you enter it as an ordered pair in brackets.
i.e. as (1,5) **ENTER** (3, 10) **ENTER** etc.

x_i	y_i
1	5
3	10
8	18
5	13
7	16
3	8
6	15
2	8
7	18
9	22
8	17
5	15
7	14
6	18
8	20
5	12
2	8
0	4
7	17
8	19

The key labeled '*Ins*' inserts space for a new number by shifting all the numbers down one space. If working with bivariate data you will need to be careful to insert into the paired column as well.

One of the options listed on the screen is '*Sort*', which is capable of dealing with Bivariate data if you are careful to enter the column number of the dependent column into the appropriate space. The '*Choos*' key will pop up a list of columns from which to choose, or you can use the **A..Z** key. See the 'Tips and Tricks' section at the end of this chapter for a useful technique using '*Sort*'.

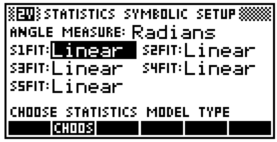




The next stage in dealing with bivariate data is to specify the relationships between columns. This is done with via the **SYMB** screen.
The S1:, S2: … refer to data sets 1, 2… This allows you to display more than one set of bivariate data by specifying the columns for each set. Columns can be used in more than one set.

The screen above right shows the default setup established when you '*Reset*' the aplet in the **LIB** screen. It specifies that columns C1 and C2 are paired and that a linear fit (m*X + b) is to be used when calculating a line of best fit. Notice that a special 'C' key is provided for your convenience in the set of programmable keys below the screen.

If you have calculated a line of best fit (see page 81) and want to remove the resulting set of numbers from the **SYMB** display and return to the 'm*X+b' default (perhaps in order to change the number of decimal places displayed or the data itself) then just position the highlight on the relevant 'Fit' line and press the DEL key.



The **SYMB SETUP** screen allows you to specify what type of fit equation is to be used. The choices available are:

Linear - m*X+b ($Y = mX + b$)

Logarithmic - m*LN(X)+b ($Y = m\ln X + b$)

Exponential - b*EXP(m*X) ($Y = be^{mx}$)

Power - b*X^m ($Y = bX^{m}$)

Quadratic - a*X^2+b*X+c
($Y = aX^2 + bX + c$)

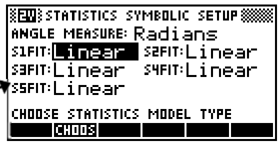
Cubic - a*X^3+b*X^2+cX+d
($Y = aX^3 + bX^2 + cX + d$)

Logistic - L/(1+a*exp(-b*X)) this function fits the data to a logistic curve ($Y = \dfrac{L}{1+ae^{-mX}}$) where L is the saturation value for

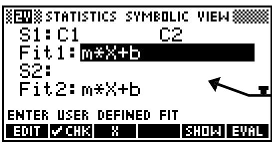
growth. If known, you can store a positive real value in L prior to the curve fit or, if you want it calculated automatically, pre-store L = 0.

and User Defined (not discussed here)

The specification of pairs of columns also allows the use of functions of columns. For example, we could pair C1 with C2+C3, or C4 with ln(C5).

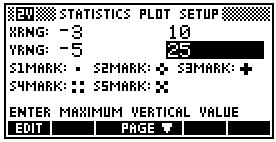


Continuing our demonstration, make sure that your **SYMB** and **SYMB SETUP** screens look like the ones shown on the right.

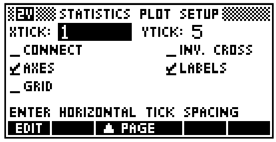


Pressing BLUE CLEAR in either of these screens will reset them back to their defaults (as shown).

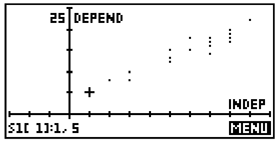
We could use VIEWS - **Autoscale** to produce an automatic plot (generally producing very satisfactory results), but let's have a look at the **PLOT SETUP** screen this time.



As you can see, it is very similar to the other PLOT SETUP screens that we have encountered earlier with the main difference consisting of the list of settings for S1MARK, S2MARK etc. These are the markings that are to be used in plotting the points, allowing you to choose different markings for different data sets.



Set your PLOT SETUP screen so that it looks like the one shown at the top of this page, also switching to the second page and ensuring that it is ticked as shown right and setting YTick to 5.



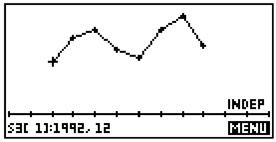
If you now press PLOT you will see the result shown right. If you look at the screen you will see a small cross and, at the bottom of the screen, a listing of S1(1): 1,5. This is telling you that the cross is currently sitting on the first point in data set S1 whose value is (1,5). Using the left/right arrow keys you can move this cross through the data set with the values being reported at the bottom of the screen. If you have more than one data set displayed on the screen then the up/down arrows move from one set to the other.

One of the settings on the second page of the PLOT SETUP screen deserves further comment at this point. One of the common tasks in many mathematical courses is the analysis of Time Series data. Unlike most bivariate data, time series values are usually plotted as a line graph - i.e. as connected points. This is allowed for by the _CONNECT setting.

For example:

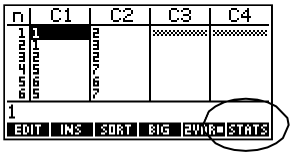
The sales of an ice-cream shop are shown as quarterly sales figures for the years 1992 to 1993. Display this data on a graph.

Yr	1992				1993			
Qtr	1	2	3	4	1	2	3	4
Sales (x$1000)	12	18	20	15	13	20	23	16



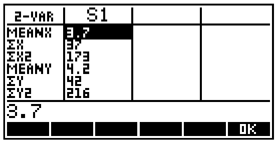
The result (with **CONNECT** ticked) is shown right.

Note: Instructions are given in the Statistics 'Tips and Tricks' section on how to create a moving average column from a set of data.



Two Variable Statistics

As with univariate statistics, summary statistics are available through the '*STATS*' button in the **NUM** view (see right).



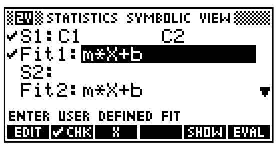
Pressing this button changes to a screen which lists the following: MEANX, ΣX, ΣX^2, MEANY, ΣY, ΣY^2, ΣXY, CORR, & COV.

Note: Be SURE that you see 'Warning # 2' on the next page about the unusual value given for the covariance.

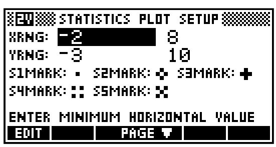
Let's use the set of data shown in the screen above to go through this process a second time and this time examine the line of best fit. The data is also listed in the box below.

x_i	y_i
1	2
1	3
2	2
5	7
6	6
5	7
4	3
5	6
6	4
2	2

Enter the data into the **NUM** view and then switch to the **SYMB** view. Make sure that S1 (Data set 1) is set to C1 and C2 and that the fit is linear (m*X + b). If not, the fit can be changed in the **SYMB SETUP** view.

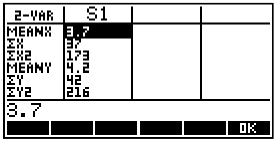


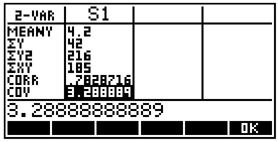
Now change to **PLOT SETUP** view and set the axes to be as shown below right.



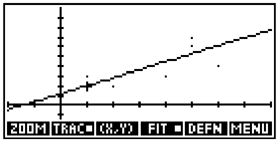
Now press the '*STATS*' button and you will obtain the results listed in the two screens shown below right…

NOTE: Make sure that the S1 data set is CHKed before you try to obtain these results. Results are only given for Data sets that are defined <u>and</u> CHKed.

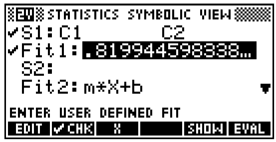




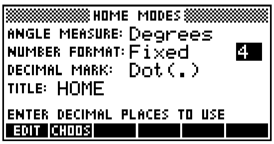
If you now press the **PLOT** button you will see the graph shown right. If there is no line of best fit on yours, press the '*MENU*' button to get the list of programmable functions along the bottom of the screen and then press the '*FIT*' button.



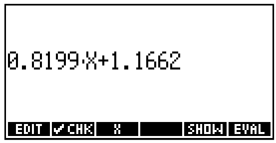
As soon as the line of best fit has been obtained, you can switch back to the **SYMB** view to get its equation. This equation is only calculated when called for by pressing the '*FIT*' button.



As you can see in the screen right, the equation is given to so many decimal places that it doesn't fit onto the screen. I only want it to 4 decimal places so I will change to the **MODES** screen (above the **HOME** key) and specify 'Fixed 4' as my Number Format (see below).



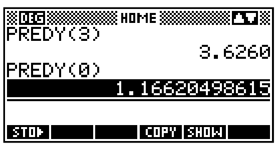
If I now change back to the **SYMB** view, position the highlight on the equation of the line of best fit (as seen above right), I can now press '*SHOW*' and obtain the view seen right which gives the equation of the line of best fit as $\hat{y} = 0{\cdot}8199x + 1{\cdot}1662$.



With a correlation coefficient of only 0.7829 (from previous page) this would probably not be regarded as terribly reliable.

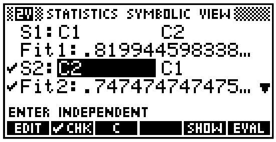
In order to make predictions from our line of best fit, we need to be back in the **HOME** view. We will use the functions PREDY (PREDict Y value) and PREDX from the Stat-Two section of the **MATH** menu.

The functions PREDX and PREDY use whatever was the last line of best fit calculated. *It is up to you to ensure that the one you want used was the one last graphed.* If I want to predict a y value for x = 3, then I simply type PREDY(3) into the **HOME** view as shown right. Note: see 'Warning # 1' on the page following about using PREDX.

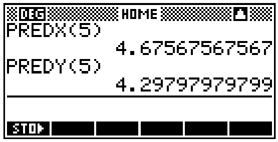


Warning #1: It is not advisable to use the PREDX function since it gives statistically questionable results.

The PREDX function simply reverses the line of best fit $\hat{Y} = 0{\cdot}8199\,X + 1{\cdot}1662$ given earlier and uses $\hat{X} = \dfrac{(Y - 1.1662)}{0.8199}$ to predict the X values.



This is mathematically incorrect, since the line of best fit (unlike the correlation) changes as the independent and dependent variables swap roles and can't be just reversed.



The formula for the slope *b* in the line of best fit $\hat{y} = a + bx$ is given by the formula: $b = \dfrac{S_{xy}}{(S_x)^2}$. While the value of S_{xy} will not change if the roles of independent and dependent columns are reversed, the value of $(S_x)^2$ on the bottom means that this formula will give a different value if you change which column is regarded as x and which as y.

If you wish to predict X values, you should change to the **SYMB** view and enter a new Data set S2 which uses C2 and C1 in reversed order, thus avoiding the need to re-enter the data.

Now plot the line of best fit and then use PREDY rather than PREDX. As you can see in the screen above, the result of PREDX(5) with C1 vs. C2 is not the same as PREDY(5) using C2 vs. C1 (which if PREDX worked correctly it should be!).

Warning # 2: As you probably know, most of the statistical measures have two possible values, called the 'population' and 'sample' values. The formulae are almost the same. In most cases, and certainly in most high school courses, the population values are the ones used.

For example: pop. variance…

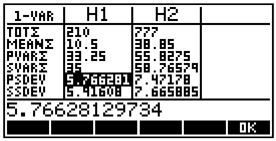
$$S_x = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n}$$

sample variance…

$$S_x = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n - 1}$$

As you can see, the only difference is that the sample version divides by *n - 1* instead of by *n*. This is a minor but crucial difference.

Both of these measures are quoted in the *Stats* screen (obtained by pressing the *Stats* button in the **NUM** view). The values are shown in the screen shot on the right.



The population values (the ones normally required) are PVAR. and PSDEV, while the sample values are SVAR. and SSDEV. Notice also that you can obtain a value accurate to 12 significant digits by highlighting the rounded value and looking in the space immediately below the table.

The only problem, and the reason for this being a warning, is that only one value is supplied for the covariance and *it is the one which is far less often used!*

The formulae for the covariance are:

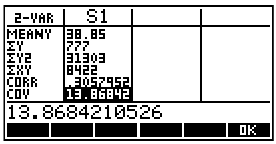
population…

$$S_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{n}$$

and sample…

$$S_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{n-1}$$

The value given in the bivariate version of the *Stats* page (see right) is the sample value divided by *n - 1* rather than by *n*. This is particularly strange in view of the fact that the usual value (the population one) is used in calculating the correlation coefficient!



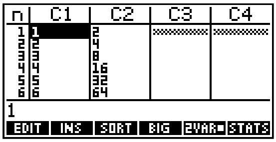
Fortunately the error is very easily corrected. All you need to do is take the value quoted in the screen (13.8684210526 from above) and multiply by *n - 1* and then divide by *n*.

In the case above, 13.8684210526 * 19 / 20 gives the correct population covariance of 13.175.

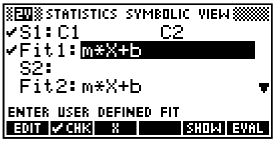
Warning # 3: Another quirk of bivariate stats needs to be kept in mind, but becomes important only when the fit chosen is not linear. This quirk is that the correlation coefficient quoted is always for the linear model even when the fit chosen is not linear.

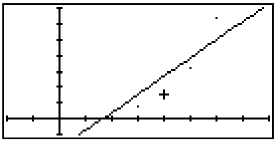
When a set of data is non-linear in nature you can choose to fit a curve rather than a straight line to the data. There are two ways to do this - you can choose a curve fit from those available, or you can transform the data mathematically so that it *is* linear. Let's illustrate this with a set of exponential data.

x_i	y_i
1	2
2	4
3	8
4	16
5	32
6	64

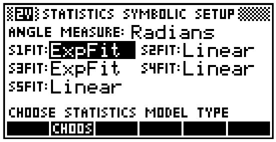


As you can see, I chose a very simple rule for the data: $y = 2^x$ If you set up a linear fit for the data in S1, and then view the bivariate stats, you will find that the correlation for a linear fit is 0.9058 As you can see from the graph, a linear fit is not a very good choice.

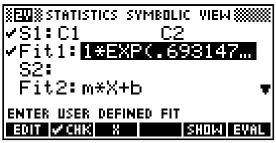




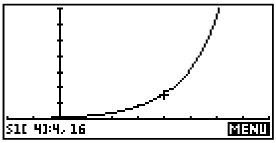
If we change now to the **SYMB SETUP** view and choose an Exponential fit rather than a linear fit then the results are far better.



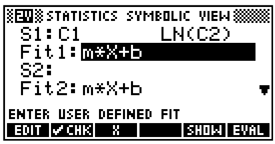
The curve which results in the **PLOT** view is exactly what is required and the equation (below) comes out as



$Y = 1 \cdot EXP(0.693147\,X)$ which means $Y = 1 \cdot e^{0.693147\,X}$ which then changes to $Y = 2^X$.



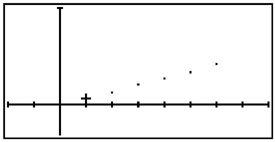
The only problem is that checking the '*STATS*' button shows that the correlation is unchanged at 0.9058 even when the new equation fits the data perfectly!



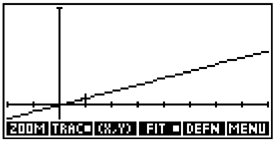
The alternative to this is to graph column C1 against ln(C2) which straightens the data. Since the data is now linear, we also use **SYMB SETUP** to change the fit back to linear (press **DEL** to clear the old equation).

$$y = a \times b^x$$
$$\Rightarrow \ln(y) = \ln(a \times b^x)$$
$$\Rightarrow \ln(y) = \ln(a) + \ln(b)\,x$$

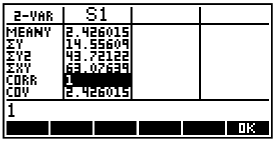
As you can see in the mathematical transformations shown left, the coefficients m and b in the resulting line of best fit correspond to the natural logs of a and b from $y = a \times b^x$.



The line of best fit (obscuring the data points) which results from the graph below right is $y = 0{\cdot}\ 69314718056X + 0$.



This gives coefficients of $a = e^0 = 1$ and $b = e^{0{\cdot}69314718056} = 2$ which gives the same equation as before.

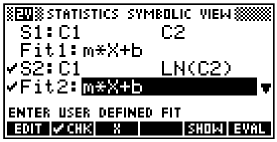


The main difference between the two methods is that checking the '*STATS*' button now gives a correlation of 1 as it should for the data chosen.

As you can see, the second of the two methods is more involved and slower than the first. If you require the equation of the curve then the first method of changing to an exponential fit is the better one by far. If you require the "correct" correlation coefficient you can then define a new 'straightened' data set and use it solely to find the value of r_{xy} via the '*STATS*' button.

Tips and Tricks - Bivariate Statistics

New columns as functions of old



As with univariate statistics, you can use functions of old columns as new sets of data. See the Univariate version of this section for two different ways of doing this.

For example, a set of data (C1,C2) that you suspect is exponential could be straightened by setting up S2: as (C1,LN(C2)).

The effects of changes of scale and origin on data and summary statistics can be investigated in this way by storing (say) -2*C2+3 into C2. You can even combine columns in this way, such as storing C1+C2 into C3.

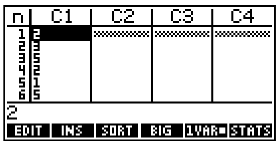
Obtaining values from the Stats page for use in calculations.

It is often useful to be able to retrieve values such as the mean and standard deviation for use in further calculations. With most simpler calculators these values are found by pressing keys rather than reading from a '*Stats*' page, so doing a calculation like 'multiply the mean by 3.5' is not hard. The values shown on the '*Stats*' page can also be retrieved for use on the HP38G, even if not quite so easily.

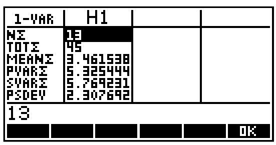
For example, the set of data below contains a suspected outlier (erroneous value). In the case shown below, one might suspect a missing comma.

{2, 3, 5, 2, 1, 5, 3, 6, 7, -2, 3, 5, 5, 55}

A common test for an outlier is to calculate the mean and standard deviation <u>without</u> the presence of the suspected outlier, and then to check to see whether the suspect piece of data is within three standard deviations of the mean. If not, then it is discarded.

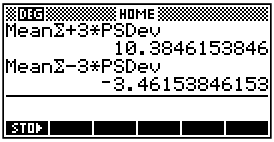


Enter the data (minus the suspected outlier) into column C1 with the calculator in '*1VAR*' mode. Ensure that the SYMB view is set up correctly and then press the '*Stats*' button.



As you can see on the right, the values of the mean and standard deviation are given in the '*Stats*' screen to 12 significant digits.

If we now switch to the HOME view, we can recall these values and use them in a calculation to find the upper and lower cut off points for acceptance of data.



As you can see on the left, the range for acceptance is -3.46 to 10.38, which makes the value of 55 almost certainly an error.

It is worth noting here that the Σ character came from the **CHARS** page, and that I typed all the formulae in uppercase - the calculator converted when I pressed **ENTER**.

> IMPORTANT NOTE! The values of the mean and standard deviation retrieved are those of the *last set calculated*. If you have more than one set of data in the **NUM** view then it is a good idea to firstly unCHK all except the one you want, and secondly, to press the '*Stats*' button in order to force a calculation of the values you want. This ensures that the ones you retrieve in the **HOME** view are the ones you want!

This technique can also be used for Bivariate data in exactly the same manner. You should ensure, as per the note above, that only the set of data you want to use is active (CHKed) and that '*Stats*' has been run for it.

All the values shown in the '*Stats*' page are retrievable. A problem is that there seems to be no way to retrieve the coefficients of the line of best fit, since they appear in the **SYMB** screen rather than the '*Stats*' screen.

The easiest way around it is to use an algebraic 'cheat'. The function PREDY( ) from the **MATH** library gives a predicted y value *using the last line of best fit that was calculated*. This means that you must not only use the **SYMB** view to ensure that your set of data is the only one CHKed and make sure **SYMB SETUP** is set to a 'Linear' fit, but also use the **PLOT** screen and the '*FIT*' button to ensure that your set of data was the last one graphed and that it has had its line of best fit displayed.

If the line of best fit is $y = m * X + b$ (as shown in the **SYMB** screen) then the calculations shown below, performed in the **HOME** page, will give the slope and y-intercept of the line of regression.

$$\begin{aligned} PREDY(0) &= m * 0 + b \\ &= b \\ \text{and} \quad PREDY(1) - PREDY(0) &= (m * 1 + b) - (m * 0 + b) \\ &= m + b - b \\ &= m \end{aligned}$$

Assigning Rank orders to sets of data (including Competition results)

It is occasionally handy to be able to assign rank orders to a set of data. You might be running a Quiz Night, or recording times for the 100 metre sprint, but in either case it is handy to be able to sort the data into descending order and assign rankings. This is easy for small sets of data, but becomes more difficult for larger sets.

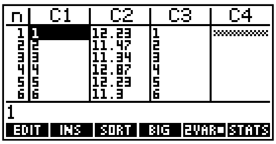
Let us assume a set of 20 competitors in the 100 metre sprint, with times recorded to two decimal places, and competitors numbered 1 to 20.

Suppose that the results were as shown right…

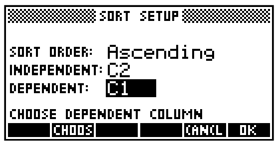
Competitor	Time
1	12.23
2	11.47
3	11.34
4	12.87
5	12.23
6	11.30
7	10.51
8	11.34
9	11.46
10	12.34
11	12.23
12	11.50
13	12.01
14	11.97
15	12.05
16	12.87
17	12.02
18	12.52
19	11.37
20	10.75

Enter the competitor numbers as column C1 and the times in column C2. In addition to this, put the numbers 1 to 20 into column C3 also. The numbers 1 → 20 become a bit tedious to type in for lists longer than 20, so you could use the expressions MAKELIST(X,X,1,20,1)➢C1 and C1➢C3 to shortcut the process.

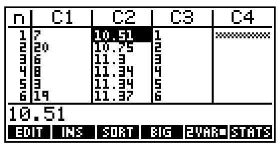
Make sure that the '*2VAR*' option is selected. The result should look like this…



Now position the highlight on column C2 and press the '*SORT*' button. In the **SORT SETUP** screen (shown below right) enter C1 as the Dependent column. This will have the effect of pairing columns C1 and C2 and then sorting column C2 into ascending order, re- arranging column C1 to reflect the changes. When ready, press '*Ok*'.



The results of this sort are shown on the right.



The final column C3 has not been re-arranged and it will be used to contain the rankings. Looking down the column it can be seen that there are two values of 11.34 (the 4th and 5th). Their ranking should therefore both be changed to 4. Continuing this process down the length of column 3 will produce the rankings for the whole 20 competitors.

Note: There are two common ranking systems in use. In the first, a set of scores as shown below would be ranked as shown, with same scores receiving the rank of the first one.

score	16	13	10	10	10	9	9	8	6	6	6	6	3
rank	1	2	3	3	3	6	6	8	9	9	9	9	13

In the second system, scores that are the same receive the average of the ranks of all those that are the same. Under that system, the ranks would be…

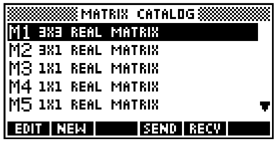
score	16	13	10	10	10	9	9	8	6	6	6	6	3
rank	1	2	4	4	4	6.5	6.5	8	10.5	10.5	10.5	10.5	13

Av. of 3, 4 & 5.

Av. of 6 and 7.

Using Matrices with the HP38G

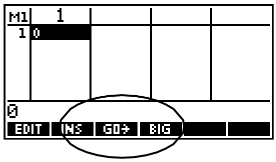
The HP38G deals quite well with matrices. A special Matrix Catalogue is provided with full editing facilities which allow easy manipulation and changes.



The Matrix Catalogue is entered by pressing the **BLUE MATRIX** key (located above the 4 key). It allows for the storage of up to ten matrices (M1,M2,..M9,M0) which can be almost any size, depending only on available memory. In the example shown right, the catalogue contains two matrices, a 3 x 3 and a 3 x 1. The reason that the catalogue specifies that they are 'real matrices' is that the HP38G is capable of storing and manipulating not only matrices of real numbers but also matrices of real vectors, complex numbers and complex vectors! The '*New*' key pops up the menu shown on the right, replacing the highlighted matrix with one of the new type that you specify.

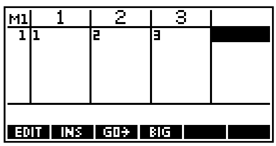
Those not yet at University will normally only require the default real type and, apart from small diversions, only those type will be covered here.

Let us begin by entering a matrix into the catalogue to practice simple editing.

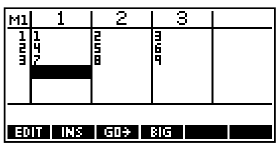


If there are any matrices currently in the catalogue, use **BLUE CLEAR** to delete the whole catalogue. Move the highlight to matrix M1 and press the '*Edit*' key. The normal state for a blank matrix is to contain nothing but a single zero (this is why they all register as 1x1 even after erasure).

If you look at the list of programmable screen keys along the bottom of the view, you will see one labeled '*GO*' with an arrow. This key determines which way the highlight will move (across or down) each time you enter a number. If you press the key repeatedly you will see it change from '*GO*↓' (down), to '*GO*→' (across), to 'GO' (no movement). You will also see the usual '*BIG*' key and an '*INS*' key that can be used to insert an extra row or column into an existing matrix. The keyboard **DEL** key can be used to delete a row or column.



With movement set to '*GO*→', type in the numbers 1, 2 and 3, pressing **ENTER** after each. Your display should now look like the screen shot right.

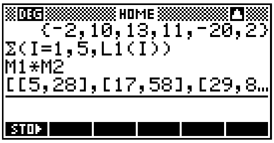


If you now press the down arrow key on the keyboard the highlight will move back to the first element in the second row. If you now enter the numbers 4, 5 and 6 you will find that the calculator automatically drops down to row three without the need to use the down arrow key, since it now knows how many columns the matrix is to contain. Finish your matrix so that it looks like the one shown right.

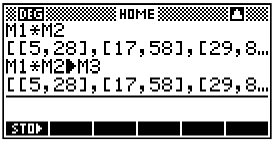
$$\begin{bmatrix} 2 & -1 \\ 3 & 4 \\ -1 & 7 \end{bmatrix}$$

Now press **BLUE MATRIX** to switch back to the Catalogue and '*Edit*' M2 to contain the matrix shown right.

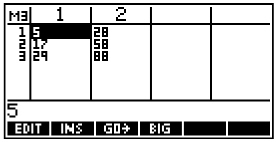
Switch now to the **HOME** view and multiply M1 * M2. As you can see, the result displayed in the **HOME** view is not very useful or readable. Pressing '*Show*' does not help in this case either.



A better method is to store the result into a third matrix and then to view it through the Edit screen of the Matrix catalogue. This is shown below…



Matrix M3 is created left and edited right.



The most common functions that you will use are INVERSE, DET and TRN (transpose), so we will begin with some worked examples using them.

Eg. 1 Solve the system of equations:

$$\begin{cases} 2x + 3y - z = -6 \\ x - 3y + z = 12 \\ 3x - y + 4z = 13 \end{cases}$$

Solution: The system can be represented as the system of matrices:

$$\begin{bmatrix} 2 & 3 & -1 \\ 1 & -3 & 1 \\ 3 & -1 & 4 \end{bmatrix}\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} -6 \\ 12 \\ 13 \end{bmatrix}$$

This system can then be algebraically rearranged to: $\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 2 & 3 & -1 \\ 1 & -3 & 1 \\ 3 & -1 & 4 \end{bmatrix} \begin{bmatrix} -6 \\ 12 \\ 13 \end{bmatrix}$

where the inverse matrix is… $\begin{bmatrix} 2 & 3 & -1 \\ 1 & -3 & 1 \\ 3 & -1 & 4 \end{bmatrix}^{-1}$

which gives a final answer of $\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 2 \\ -3 \\ 1 \end{bmatrix}$

Mathematically what we have done is:

$Ax = b$ where A is the coeff. matrix and b is the constant matrix.

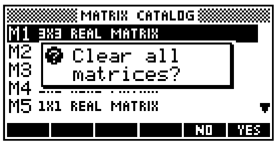
$$x = \frac{1}{A} \times b$$

which is usually written as: $x = A^{-1} \times b$

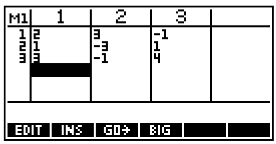
or as: $x = inverse(A) \times b$

The method for doing this on the HP38G follows…

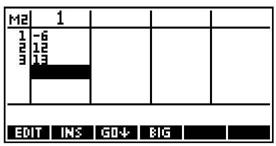
Step 1. Enter the Matrix catalogue. Use **BLUE CLEAR** to erase all matrices.



Step 2. Enter the 3x3 matrix of coefficients in M1.



Step 3. Enter the 3x1matrix of constants into M2. Notice the change to '*Go*↓' in order to make entering numbers easier.

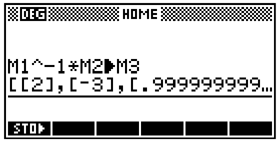


Step 4. Change to the **HOME** view, evaluate $A^{-1} \times b$ using any of the following three methods (all of which are acceptable to the HP38G), and store the result into M3.

(a) $M1^{-1} * M2$

(b) $M2 \,/\, M1$

(c) INVERSE(M1)*M2



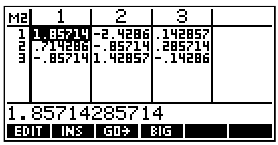
The best of these is probably (a) because it doesn't involve fetching the INVERSE function from the **MATH** menu like (c), and reminds you, unlike (b), that the operation is really left-multiplication by the inverse, not a division (which is not strictly speaking defined for matrices). You may, of course, please yourself.

The answer is displayed in the **HOME** view as ((2),(-3),(.999999999999)) which is really the same as x = 2, y = -3, z = 1. The strange answer for z = 1 is caused by rounding error. The reason is that the determinant of the inverse matrix is -33 giving recurring numbers in the calculations when it is used in divisions.

Eg. 2 Find the inverse matrix A^{-1} for the matrix $A = \begin{bmatrix} 2 & 1 & 4 \\ 1 & 1 & 3 \\ -2 & 4 & -1 \end{bmatrix}$

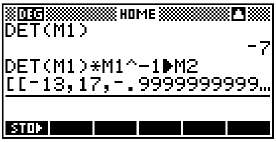
The first step is to store the matrix A into M1. If you now simply store its inverse into M2 you will find, depending on the determinant, that the result is probably a collection of decimal values (see right).

While correct, this is hardly the best way to display the answer.

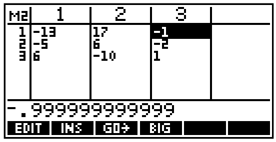


A better way it to write the answer as a fraction $\dfrac{1}{\det(A)}$ multiplied by a matrix of whole numbers.

i.e.



with M2 being…



Thus we can finally write: $A = \dfrac{1}{-7}\begin{bmatrix} -13 & 17 & -1 \\ 15 & 16 & -2 \\ 6 & -10 & 1 \end{bmatrix}$

Eg. 3 A company manufactures three types of coats; Cotton, Tweed and Wool at factories in Mid-West, Eastern and Hopwood. The numbers of coats manufactured in October were at Mid-West; 345 Cotton, 174 Tweed and 97 Wool, at Eastern; 462 Cotton, 203 Tweed and 122 Wool, and at Hopwood; 111 Cotton, 62 Tweed and 54 Wool. The cost of each type of coat to manufacture is $45 Cotton, $87 Tweed and $210 Wool. The coats retail at $57 for Cotton coats, $101 for Tweed and $250 for Wool.

(a) Display the information given above in the form of a production matrix N, a cost matrix C and a retail matrix R.

Using matrix multiplication techniques:

(b) find the total costs incurred by each factory.

(c) find the total income before costs for each factory.

(d) find the total profit at each factory & the total profit for all three factories.

(a)

Enter these as M1, M2 and M3 into the matrix catalogue, using the dimensions shown.

$N =$

$M1$	C	T	W
M	345	174	97
E	462	203	122
H	111	62	54

$C =$

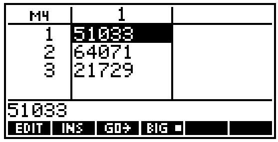
$M2$	C	T	W
$	45	87	210

$R =$

$M3$	C	T	W
$	57	101	250

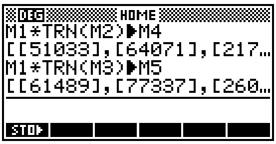
(b) Total costs = $N \times C^T$, where C^T is the transpose of C.
This is done in the home view, storing the resulting matrix in M4.

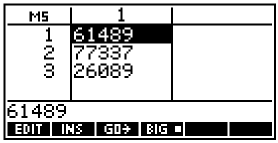
These results are more easily seen in the matrix edit view with '*Big*' switched on.



Thus the answer is: $51033 at Mid-West, $64071 at Eastern and $21729 at Hopwood.

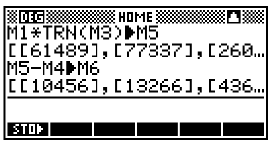
(c) The same method for Total income = $N \times R^T$, stored into M5 gives…





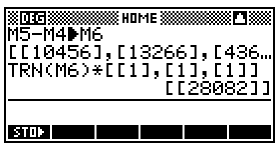
… with the final answer being: $61489 at Mid-West, $77337 at Eastern and $26089 at Hopwood

(d) Profit = Income - Costs
= M5 - M4



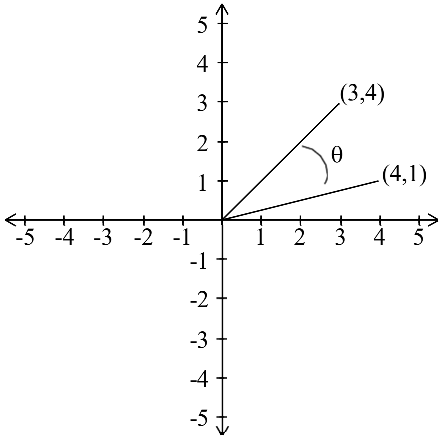
with the final answer being $10456, $13266 and $4360 at Mid-West, Eastern & Hopwood respectively.

Total combined profit is given (remembering that matrix operations must be used) by multiplying $M6^T$ by $\begin{bmatrix}1\\1\\1\end{bmatrix}$.



This gives a total profit of $28082

Eg. 4 Find the angle between the vectors $a = (3,4)$ and $b = (4,1)$.



Using the formula that

$$\underline{a} \bullet \underline{b} = |\underline{a}|.|\underline{b}|.\cos\theta$$

where $\underline{a} \bullet \underline{b}$ is the dot product, we can rearrange to obtain:

$$\cos\theta = \frac{\underline{a} \bullet \underline{b}}{|\underline{a}|.|\underline{b}|}$$

Therefore:

$$\cos\theta = \frac{(3,4) \bullet (4,1)}{|(3,4)|.|(4,1)|}$$

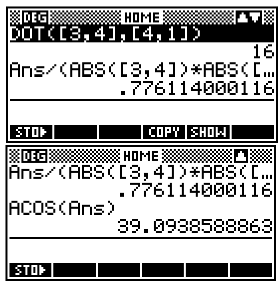
$$= \frac{3 \times 4 + 4 \times 1}{\sqrt{3^2 + 4^2}.\sqrt{4^2 + 1^2}}$$

$$= \frac{16}{5\sqrt{17}}$$

$$\theta = 39 \cdot 09^\circ$$

On the calculator, the functions DOT and ABS give the dot product and magnitude respectively, *when fed with vectors.* The HP38G writes vectors as row matrices. For example $a = (3,4)$ would be written as [3,4].

The calculations are shown in the two screen shots on the right.



The list of matrix functions available through the **MATH** menu is covered on pages 159 - 163. Not all functions are covered, since many of them go far beyond the requirements of the average student at whom this book is aimed.

Using the Notepad Catalogue with the HP38G

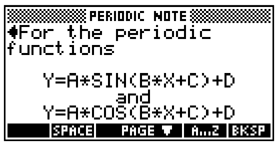
The HP38G provides Notepad which can be used either to attach notes to an aplet or to create independent notes for any use. The six standard aplets don't have any notes attached to the them unless you add them, but any copies you transfer from another calculator may have had notes added to them by other people. In particular, any special aplets you download to your calculator from the Internet (perhaps via your teacher) will almost certainly come with an accompanying set of instructions in the form of a note and perhaps a sketch also.

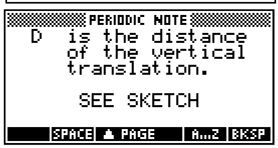
Every aplet has a note attached to it, whether it is actually used or not. This note is available via a button labelled **NOTE** (on the **VAR** button). Thus an instruction to 'press BLUE NOTE' refers to the aplet Note.

In addition to this, there is a Notepad Catalogue available via a button labelled NOTEPAD which can be found above the '1' button. Thus an instruction to 'press BLUE NOTEPAD' refers to the Notepad Catalogue, not to the aplet Note.

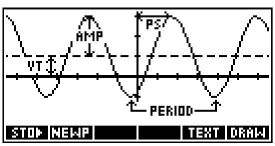
Since notes attached to aplets are explained in more detail in the chapter "Creating an aplet for the HP38G" on pages 104 - 124, only a brief example of an attached note is given below:

The PERIODIC aplet is one that can be used to teach about the periodic nature of the graphs of sin, cos and tan. It has been downloaded into the calculator from the Hewlett-Packard site on the Internet and is now available to be run via the LIB key.





When the aplet is run, the first thing that you will see is the Note attached to the aplet. This is very common with these special aplets - since they are not standard aplets, the author ensures you have a chance to see some instructions first.



This particular set of notes consists of four pages, with only the first and last of them are shown on the right. As you can see, this aplet also has a sketch attached to it. This can be viewed via the SKETCH key above the MATH button. The sketch is shown left. Sketches can also have multiple pages and are covered in the following chapter.

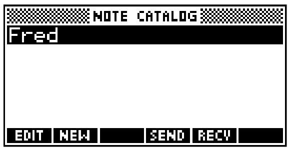
The Notepad Catalogue can be used to hold various notes to yourself. You might for example have one for Homework and/or Assignments. As an exercise here, we will develop a Note containing some common formulae. *What you are allowed to keep and take into tests is, of course, a matter for the policy of your school's Mathematics department. It is not a good idea to cheat by taking illegal material into a test, since it could well result in (at the very least) a score of zero on the test.*

Notes can be shared between friends, since they can be transmitted over the built in infra-red link in the same way as for aplets, lists, matrices and programs. It is worth pointing out that this will not help you in a test situation, since the infra-red link in the HP38G has been deliberately 'nobbled' in the factory so that it will only operate over extremely short distances. It's going to be pretty obvious what you're doing if you try to transmit Notes in a test.

Notes also consume memory. If you start accumulating Notes you will find that you don't have room for your aplets (which are surely more useful).

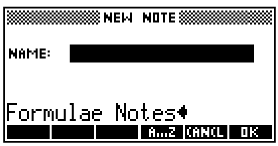
In addition to this, the HP38G was never designed nor intended to be a typewriter. Typing text is a slow and laborious process. As you begin to become more familiar with the positions on the keyboard where the various letters of the alphabet can be found your typing speed will improve, but it will never remotely compare to typing on a keyboard. If you want to prepare anything more than casual Notes, then it is best to invest in the HP Connectivity Kit. This Connectivity Kit, discussed in more detail in the chapter on Aplets, allows transfer not just of aplets but of Notes as well. The Connectivity Kit does not however allow editing of the note and you cannot use a normal text editor to finish it off and then transfer it back to the calculator. A FREE piece of software is available over the Internet from Hewlett-Packard called the Aplet Development Kit which allows easy editing. It runs only under Windows, not on Mac computers.

Having said all this, let's create a small Note containing some commonly used formulae. If you press BLUE NOTEPAD (not BLUE NOTE), you will see the Notepad Catalogue shown right. Yours will probably be empty.



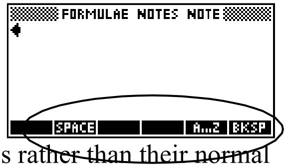
As you can see, the keys at the bottom of the screen allow you to '*Edit*' an existing Note, create a '*New*' one or to send/receive Notes to/from another HP38G (or PC/Mac). A Note is deleted using the **DEL** key, while the **BLUE CLEAR** key will delete all Notes in the catalogue.

Press the '*New*' key to begin a fresh Note. You will be presented with the screen on the right, requesting that you enter a name for the Note. Names can be any length and can contain any characters, alphabetic, numeric, spaces as well as any from the CHARS menu.



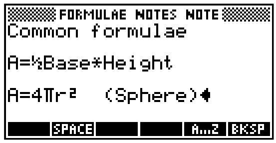
When you press ENTER after typing in the name, you will see a blank screen waiting for you to begin typing in your Note.

Before we begin, a word about making your typing easier. The normal method to enter an alphabetical character is via the button below the **ENTER** key labelled A..Z. Lowercase letters are obtained by pressing the **BLUE** key first. This A..Z key can be held down with one hand while you type with the other, but this is hardly convenient. A space is obtained via BLUE SPACE, with the SPACE located on the 2 key.

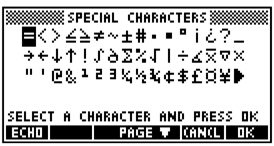


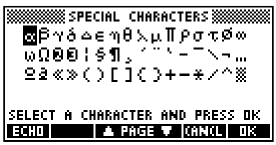
At the bottom of the screen in the Notepad view (and in many other views too) you will see programmable keys labelled A..Z, SPACE and BKSP (backspace). If you press the A..Z key then from then on all the buttons on the calculator will give their alphabetic values rather than their normal mathematical functions. Pressing the BLUE key first before the A..Z key will lock it into lowercase rather than into uppercase. Pressing the A..Z key again disengages it.

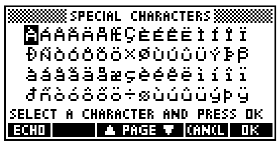
The reason for the SPACE key is that the normal SPACE key is located on the same one that gives a **T** once the A..Z key is active.



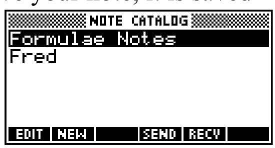
Use the keys discussed above to type in the screen shown on the right. Note that the non-alphabetic characters such as the = sign and the π symbol are obtained through the CHARS menu. The three pages of the CHARS menu are shown below. As you can see, there are many special characters available for use. The arrow keys can be used to move around in the text and insert or delete characters.







Once you have finished, and perhaps added some more formulae of your own, just press the BLUE NOTEPAD key again to return to the catalogue level. You will find that your new Note is now listed. There is no need to save your note, it is saved continuously as you work. This unfortunately also means that there is no way to undo a mistake by reverting back to a previously saved version.



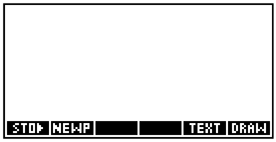
You may wish to try transferring your newly created Note to a friend's calculator over the infra-red link.

Using the Sketchpad with the HP38G

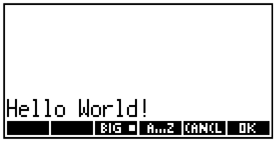
If you have not already done so, read at least the first page of the previous chapter entitled "Using the Notepad Catalogue with the HP38G". As is explained there, every aplet has associated with it a Sketch, consisting of up to ten pages. It can be viewed by pressing **BLUE SKETCH**, which is located on the **VAR** button.

None of the six standard aplets come with pre-prepared sketches but you will often find that an aplet that you download from the Internet (perhaps via a teacher or a friend) will have some Notes and Sketches attached by way of instructions for use.

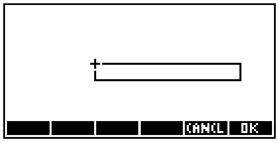
The facilities provided in the Sketch view are good for a bit of fun, but you will quickly discover how very primitive they are when you try to do anything at all complex. This is not meant as a criticism of the calculator. It does an extremely good job at what it was designed for - working with numbers - but it was never designed to compete with a true computer drawing package. If you're intending to do anything serious then use a proper Paint package in conjunction with the Aplet Development Kit (see page 98).



When you first enter the Sketch page you will see the view on the right. There are four screen keys available. The '*Text*' button allows you to place strings of text on the screen.



If you press '*Text*' then you will be prompted to enter a string of text at the bottom of the screen. You will notice that an **A..Z** key is provided to lock in alphabetic keys, but unfortunately no **SPACE** key is provided, which means you have to disengage **A..Z** at the end of each word.

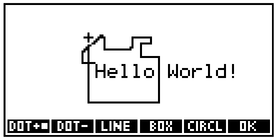


When you press **ENTER**, a rectangle will appear in the middle of the screen. The rectangle is the same size as the text will be. Using the arrow keys you can now move the text to the position in which you want it and then press **ENTER** again to fix its position.

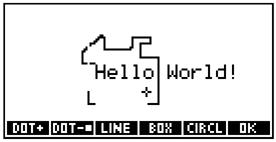
New Sketch pages (up to a total of ten) can be produced by pressing the '*NewP*' button. They can be erased with the **DEL** key.

The '*Draw*' button gives access to a slightly enlarged menu of drawing tools. The '*Ok*' button seen on the far right exits from this menu back to the original one.

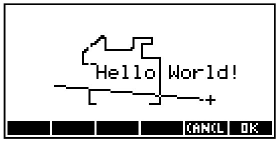
The small cursor (cross) in the middle of the screen can be moved around using the arrow keys. If you press the screen key labelled '*Dot+*' then a trail will be drawn as you move the cursor. Notice the small dot next to the '*Dot+*' showing that it is engaged.



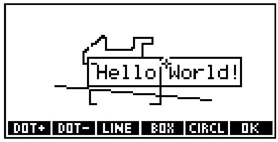
Pressing the '*Dot-*' button turns the cursor into an eraser (and automatically disengages '*Dot+*' as well). Pressing the same button again disengages both buttons and leaves the cursor free to move with no effect on the Sketch.



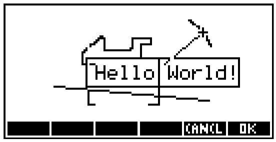
Moving the cursor to one end of a proposed line, you can now press the '*Line*' button and move the cursor to the other end of the line. When the line is correctly positioned, press the '*Ok*' button (or '*Cancel*').



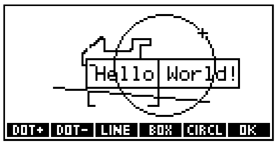
A box is drawn in the same way. Position the cursor at one corner, press the '*Box*' button, move the cursor to the diagonally opposite corner and press '*Ok*'.



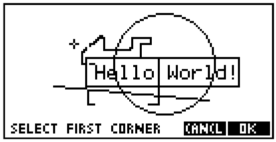
The circle command is similar. You should position the cursor at the center of the proposed circle. Pressing '*Circl*', move the cursor outwards from the centre, forming a radius. As you do so you will see a small arc appear, giving you an indication of the curvature of the proposed circle.



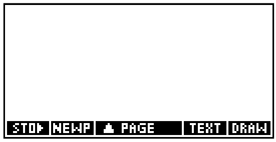
Pressing '*Ok*' (or **ENTER**) will then complete the circle.



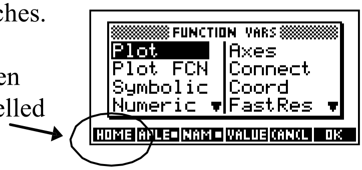
Using the '*STO➤*' button you can capture part of the screen and store it into any of ten graphics memories G1,G2..G9,G0 (called 'GROBs'). When you press '*STO➤*' , which is back on the original menu (so press '*Ok*' to leave the drawing tools), the message you see on the right will appear, asking which GROB to use.



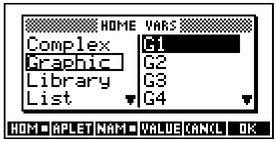
Once you have chosen a GROB to store the screen capture, you will need to specify the corners of the rectangle to be captured.



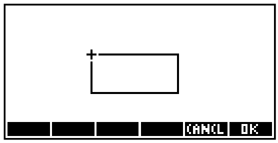
It is now possible to paste the captured screen portion into the a Sketch page using the **VAR** button. The screen does not have to be blank but to make things clearer, create a new sketch page using the '*NewP*' button (see right). Notice the appearance of a new '*Page*' button to allow movement between Sketches.



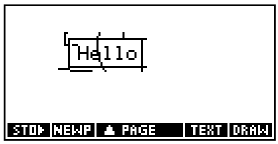
Press the **VAR** button and, when you see the screen shown right, press the programmable button labelled '*Home*'. (***NOT*** the normal **HOME** key.)



Move down through the menu until you reach '*Graphic*' and across to the particular GROB you chose. Now also press the button labelled *'Value'* and then press '*Ok*'.

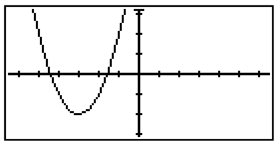


You will now find yourself back in the graphics screen with a rectangle representing the size of the GROB to be pasted in.



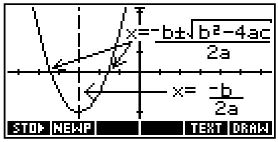
Move the rectangle to the desired position and press '*Ok*'. The GROB will appear. GROB, by the way, is short for 'graphics object'.

This technique can be very useful in building a Sketch, particularly when used in conjunction with the ability to capure **PLOT** screens and store them in GROBs.



To capture a **PLOT** screen, just arrange the **PLOT** display so that it shows the features you wish to capture. For example, if you don't want the screen menu showing, make sure it is set up that way before you proceed. When ready, press *and hold down* the **ON** button, press the **PLOT** button and then release both. The screen will be automatically stored into GROB G0.

Now change into the sketch view, press the VAR button, select the programmable key '*Home*' rather than '*Aplet*', move the highlight to Graphic and then move it right and find GO. Press the '*Value*' key and then press ENTER. Unlike the previous example where the pasted GROB now had to be located on the sketch page, the captured screen in this case will be pasted in as a fresh page.



Having pasted it into the Sketch page, you can now modify it by adding text and other information.

One has to question however whether the time needed to do this and the low quality of the result make the whole process worthwhile. If you're intending to do this to produce a set of 'cheat notes' for your next test or exam, you might be far better off spending the time studying!

Note: The screen capture facility of ON+PLOT demonstrated here can be used to capture any screen as a GROB, not just a PLOT screen.

Using, copying & creating aplets on the HP38G

Before you read this chapter, you should have read the chapter at the beginning of the manual entitled “Everything Revolves around Aplets!”.

As has been discussed before, the designers of this calculator provided a set of six standard aplets for you to use, changing the capabilities of the calculator as you change aplet. These standard six aplets will cover most, if not all, of your requirements and, to a certain extent, you can modify them to suit your needs and copy them for your friends. Unless you particularly want to learn about the programming language which is available for really significant changes, there is no reason why you should worry about it.

As well as making small modifications to the standard six aplets, you can “download” additional aplets written by strange people who *do* enjoy programming. These aplets come via the Internet, but you can probably obtain them from your teacher, from other HP38G’s, or from a PC or Mac onto which they have been copied. Once aplets have been copied from the Internet onto a PC or Mac a “Connectivity Kit” is available from Hewlett-Packard (and dealers) which allows you to connect a cable from the PC or Mac to your calculator and then download aplets to the HP38G.

The information which follows is discussed in the following order…

- creating a copy of a standard aplet
- copying from HP38G to HP38G via the infra-red link.
- downloading from the Internet using the Connectivity Kit.
- transferring notes and sketches via the Connectivity Kit.
- programming with the HP38G - the creation of new aplets.

Part 1: Creating a copy of a Standard aplet.

Imagine yourself in either of these two scenarios….

(i) you are a student and you have filled the Function aplet with a set of equations needed for tonight’s homework and set up the PLOT screen so that it looks exactly the way you want it to. Now you find that you need the Function aplet to do something else equally important which will mean wiping all that work!

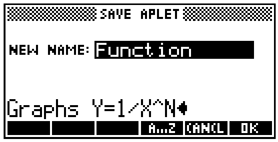
(ii) you are a teacher and you are planning a lesson where you will examine a collection of about half a dozen data sets and then graph the results. You don’t want to spend half the lesson waiting while the students type the data into the Statistics aplet and then watch while they all use different axes and get totally different graphs!

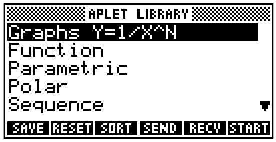
In either of those two cases, the solution is to make a *copy* of the aplet concerned. You can make as many copies of any of the six standard aplets as you wish, with the only limit being the calculator's memory.

Let's look at each of the two scenarios in turn.

In the first case, what the student needs to do is to make a copy of the Function aplet to hold his homework (the functions he had already set up) and then do the unexpected extra work in the now free Function aplet.

Press the **LIB** key to see the list of aplets. Move the highlight to Function (or whichever one you wish to copy) and press the programmable key labeled '*Save*'.



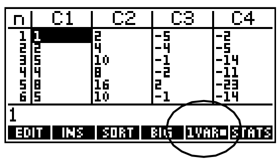


You will now be asked to nominate a name for the newly created aplet. It is a good idea to name it something that will remind you of its purpose and contents later. After all, you may end up saving it permanently onto a PC or Mac using the Connectivity Kit and when you look at it six months from now a name of "Homework" is not going to tell you much!

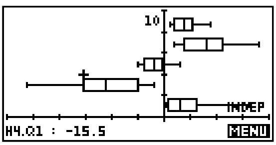
Your name can have spaces and other characters, including ones in the **CHARS** menu.

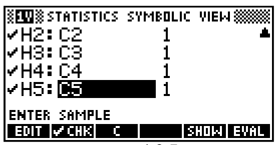
Our student's newly created copy of the Function aplet is now totally independent of its parent aplet and contains the precious homework. She can now '*Reset*' the original Function aplet back to factory defaults and go on with the extra work that she wanted to do.

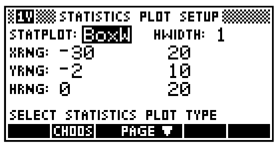
Our second scenario had a teacher not wanting to waste the time that would be needed for his students to type in five sets of data. In this case also, the solution is to make a copy of the aplet - in this case of the Statistics aplet.



The teacher first needs to set up the Statistics aplet to be exactly the way he wants it… five data sets of 20 numbers each, **NUM** view set to univariate stats (1VAR), **SYMB** view set up for five Box and Whisker graphs and axes set up to display all sets.







The next stage is to move to the LIB view and '*Save*' this modified Statistics aplet under a new name - say "Related Sets". If desired, he might also '*Reset*' the Statistics aplet at the same time, ready for the next use.

This saved aplet can now be downloaded (see Part 2 below) to all the students' calculators using the built in infra-red link which is standard for all HP38Gs, ensuring that each student has the correct data sets, and that their new copy of the Statistics aplet is pre-set to the teacher's needs.

An ambitious teacher might even complete his aplet by adding a set of instructions to the Note which is associated with the aplet. This would allow an absent student to download a copy from a friend's HP38G and know immediately what they are supposed to do. As was discussed in the chapter entitled "Using the Notepad Catalogue with the HP38G", every aplet has its own note that is tied solely to that aplet and is available via the BLUE NOTE button on the VAR button.

It is not suggested that anyone would seriously use the HP38G as a typewriter or word processor, but the Connectivity Kit allows one to do the typing on a PC or Mac and then transfer the result to a HP38G. Indeed, if the 'absent' student had access to the Internet and a Connectivity Kit themselves, then there is no reason that the teacher could not post the aplet on the Mathematics Department's Home page for downloading by any students who need access. This, however, is probably an unrealistic luxury for most schools at present.

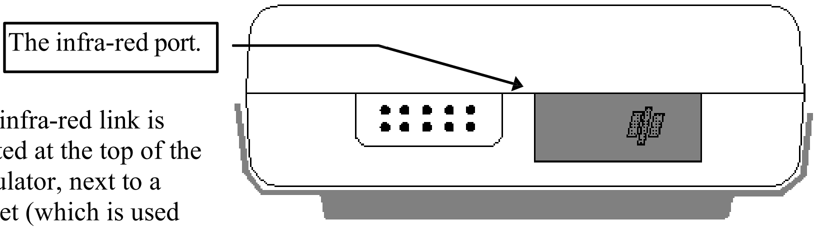
In both of these cases, the procedure has been to save a copy of one of the standard aplets under a different name. In neither case was there any need to do any programming and the amount of memory taken up by these copies is fairly minimal because they share most of their resources with their parent aplets.

Part 2: Copying from HP38G to HP38G via the infra-red link.

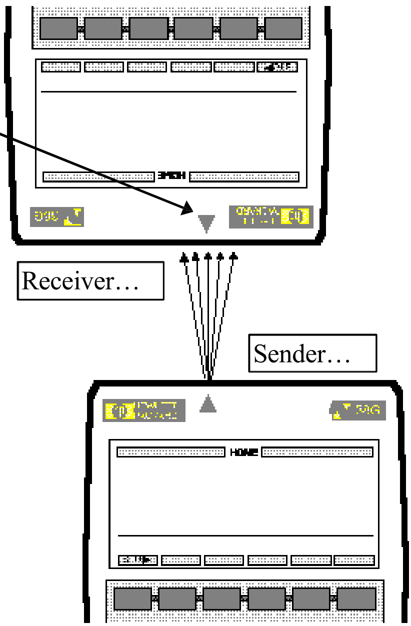
Any aplet can be copied from one HP38G to another via the built in infra-red link at the top of the calculator. Indeed it is not only aplets which can be copied, but lists, notes, sketches, matrices and programs.

The key to this ability is the presence of a programmable key labeled '*Send*' (and its companion key '*Recv*'). This is shown in the LIB view on the right.

These keys can be used to send a copy of the highlighted aplet to any other HP38G.



The infra-red link is located at the top of the calculator, next to a socket (which is used to connect the HP38G to a computer if you own the Connectivity Kit). This link is exactly like the remote control of a VCR, and allows two calculators to talk to each other. In the interests of security in tests and exams, the distance over which they can talk is limited to about 9 - 10cm.



If you look carefully at the top of the calculator, near the "Hewlett-Packard" label, you will find a small triangle of smooth plastic. This marks the position of the infra-red port so that you can line it up when looking down from above. Put the two calculators top-end to top-end and line up the arrows with the calculators no more than 9 - 10 cm apart.

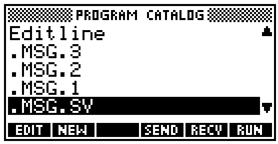
Both calculators should be showing the LIB view, with the highlight on the aplet you wish to send. Now press the '*Send*' button on the sending calculator and the '*Recv*' button on the receiving calculator.

On both screens you will see the pop-up choice shown below. Ensure that the highlight is on ‘HP 38G’. The other choice is there for transmitting aplets to and from a PC or Mac via the Connectivity Kit.

When both calculators are showing this menu and are lined up correctly, press the ENTER key. While the aplet is being transmitted you will see a similar message to the one shown right. When the transmission process is complete, the new aplet will appear in the LIB view of the receiving calculator.

If you see a message saying that there has been a “Time-out”, it probably means that you did not line the calculators up precisely enough. The first thing they do is say the electronic equivalent of “Hi there” to each other, and if there is no answer from the other machine within about 30 seconds, then this is the message you receive.

Important note: If your aplet is one that has been created by someone else (rather than simply a copy of one of the standard six) then it will probably have one or more programs associated with it. For example, all the aplets available from the Hewlett-Packard home page come with sets of up to 6 or 7 programs to do the work, and without which they are totally useless.

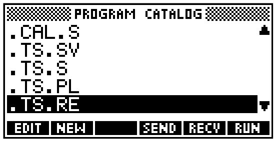


Fortunately you do not normally need to worry about this, since the calculator knows about them and will transmit them all with the aplet (increasing the transmission time quite a bit). If you want to see them, press BLUE PROGRAM after transmission finishes to see a list. Note: Even if there are no other programs currently stored, you will always see the ‘Editline’ entry. It contains the record of the last calculation you did in the HOME view.

Apart from curiousity, there is one important respect in which you need to know about these programs, and that is when it comes time to delete an aplet. As you would expect, this is done in the LIB view by highlighting the aplet and then pressing the DEL key.

If the aplet is a simple copy of one of the standard six, then that is the end of the process. If, however, the aplet has a set of one or more programs associated with it, then those programs have not been deleted and are still taking up memory. To delete these left over programs you will need to switch to the PROGRAM view and remove them. This *must* be done or your memory will be gradually used up.

As an example of this, consider the aplet called "Time Series" shown in the LIB view above right. Looking at the list of programs shown in the PROGRAM view, you will see a set of programs which all begin with the letters .TS.
The convention that is being encouraged by Hewlett-Packard is to name the programs so that it is fairly obvious which ones belong to which aplet, hence the .TS code for "Time Series".



Simply position the highlight on each of the programs in turn and press the DEL key. If your calculator only contains one aplet with programs tied to it, then you will find it faster to use the BLUE CLEAR key to delete all programs at once.

The coded prefix means that you won't have problems working out which programs belong to which aplet. Depending on the aplet, the linked programs can take up a fair amount of memory, so that it is unlikely that you will be able to fit more than two or three of these type of aplet onto your calculator at once. The naming convention should ensure that you are able to work out which is which.

This is, in fact, one of the main problems that you will have with these aplets. There are so many of them available, performing incredibly useful tasks, that you will find yourself frustrated that you cannot have all of them stored permanently. The advantage of having easy access to the Connectivity Kit is that it allows you to off-load any aplets not being used onto a PC or Mac, which both have essentially unlimited storage. That way you can download them as they are needed.

As well as connecting to a PC or Mac via the Connectivity Kit, you can also purchase from Hewlett-Packard an actual disk drive called a 'Drive 95', *powered by the calculator itself*, to which you can also download aplets that are not in use.

In addition to aplets, there are many other data structures on the HP38G which can be sent and received to other HP38Gs via the infra-red link. These include Lists (via the List Catalogue view), Matrices (via the Matrix Catalogue view), free standing Notes (via the Notepad Catalogue view) and Programs (via the Program Catalogue view). Each of these Catalogues has a '*Recv*' button and, unless the Catalogue is empty, a '*Send*' button. Any notes and sketches which form part of an aplet (via the BLUE NOTE & SKETCH keys) will automatically be transferred with the aplet.

Warning! Your school is likely to take a very dim view of any circulation of obscene or unsuitable material as notes or sketches! Don't do it.

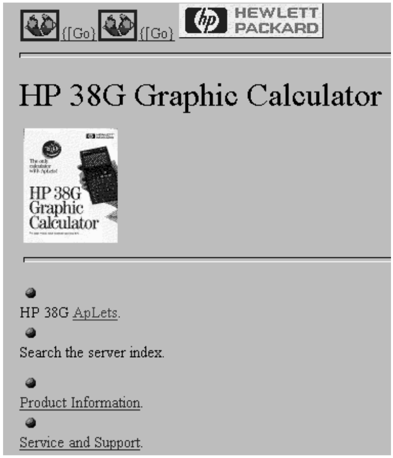
Part 3: Downloading from the Internet using the Connectivity Kit.

Aplets are available from Hewlett-Packard via the Internet to do many mathematical tasks such as exploring graphs, bivariate and time series analysis, as well as many tasks called for in Physics and Chemistry. There are currently only a few Web sites available with aplets but this should increase with time.

The Hewlett-Packard home site is the best and is found at…

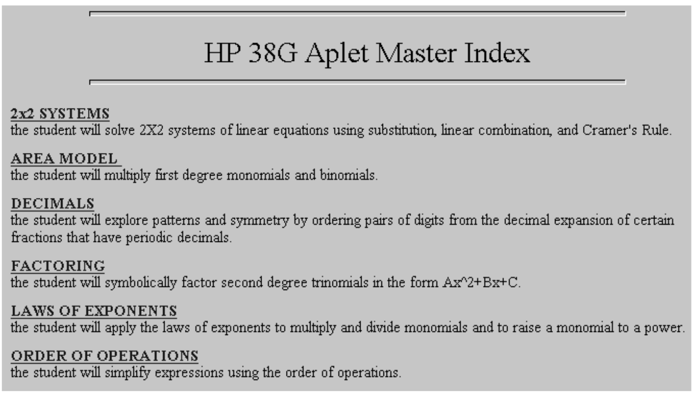
http://hpcvbbs.external.hp.com:80/calculators/hp38g/aplets/index.html

If you have access to the Web you might wish to check this site out to see the list of aplets and get a feel for their capabilities even though there's no point downloading them without access to a Connectivity Kit.



It may not be worth the (small) expense for you to buy one of these Connectivity Kits yourself. If your school has decided to specify that you buy the HP38G then they have probably bought at least one kit themselves. Even if they have not provided access to students, they can download any aplets needed into a teacher's calculator, who will no doubt then download them into yours via the infra-red link.

Downloading an aplet from the Web is very simple. Assuming that it hasn't changed, accessing the Hewlett-Packard site will present you with the page shown above right. If you then click on the 'HP38G Aplets' link, you will find yourself in a screen which lists the aplets by category (Algebra, Trigonometry, Geometry, Precalculus, Statistics, Chemistry, Physics..) as well as a link to a Master Index.



HP 38G Aplet Master Index

2x2 SYSTEMS
the student will solve 2X2 systems of linear equations using substitution, linear combination, and Cramer's Rule.

AREA MODEL
the student will multiply first degree monomials and binomials.

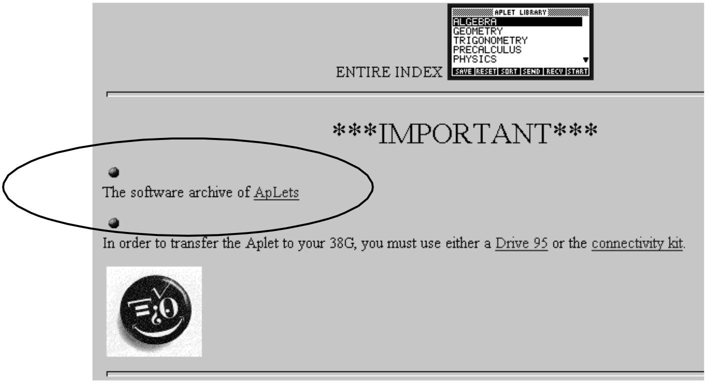
DECIMALS
the student will explore patterns and symmetry by ordering pairs of digits from the decimal expansion of certain fractions that have periodic decimals.

FACTORING
the student will symbolically factor second degree trinomials in the form Ax^2+Bx+C.

LAWS OF EXPONENTS
the student will apply the laws of exponents to multiply and divide monomials and to raise a monomial to a power.

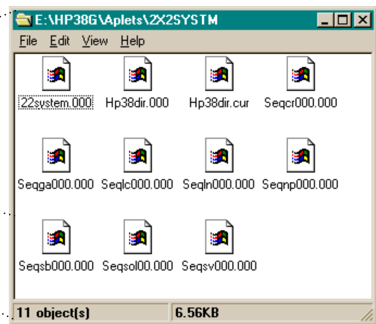
ORDER OF OPERATIONS
the student will simplify expressions using the order of operations.

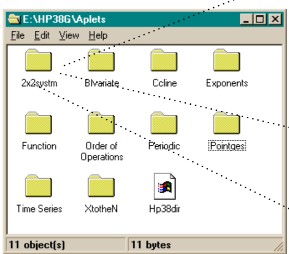
This master index, part of which is shown on the previous page, is worth having a look at, since it gives you a good idea of the aplets available. The main area you will probably be interested in is the software archive of aplets.



From this archive you can down load all the aplets as .ZIP files. A ZIP file is a special type of file which contains one or more compressed files. The reason for the compression is simply to allow you to download them from the Internet more quickly, and you should de-compress them as soon as you have them onto your PC or Mac. There are many shareware programs which will de-compress ZIP files for you and there is no point in keeping them as a ZIP file because the HP38G can't read it.

It is *essential* to de-compress each aplet into a separate directory, since each aplet has a pair of files called HP38DIR.000 and HP38DIR.CUR and these are different for each aplet. Storing them in the same directory will overwrite these files. Shown below and right is the contents of one of the directories in part of my collection.



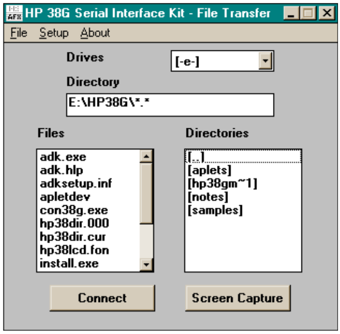


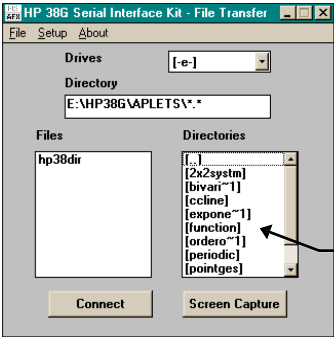
We now have the task of downloading from the PC or Mac to the HP38G via the Connectivity Kit. The Connectivity Kit consists of a cable and some software. Unfortunately the both the cable and the software are different for a PC and Mac, so having only one kit will not allow you to use both types of computer. When you install the software that comes with the Kit, it is best to install it in its own folder (directory) and then to create a folder inside this to hold all the aplets.

All explanations and pictures which follow apply to a PC. The software on a Mac is similar enough that you should have no great trouble adapting.

When you start up the program (called CON38G.EXE on the PC and ‘HP Connect’ on the Mac) you will see a sight like the one below right.

I store my aplets in the directory called ‘[aplets]’, so I will double click on that directory to open it and see the window below left. If you don’t have an [aplets] directory it is a good idea to create it. You won’t have anything in it until you download aplets from the web to fill it.

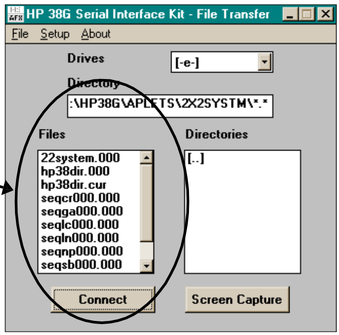




List of directories containing aplets.

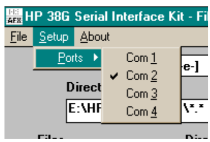
Now supposing that I want to download to the calculator the aplet called ‘2x2 system’. I would now double click on that directory. Once this is done I will finally be looking at the set of files which comprise the aplet.

*The essence of this part of the process is to end up looking at a directory containing **only** the files belonging to your aplet.*



The next stage is to connect the cable to your calculator and to the back of the computer. Be gentle when plugging into the calculator - don’t bend the pins in the socket.

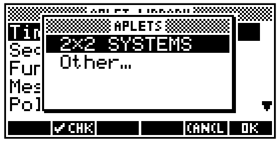
There is no choice as to where to connect it on the calculator, but most computers offer a choice of at least two ‘ports’ into which the cable can be plugged. On a PC these are called COM1, COM2, etc. while on a Mac they are called the Com port and the Printer port. It doesn’t much matter which one you use, so long as you record the choice in the menu called ‘Setup’.



On some PCs the COM ports have differently shaped sockets, which will dictate your choice. If you seem to be doing everything right later on but nothing is coming through, then it may be that you forgot to do this or made the wrong choice. Some PCs have COM ports with different numbers of pins to the plug supplied with the kit. An adaptor can be bought from your local computer dealer for a few dollars.

Having connected the cable to the calculator, change into the LIB view and press '*Recv*'. This time, choose 'Disk drive..' from the menu which pops up. Click on the button labeled 'File Transfer' and then on the one labeled 'Connect' on the program. Also hit the **ENTER** button on the calculator.

If all has gone well, you should find that you are looking at another pop-up menu which lists the aplet you are trying to download, together with the word 'Other..' If all you see is the word 'Other..' then it may mean that your de-compression of the aplet has not worked properly or that the download was corrupted, and that the aplet is not readable. If you did not store your aplets in separate directories then the files will be mixed up and there may be a choice of aplets in the menu.

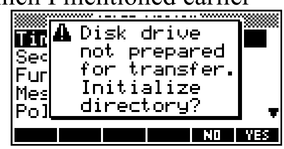


All else being well, if you now highlight the name of the aplet and press '*Ok*', then you will then be entertained to a series of messages as the aplet and all its associated programs transfer down the cable to your calculator. If there is insufficient room on your calculator then there will be an error message at some stage telling you this. If this happens you will need to delete the incomplete aplet and however many of its programs successfully downloaded.

Sending aplets in the reverse direction back to the PC or Mac is simply the reverse of this process. As part of the process of illustrating how to program on the HP38G (see pages 117 - 124), I have written a small aplet called "Message" which I will now illustrate saving onto my PC. You can practice by saving some other aplet, perhaps a copy of one of the standard six.

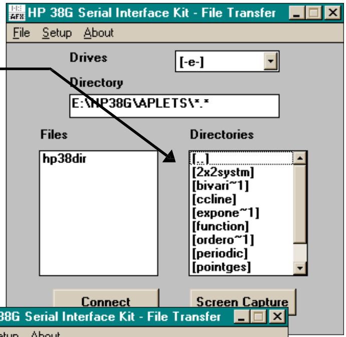
Note: 1. The original Mac software had some problems that meant that it was sometimes difficult to download aplets. If you receive a message on a Mac telling you 'File Not Found' then it may be caused by this software. (It might also be because you've accidentally deleted a file!). You can obtain a more up to date version of this software from HP or download it from my website (see page 124).

2. When you save an aplet into an empty directory on a Mac or a PC the two files HP38DIR.000 and HP38DIR.CUR which I mentioned earlier need to be created. You will see the message shown right. Tell it '*Yes*'. All this does is deposit a these files in the directory - it's not asking you if it can go ahead and reformat your hard disk!

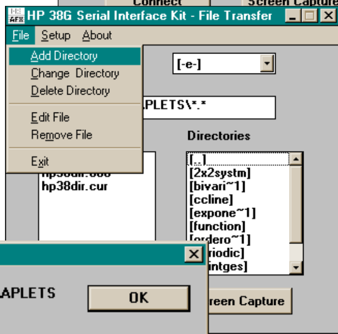


Assuming that you have organised yourself as I have, then you have a directory called ‘APLETS’ within which there is a separate directory for each of the aplets you own. Make sure that you are looking at the view of the ‘APLETS’ directory (as in the screenshot right).

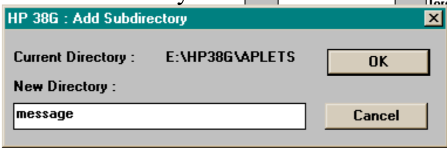
List of aplet folders (directories).



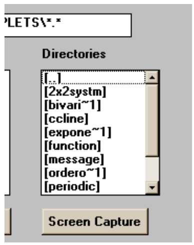
If you pull down the File menu on the menu bar at the top of the Connect program, you will see a number of options to do with creating, deleting and changing directories. Changing directories is easier to do with a double click as we did earlier, but having the creation and deletion options is very handy.

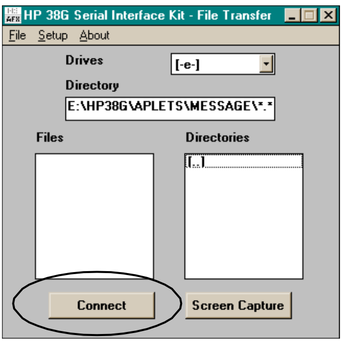


Click on that option and a box like the one you see here will pop up, allowing you to create a new directory especially for the Message aplet.

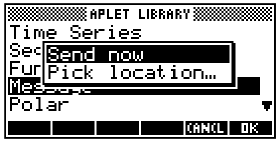


When you have done this, you will find that a new folder will appear in the list (see right). Double click now on this empty folder and you should find yourself looking at a screen like the one below left, where the directory window contains only the [..] entry (which one double clicks on to move up the directory tree) and where the file window is empty.





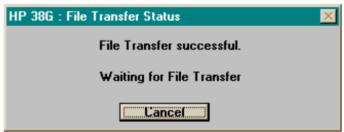
You are now ready to perform the transfer. In the LIB view of the HP38G, position the highlight on 'Message' (or whatever yours is called) and press the '*Send*' key. Choose the option of 'Disk drive…' and you will see a further menu (see below).



We've already picked the location using the Connect program, so just choose the 'Send now' option. You will now need to quickly click on the button labeled 'Connect' (see above) on the software window.

Because this is a new directory, you will see the message shown right. Don't panic! This is not a request to allow your hard drive to be reformatted. The program simply needs to deposit a small file in the directory. Let it.

You will now see a series of messages on both the PC (or Mac) and the calculator about how it is transferring files. When the process finishes, the HP38G will revert back to the standard LIB view and the PC will display the message shown right. If you wanted to, you could now transfer another aplet (although it would not be wise without creating a new directory, since the two sets of files would mix together) but the best option is to click on 'Cancel'.



Your aplet is now safely stored. If you wish to transfer another aplet, double click on the [..] directory to move up one level in the directory structure. You should find yourself looking at your list of aplet directories. You should create a new directory for the next aplet and then proceed as before.

Warning!

There was originally a problem with the Connectivity Kit when used with Macintosh computers. Downloading the ZIP files and expanding them into separate folders works, but the Connectivity Kit reports errors when you attempt to download the aplets to an HP38G. This has since been fixed and you can obtain the latest version of the Mac software from HP. You can also download it from my website (see page 124).

Part 4: Transferring notes and sketches via the Connectivity Kit

The only way to transfer a sketch from one HP38G to another (or to a PC or Mac) is as part of an aplet. Unlike notes, sketches cannot exist separately to their parent aplet.

Once transferred via the Connectivity Kit to a PC or Mac, it is not possible to edit a note or sketch using a text editor or a paint package, since they will not be able to save the result in a format that the HP38G will recognize. When you try to transfer the note or sketch back to an HP38G, you will receive an error message saying basically “I can’t read this”. The answer to the problem is the Aplet Development Kit, which you can download for FREE from the Internet (at the HP site) This kit allows you to edit notes, sketches and programs and also saves them in the correct format. Unfortunately for Mac users, Hewlett-Packard have so far only produced a Windows version (Win 3.1 or Win ’95). No doubt this will change with time.

When you run this Aplet Development Kit you will find that you can:

- open exiting Notes and type new text in them using the computer keyboard or create new Notes.
- open programs and edit them or create new programs
- open aplets and view their associated note and sketch. This sketch can then be cut and pasted to a Paint program and eventually returned to the aplet.

This Aplet Development Kit comes with an extensive Help file and some examples of aplets that can be created with it. For this reason, we will not devote any more time to it in this manual. The section on programming which follows will be treated as if all the programs are written on the HP38G. In reality the process is considerably faster and easier if the Aplet Development Kit is used. You can find a link to the download site for the ADK at my website (see page 124).

Part 5: Programming with the HP38G - Creating new aplets.

The key to the entire process of creating completely new aplets is the VIEWS menu and its controlling function SETVIEWS. This function allows you to override the normal behaviour of an aplet and superimpose new behaviours by linking in a set of programs written by you.

It is slightly deceptive to call these aplets “new”, since they still derive from one of the standard six, but the modification of the VIEWS menu usually means that their final appearance and behaviour is very different to the aplet from which they derive.

The first stage in the creation process is to decide which of the standard six aplets you wish to make the “parent” of your new child aplet. For some simple aplets this may not matter, but for others this can be a very important choice, since all the abilities of the parent are inherited by the child.

If your new aplet is going to be concerned with analysing data then your best choice for a parent would probably be the Statistics aplet. On the other hand if you were planning to write an aplet to teach the behaviour of trig graphs then the Function aplet would obviously be your best parent aplet. All the tools of the parent are available to the child, so consider carefully what tools you will require.

Make a copy of the parent aplet and give the copy whatever name you want to use for your new aplet. This copy will form the core of your new aplet. Decide also what prefix to use for the programs you will associate with your new aplet. The prefix needs to be recognizably linked to the name of the aplet, so that the user can know which programs to delete when they want to clear the aplet out after use.

For example, an aplet called “Linear Equations” might have a list of programs of:

.LE.SV	.LE.S
.LE.EN	.LE.DIS

An aplet called “Time Series” might use a prefix of .TS and have programs:

.TS.SV	.TS.S	.TS.SA
.TS.ED	.TS.AV	.TS.RE
.TS.PL		

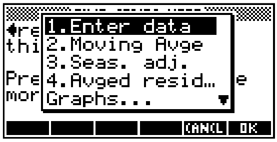
The next stage is to plan your VIEWS menu.
The VIEWS menu is the controller of your aplet. It pops up either at your command or when the user presses the VIEWS button, and offers a choice of options to the user. Each of the options in your VIEWS menu will be tied to a program you will write, and when the user chooses an option and presses ENTER, the appropriate program will be run by the HP38G.

It is very important to the usefulness of your aplet that you carefully plan the VIEWS menu to be clear, concise and user-friendly. It is possible to have sub-menus in the VIEWS menu by calling a program which then pops up another menu of options. Options of this type are usually denoted by an ellipsis (…) following the option.

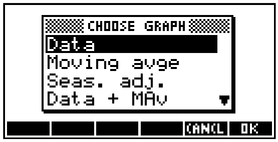
An example of the VIEWS menu from an aplet is shown below. The aplet is called "Time Series" and is designed to analyse time series data. This type of data is bivariate data having not only a regular underlying linear increase/decrease, but also a regular seasonal component causing regular fluctuations. An example of this might be a company selling ice cream. Their overall profit might be rising steadily but their sales in any particular month would be affected in a regular predictable way by the seasons of the year, causing significant fluctuations in profit which disguises the underlying upward/downward trend.

The parent aplet for "Time Series" is the Statistics aplet, because it allows the use of the linear regression tools, and the normal practice after the user makes their choice from the **VIEWS** menu is to drop back into the **NUM** view showing the data.

The VIEWS menu is:



The last option of 'Graphs…' runs a program which pops up another menu, shown right. The reason for this separation is to avoid overcrowding the VIEWS menu.



The SETVIEWS command follows a repetitive pattern of listing a menu option, followed by the name of the program the calculator should run if the user chooses that option, *followed by a code number which tells the calculator which view to leave the user in once the program finishes.*

You should therefore also think about what you want the user to be looking at once the program they have triggered stops running. Do you want them to be looking at the **PLOT** view (perhaps the option they chose was to draw a graph, with the program being simply there to set up appropriate axes) or should they be looking at the **VIEWS** menu again?

The syntax for SETVIEWS is as follows…

SETVIEWS "Menu line1"; "Program name"; View_No.;
"Menu line2"; "Program name"; View_No.;
"Menu line3"; "Program name"; View_No.: (colon on final entry)

where View_No. is:

0. Home view	11. List Catalogue
1. Plot view	12. Matrix Catalogue
2. Symbolic view	13. Notepad Catalogue
3. Numeric view	14. Program Catalogue
4. Plot Setup	15. Views menu item 1 (Plot-Detail in Func.)
5. Symbolic Setup	16. Views menu item 2 (Plot-Table in Func.)
6. Numeric Setup	17. Views menu item 3 (Overlay Plot in Func.)
7. Views menu	18. Views menu item 4 (Auto Scale in Func.)
8. Aplet Note view	19. Views menu item 5 (Plot Decimal in Func.)
9. Aplet Sketch view	20. Views menu item 6 (Plot Integer in Func.)
10. Library Catalogue	21. Views menu item 7 (Plot Trig in Func.)

The SETVIEWS command is *always* placed in a program with a name ending with .SV (such as .FRED.SV)and, when executed, it severs the link to the normal VIEWS menu inherited from its parent and replaces it with this new set of options.

The contents of SETVIEWS in important in another way in that it also determines the programs that are transmitted with the aplet when it is copied via cable or infra-red link. Only those programs named in .FRED.SV will be transmitted.

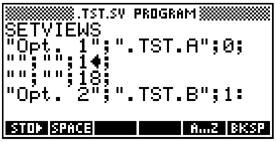
In addition to the lines which form the menu for your aplet, there are some special entries which are treated differently.

i. If you include entries called "Start" or "Reset", then the programs associated with those entries will be run when the user '*Start*'s the aplet or presses the '*Reset*' button (the ones at the bottom of the screen in the LIB view).

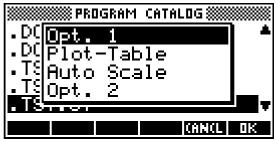
ii. If you include an entry which consists of a single space character " ", then the entry will not appear in the VIEWS menu, but the program linked to it *will* be transmitted with the aplet, since it is named in .FRED.SV. This can be handy if you have a program which is not directly called in the menu but is called by another program to do part of the work.
For example, the .FRED.SV program itself needs to be included in the list in this fashion.

iii. If you include an entry which consists of empty quotes "", then you can access the entries from the normal Function VIEWS menu. The standard menu options of "Autoscale", "Plot-Detail" etc. can be included in this way.

Shown below is a SETVIEWS program which illustrates this…

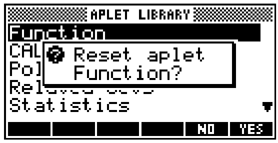


producing a menu of…

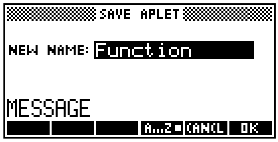


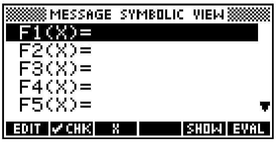
My experience has been that it is worth including both a "Start" entry and an invisible " " entry even if they are not required and don't run any programs (i.e the entries could consists of "Start";"";7; and " ";"";7;). If these entries are not included then the aplet will *sometimes* turn out to be unstable, doing silly things like running the Solve aplet instead of switching to the **NUM** view in the parent Function aplet! The '*Start*' entry above is certainly worth including anyway, since it means that as soon as the aplet is run the **VIEWS** menu will be displayed (view number 7).

Let's now use this SETVIEWS command to design a very simple and totally useless aplet, which will illustrate a few of the concepts useful in programming the HP38G. We'll call it the MESSAGE aplet and create it as a descendant of the Function aplet.



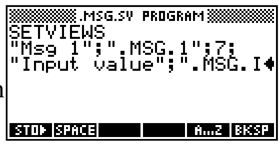
Change into the **LIB** view, move the highlight to the Function aplet and '*Reset*' it. Now save it under the new title of 'MESSAGE' and then '*Start*' this new aplet.





You will find that you are looking at the normal **SYMB** view but for the Message aplet instead of the Function aplet.

Now press **BLUE PROGRAM** to view the Program Catalogue. Press '*New*' to create a new program and call it **.MSG.SV** (see right, with part of the new program typed in)



Into this empty program, type the following…

Use the CHARS view to fetch any special characters.

```
SETVIEWS
"Message 1";".MSG.1";7;
"Input value";".MSG.IN";7;
"Message 2";".MSG.2";0;
"Show func.";".MSG.FN";7;
"Start";".MSG.S";7;
"Quit";"";0;
" ";"";7:
```

When you finish typing, just hit **BLUE PROGRAM** again to exit back to the Catalogue level. There is no need to save, this is done continuously as you type.

DON'T RUN THIS NEW PROGRAM YET! The names of the programs that you have included in your SETVIEWS command do not yet exist and you will simply receive an error message if you run the program at this stage.

Let's now create the needed programs (shown below).

.MSG.1

```
MSGBOX "Hello world! 3+4 = "3+4:
```

.MSG.IN

```
INPUT N;"MY TITLE"; "Please enter N.."; "Do as you're told.";20:
MSGBOX "You entered "N" when prompted.":
```

.MSG.2

```
ERASE:
DISP 4;"You entered "N:
DISP 5;" when prompted.":
FREEZE:
```

Notice the way semi-colons are not needed between items in **MSGBOX** and in **DISP**. The initial number in DISP is which line of 7 in the HOME view to display the information following.

.MSG.FN

```
ERASE:
((((QUOTE(X)+2)^3)^4)+4)/(QUOTE(X)- 2)➢F1(X):
→GROB G1;F1(QUOTE(X));0:
→DISPLAY G1:
FREEZE:
ERASE:
→GROB G1;F1(QUOTE(X));1:
→DISPLAY G1:
FREEZE:
ERASE:
→GROB G1;F1(QUOTE(X));2:
→DISPLAY G1:
FREEZE:
ERASE:
→GROB G1;F1(QUOTE(X));3:
→DISPLAY G1:
FREEZE:
```

Note: GROB stands for "Graphic Object" and creates a graphic object from the expression supplied, storing it in the graphic memory nominated, using the font specified.

.MSG.S

```
MSGBOX "Aplet starting now":
```

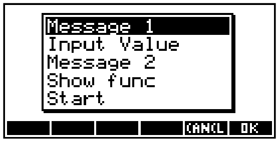
Having created all of the programs that make up the aplet MESSAGE, we can now run the program **.MSG.SV** and sever the link to its current **VIEWS** menu (inherited from its parent the Function aplet) and substitute this new menu. *Before you do this*, check that you are still in the correct aplet. Press the **SYMB** button and check that the title at the top still says "MESSAGE SYMBOLIC VIEW". If it doesn't show this, then run the MESSAGE aplet again to ensure that it is the one whose **VIEWS** menu will be substituted. Now swap back to the Program Catalogue, position the highlight on the program .**MSG.SV** and hit the button labeled '*Run*'. Apart from the screen going blank for a moment nothing will appear to happen, but in fact the link to the normal Function **VIEWS** menu which 'MESSAGE' inherited from its parent aplet Function has been severed and a new link to the menu you built in **.MSG.SV** has been substituted.

Providing that you have done everything correctly, this is now the end of the process - the aplet is now ready to be run. In the **LIB** view, move the highlight to the MESSAGE aplet and press '*Start*' or **ENTER**.

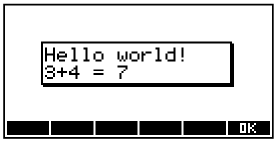
When you do this, the aplet will run the program .MSG.S which will display a MSGBOX message.

The line controlling this was:

```
"Start";".MSG.S";7;
```



Since this ends with a view number of 7, this means that after the program terminates (when you press '*Ok*'), the **VIEWS** menu will display.



If you choose the option 'Message 1', then this will cause the program .MSG.1 to be run, displaying the screen on the right.

The program line for this was:

```
MSGBOX "Hello world! 3+4 = "3+4:
```

The next option is 'Input value'. Choosing this option will create an input screen. The statement controlling this was:

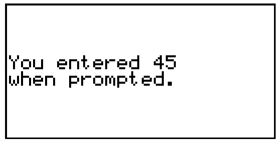
```
INPUT N;"MY TITLE"; "Please enter N.."; "Do as you're told.";20:
```

Examine the snapshot on the right and notice the connection between the various parts of the **INPUT** statement and their effect. Note the suggested value of 20, and note also that the prompt of "Please enter N.." was too long to be displayed.

When you enter a number in to the input screen and press **ENTER**, the next line in **.MSG.IN** will display this value in a MSGBOX. When you press '*Ok*', the view number of 7 specified in **.MSG.SV** will cause the **VIEWS** menu to be displayed again.

Notice that the input window is still displaying in the background when the VIEWS menu appears again. To stop this happening, you could have included in **.MSG.IN** a line of ERASE: , which is a command to erase the display screen. Try editing the program and running it again.

The option of 'Message 2' displays the same message as we saw before, but presented in a different way. The DISP command divides the display screen up into 7 lines (1 - 7) on which you can display data.



For example, suppose memory A contained 3.56, then the command:

```
DISP 3;"The value of A is: "A:
```

would display the message The value of A is: 3.56 on line 3 of the display screen.

Notice also that this time when you press **ENTER**, you end up in the **HOME** view rather than in the **VIEWS** menu again. This is not an error! If you look at the line in **.MSG.SV** controlling this option you will see that its post execution view number was 0 (**HOME**) rather than 7 (**VIEWS** menu) like the others. To see the **VIEWS** menu again, you will need to press **BLUE VIEWS**.

The final option is 'Show function'. The program this runs is a little more complex than the ones shown so far. I include it for your information since it illustrates a very useful technique.

The line: `((((QUOTE(X)+2)^3)^4)+4)/(QUOTE(X)-2)➢F1(X):`

stores the function (expression) $\frac{\left((x+2)^3\right)^4}{(x-2)}$ into the function store F1(X). Notice

the way the X's have to be entered as (QUOTE(X) so that the letter X is used rather than the numerical contents of memory X.

The next lines (repeated four times) display this expression using the four different fonts available.

The line: →GROB G1;F1(QUOTE(X));0:
converts the expression F1(X) into a GRaphic OBject (GROB). The number at the end, which changes in each repeat, controls which font is used in displaying the function.

The line:

→ DISPLAY G1:

displays this GROB on the screen, and the line:

FREEZE:

freezes the display until a key is hit.

It is probably obvious to anyone who has done any programming that the explanation so far has only scratched the surface. However, since this is only really intended to be a guide to mastering the HP38G at the student level, this will have to do. Certainly what has been discussed here is more than is provided in the manual, and is enough that an experienced programmer will be able to make a start without the errors that I made.

The information provided in the manual on this topic is minimal and, although HP have been very helpful to me once they found out I was writing aplets, information on programming to the general pubic to date has been VERY scarce. The best way to learn is to dismantle some existing aplets using the ADK (see page 116) to see how they work. Note that if the aplet has originally been produced using the ADK then it will not have a **SETVIEWS** command. The setting of the **VIEWS** menu is done in a different way when using the ADK and not **.SV** file is needed.

I have produced some aplets of my own which you can download from my website. All have accompanying documentation and many have worksheets which can be used in the classroom. All of them are FREE. If you have some ideas for some aplets that you would like to see produced but do not have the skills to create, then feel free to contact me.

My E-mail address is: ccroft@sthildas.wa.edu.au
and my website is: http://www.sthildas.wa.edu.au/~ccroft/

If you feel that some of my aplets are worth using and you would like to put a link to one or more of them on your own web page then please do not download the file and place a link to this copy on your site. Instead, place a link to the aplet on my site. The reason for this is that if I change something in the aplet (which happens sometimes) then a link to my site will mean that people will always obtain the most recent version.

Another web site that is worth visiting is the Maths department page at our school St. Hilda's Anglican School for Girls. This web page contains links to many sites of interest to mathematics students and teachers.

The address is: http://www.sthildas.com.edu.au/~maths/

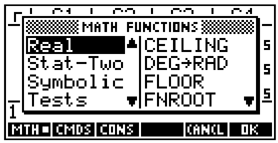
The MATH Menu

The **MATH** menu is acessed via the key labelled '*MATH*' just to the left of the row of arrow keys. Any time that you are typing a value into any formula or setup screen you can insert mathematical functions via the **MATH** key.

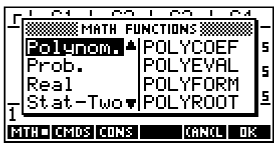
The **MATH** menu is divided up into sections by mathematical topics. These topics are:

Real	- rounding, roots, conversions and % functions.
Stat-Two	- bivariate functions.
Symbolic	- functions for manipulating equations and symbols.
Tests	- used in programming more than normal work.
Trig	- sec, cosec etc.
Calculus	- integration and differentiation operators
Complex	- functions to manipulate complex numbers.
Constants	- e, i and various others of use more in programming.
Hyperb.	- the hyperbolic trig functions.
List	- functions allowing manipulation and creation of lists of numbers, including columns of stats data.
Loop	- iterative functions.
Matrix	- a rich collection of functions to manipulate matrices.
Polynom.	- another rich collection, this time to manipulate polynomials.
Prob.	- functions used in probability calculations.

Some of these functions have no application at high school level and so will not be covered in this manual. Others will be covered to varying depths. Anyone needing those not covered will hopefully find that after reading this manual they can be relatively easily deciphered from the manual that comes with the calculator.

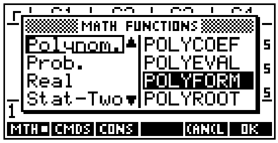


The mechanics of accessing the **MATH** menu is very simple. We will illustrate the process using the Polynomial function **POLYFORM**, which is an extremely useful one. Change into the **HOME** view and then press the **MATH** key. When you do you will see the screen on the right. The menu always first appears with the Real functions highlighted.

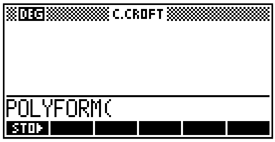


We could use the arrow keys to scroll down the list to the Polynomial functions but it is far faster to simply hit the key labelled with the letter '**P**' (on the '**5**' key). It is not necessary to hit the **A..Z** key first. You will notice in the screen on the right that there are two groups of functions beginning with a '**P**' - being Polynomial and Probability. In order to reach Probability one can either use the arrow keys or simply hit the '**P**' key again.

Once you are in the correct group, hit the right arrow key to move into the list of functions belonging to that group. Once again you have a choice now of using the up/down arrow keys or of hitting the key corresponding to the first letter of the function desired. In this case, since every single function in the Polynomial group begins with a 'P', there is no difference between the two methods. Move the highlight down to POLYFORM (as shown right) and then hit the ENTER key.



Your HOME view should now look like this…



You will notice that the first bracket has already been inserted for you. This is the usual practice.

Type in after it the following…

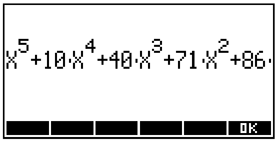
(X+2)^5-(3X-1)^2,X)

(using the Xʸ key to get ^ and without using any spaces)

and then press the ENTER key.

You will find that the expression $(x + 2)^5 - (3x - 1)^2$ has been expanded on the following line to X^5+10*X^4+40*X^3+71*....

There are two ways of seeing the complete result.

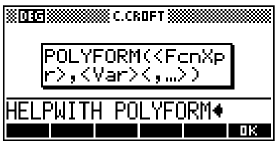


You can move the highlight up to that line and '*Copy*' it. You could then move back and forth through the line to see it in full.

A better method is to press the programmable key labelled '*Show*'. This gives (after a regrettable pause) the result shown above right. The portion off the edge of the screen can be seen by scrolling right using the arrow key. More details will be given of this function in the Polynomial group when we get to it.

On the pages which follow we will look at most of the functions in each group. Some of the functions are not likely to be used at school level and so will not be covered. If you need them then your level of study is almost certainly high enough that you can work them out for yourself from the normal manual!

You can obtain 'help' for any function in the HOME view by typing HELPWITH and then the function name. An example is shown right.



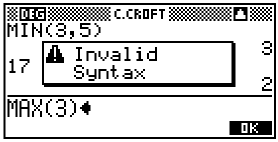
<FcnXpr> stands for "Function expression" and <Var> stands for "Variable name".

Thus this is saying that you have to type in an expression to be expanded and follow this with a comma and the name of the variable around which the function is built.

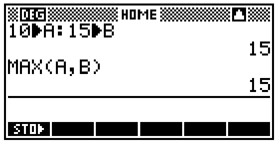
There is a limit to how much this **HELPWITH** statement will aid a normal user of the calculator, since these syntax statements are usually more suited to a programmer than to a student.

One piece of terminology that will be used in this section of the manual is ‘argument’. The arguments of a function are the pieces of information it is expecting you to feed it before it will give you an answer. These pieces of information might be numbers, variable names, lists, matrices or algebraic expressions.

The calculator is like any computer in that it will not guess what you mean. If you don’t feed it the information it requires then it will simply give you an error message!



For example, the function MAX expects two arguments, both of them numbers. Feeding it only one (or more than two) will produce the result shown right.



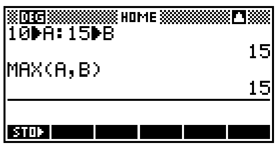
These numbers could also be the contents of memories. Suppose you have stored 10 in memory A and 15 in B. In that case MAX(A,B) will give 15.

Finally, if you look at the screenshot at the top of the previous page you will see that there are two other sets of menus available… ‘**CMDS**’ and ‘**CONS**’, standing for ‘Commands’ and ‘Constants’. Pressing the buttons under these items will result in different menus of functions being displayed. You can try them if you like but the functions listed in these menus are generally only of use to programmers, although there are a few tricks mentioned at various places in this manual which use them.

The format used in the listings which follow is:

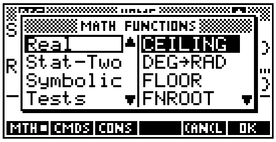
FUNCTION NAME(argument list)

An explanation of the use of the function, its quirks and its advantages. Included with this explanation will be two or three examples of its use, together with screen shots showing these.



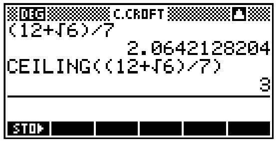
See also: List of related functions.

The 'Real' group of functions



CEILING(<num>)

This is a 'rounding' function but different in that it always rounds up to the integer above. It is mainly of interest to programmers.



Eg. CEILING(3.2) = 4
CEILING(32.99) = 33
CEILING((2+v5)/7)
= CEILING(2.0642.) = 3

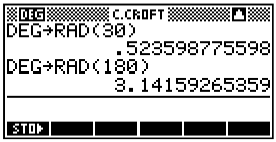
Note: CEILING(-2.56) = -2 not -3. The CEILING function rounds up to the next integer *above*, which is -2.

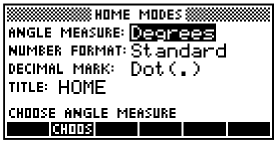
See also: ROUND, TRUNCATE, FLOOR, INT

DEG→RAD(<deg>)

This function converts degrees to radians.

Eg. DEG→RAD(30) = 0.5235.
DEG→RAD(180) = 3.1415926.





Note: If you are wanting to use some other angle measure than degrees (the default setting) then it is probably easier to change the angle mode rather than converting everything. This is done in the **MODES** page, which is found above the **HOME** key. This screen allows you to change the title that appears at the top of the **HOME** page, the numeric format used (see pages 15,16) and what symbol is to be used for the decimal point (the alternative is a comma).

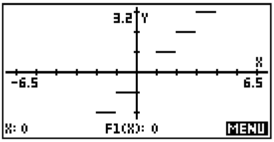
See also: RAD→DEG, HMS→, →HMS

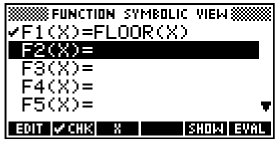
FLOOR(num)

This function is the same as the CEILING function, except that it always rounds down. Again, this is usually of interest to programmers.

Eg. FLOOR(3.75) = 3
FLOOR(45.01) = 45
Note: FLOOR(-2.56) = -3 not -2.

The FLOOR function is the same as the mathematical function 'greatest integer' which is studied in many many mathematical courses.

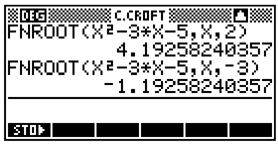




If you want to graph the greatest integer (FLOOR) function then you will need to use the **PLOT SETUP** screen to turn off CONNECT first, since the graph is supposed to be a discontinuous step function.

FNROOT(express.,guess)

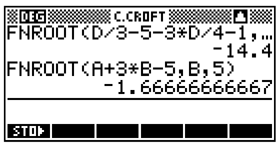
This function is like a mini version of the Solve aplet. If you feed it an algebraic expression and an initial guess it will start from your guess and find the value which makes the expression zero.



You need to tell it what variable to expect in the expression in addition to providing it with an initial guess. If there is only one answer then any guess will do, but if more than one solution is possible then more care needs to be taken with your guesses.

Eg. (a) Solve $x^2 - 3x - 5 = 0$
Use: FNROOT(X2-3X-5,X,2)

(b) Solve $\frac{d}{3} - 5 = \frac{3d}{4} + 1$
Use: FNROOT(D/3-5-3D/4-1,D,0)



(continued….)

If your expression involves more than one variable (see previous page) then whatever values are currently in memory are used for the other variables.

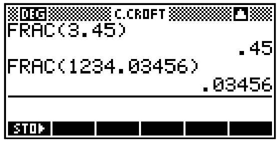
(c) Solve $a + 3b = 5$ (with memory A currently containing 10)
Use: FNROOT(A+3B-5,B,5)
which becomes 10+3B-5 = 0 when A is substituted
giving a solution of B = -1.666667

I don't know about you, but I think it's easier to simply use the Solve aplet!

See also: QUAD, POLYROOT

FRAC(num)

This function gives the decimal part of any number, discarding the integer part.



Eg. FRAC(3.45) = 0.45
FRAC(1234.03456) = 0.03456

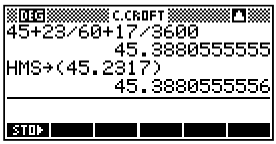
See also: INT,FLOOR,CEILING,ROUND,
TRUNCATE,FRAC

HMS→(dd.mmss)

This function works with both time and angles. It converts degrees, minutes and seconds to degrees, and also hours, minutes and seconds to decimal time.

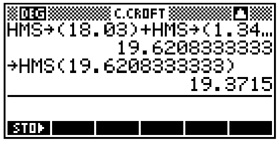
For those not familiar with the old style of representing angles, the convention used before decimal degrees became common was to divide each degree up into 60 minutes and each minute up into 60 seconds.

Thus $45^o23'17''$ is the same as $\left(45+\frac{23}{60}+\frac{17}{3600}\right)^o$, which is the same as $45\cdot 38805555^o$. The calculator can convert this if you put $45^o23'17''$ into the form 45.2317 and then use the HMS→ function. This is shown right.



Eg. sin($45^o23'17''$) would be done as SIN(HMS→(45.2317))
cos($5^o3'7''$) would be done as COS(HMS→(5.0307))

This function, together with →HMS, can also be used to deal with time.



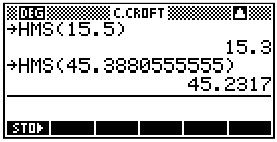
Eg. What time will it be 1 hr 34 min. and 15 sec. after 3 min. past 6 pm?
Type: HMS→(18.03)+HMS→(1.3415)

Ans: 37 min. 15 sec. past 7 pm. (see right)

See also: →HMS, RAD→DEG, DEG→RAD

→HMS(num)

This function works in the same way as the HMS→ function (see above) but in the opposite direction. It converts decimal degrees(or time) to degrees(or hours), minutes and seconds. The format of the returned answer is DD.MMSS (HH.MMSS)

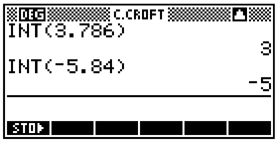


Eg. $15{\cdot}5^o$ would become $15^o30'$.
45.38805555 becomes 45.2317 ($45^o23'17''$)
3.75 hours becomes 3.45 (3 hours 45 min.)

See also: HMS→, RAD→DEG, DEG→RAD

INT(num)

This function is related to the FLOOR and CEILING functions. Unlike those two, which consistently move down or up respectively, the INT function simply drops the fractional part of the number.



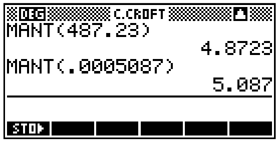
Eg. INT(3.786) = 3
INT(-5.84) = -5

See also: FLOOR, CEILING, ROUND, TRUNCATE, FRAC

Note: The INT function is not equivalent to the common mathematics function 'greatest integer'. The FLOOR function is the correct one to use for this.

MANT(num)

This function returns the mantissa (numerical part) of the number you feed it when transformed into scientific notation. It would be used with the XPON function, which returns the power part of the number in scientific notation.



Eg. Change 487 · 23 into scientific notation to get $4 \cdot 8723 \times 10^2$.
MANT(487.23) = 4.8723
XPON(487.23) = 2

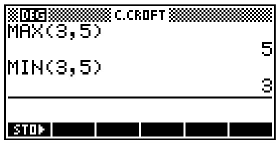
Change 0· 0005087 into scientific notation to get $5 \cdot 087 \times 10^{-4}$.
MANT(0.0005087) = 5.087
XPON(0.0005087) = -4

This function could be of use to you if you are just learning scientific notation, but is of more use to people writing programs. A programmer would not know in advance what number was going to be used and so would use the MANT and XPON functions to find out its size.

See also: XPON

MAX(num1,num2)

This function returns the larger of two values entered. This is not needed in your normal calculations, since you could just look at the numbers, but a programmer will be writing a program which deals with numbers not known in advance.



Eg. MAX(3,5) = 5

See also: MIN

MIN(num1,num2)

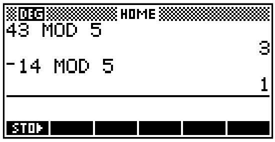
As with MAX, this function is used mainly by programmers. It returns the smaller of the two numbers entered.

Eg. MIN(3,5) = 3

See also: MAX

num MOD divisor

For those not familiar with modulo arithmetic (an interesting branch of maths if you would like to follow it up), it will suffice to say that this function gives you the remainder when one number is divided by another. It is considered to be an mathematical operator in the same way that a plus, minus, times or divide sign is. Because of this it does not need its arguements placed in brackets as most of the other functions in the MATH menu do.

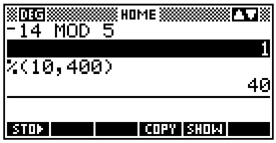


Eg. 43 + 5 = 48
43 MOD 5 = 3
35 MOD 7 = 0
-14 MOD 5 = 1

The method used by the MOD function in evaluating A MOD B is to find the largest multiple of B which is still smaller than A. It then subtracts this multiple from A.

i.e.	43 MOD 5…	Largest multiple is 40.	43 - 40 = 3
	-14 MOD 5…	Largest multiple is -15.	-14 - (-15) = 1

% function



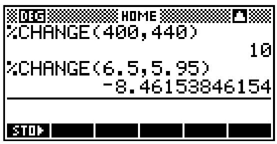
To find x% of y, use the function %(X, Y).

Eg. 10 % of $400 = $40

See also: %TOTAL, %CHANGE

%CHANGE

This function calculates the percentage change moving from X to Y using the formula 100(Y-X)/X. It can be used to calculate (for example) percentage profit and loss.



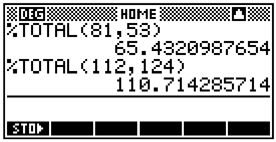
Eg. I buy a fridge for $400 and sell it for $440. What is my profit as a percentage?
Use: %CHANGE(400,440)

I sell a toy for $5.95 that normally sells for $6.50 What is the discount as a percentage?
Use: %CHANGE(6.50,5.95)

See also: %, %TOTAL

%TOTAL

To find out what percentage X is of Y, use the function %TOTAL(Y,X)
Note the reversed order! The manual supplied with the calculator incorrectly states them the wrong way round.



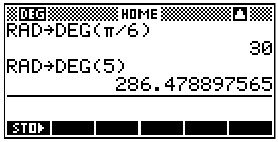
Eg. What percentage is a score of 53 out of 81 on a test?
Use: %TOTAL(81,53)

What percentage is 124 of 112?
Use: %TOTAL(112,124)

See also: %, %CHANGE

RAD→DEG(rad)

This function converts radians to degrees.

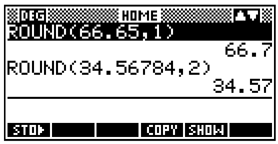


Eg. RAD→DEG(p/6) = 30^{o}
RAD→DEG(5) = 286.48^{o} (2 d.p.)

See also: DEG→RAD, HMS→, →HMS

ROUND(num,dec.pts)

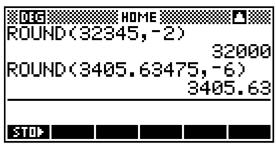
This function rounds off a supplied number to the specified number of decimal places (d.p.).



Eg. Round 66.65 to 1 d.p.
Use: ROUND(66.65,1) = 66.7

Round 34.56784 to 2 d.p.
Use: ROUND(34.56784,2) = 34.57

This function is also capable of rounding off to a specified number of significant figures (sig.fig.). To do this, simply put a negative sign on the number of places.



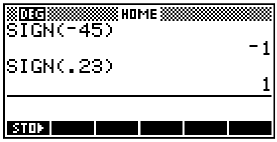
Round 32345 to the nearest thousand.
Use: ROUND(32345,-2) = 32000

Round 3405.63475 to 6 sig.fig.
Use: ROUND(3405.63475,-6) = 3405.63

See also: INT, FLOOR, CEILING, TRUNCATE, FRAC

SIGN(num)

This is another function which is designed more for the programmers. It returns a value of +1, 0 or -1 depending on whether the number supplied is positive, zero or negative.



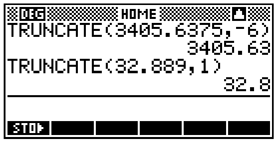
Eg. SIGN(-45) = -1

See also: XPON, MANT

Note: ***See also* SIGN *revisited in the Complex group of functions (pages 148-149).***

TRUNCATE(num)

This function operates similarly to the ROUND function, but simply drops the extra digits instead of rounding up or down. It is somewhat similar in effect to the FLOOR function but the TRUNCATE function will work to any number of decimal places or significant figures instead of always dropping to the nearest lower integer value.

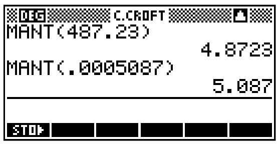


Eg. TRUNCATE(3405.6375,-6) = 3405.63
TRUNCATE(32.889,1) = 32.8

See also: INT, FLOOR, CEILING, ROUND, FRAC

XPON(num)

This function returns the exponent (indicial part) when transformed into scientific notation of the number you feed it. It would be used with the XPON function, which returns the power part of the number when in scientific notation.



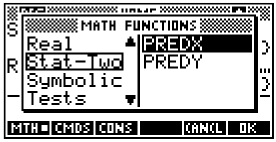
Eg. Change 487 · 23 into scientific notation to get $4 \cdot 8723 \times 10^2$.
MANT(487.23) = 4.8723
XPON(487.23) = 2

Change 0· 0005087 into scientific notation to get $5 \cdot 087 \times 10^{-4}$.
MANT(0.0005087) = 5.087 XPON(0.0005087) = -4

This function could be of use to you if you are just learning scientific notation, but is of more use to people writing programs. A normal user would just look at the number and see the answer, but a programmer would not know in advance what number was going to be used and so might use MANT and XPON.

See also: MANT

The 'Stat-Two' group of functions



<u>*PREDY(xval)*</u>

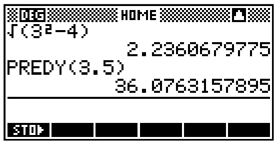
This function predicts the y value for a pair of columns set up as bivariate data in the Statistics aplet. This is discussed in more detail in the section covering the Statistics aplet, but a brief summary will be given here.

Assuming that:

(i) the bivariate data is entered into a pair of columns (eg. C1 and C2, with C1 containing the independent data and C2 the dependent data),

and (ii) that these two columns have been specified in the **SYMB** view to be paired bivariate data,

and (iii) that the data has been graphed in the **PLOT** view and that the FIT screen button has been used to plot the line of best fit for the pair of columns,



then the function PREDY(3.5) will produce a predicted y (dependent) value for the x (indep.) value of 3.5.

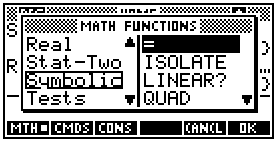
NOTE: The line of best fit used in the function PREDY is whichever one was last plotted. *It is up to you* to ensure that this is in fact the one you want used!

<u>*PREDX*</u>

WARNING: This function is presumably supposed to do the reverse of the PREDY function. In fact, an argument can be made that it is mathematically incorrect and I would recommend for that reason that it should not be used.

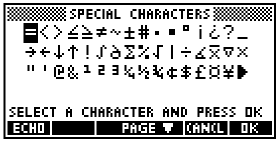
The reasons for this are discussed in detail on page 82 of the Statistics aplet section. It is recommended that the user read these before its use is contemplated.

The 'Symbolic' group of functions



The = 'function'

Although this is listed in the Maths menu as if it were a function, it is not really. The = sign is simply used in exactly the way that you would expect it to be, mainly in the Solve aplet (see pages 61). I suspect that it is included in this menu simply for the sake of completeness.



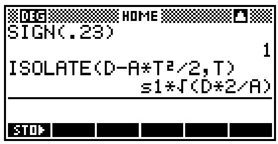
If you want to get access to the = character, it is far easier to obtain it through the **CHARS** menu (see right). In the Solve aplet, the = sign is provided as one of the screen keys.

ISOLATE(expression,var.name)

This is a really useful function. It will rearrange a formula so that its subject is another variable. To do this, the formula must be rewritten so that it is an expression equalling zero. The ISOLATE function then rearranges the formula around the first occurance of the variable you indicate.

Eg. 1 Rearrange the formula $d = \frac{1}{2}at^2$ so that the variable 't' is the subject.

Firstly, rewrite: $d - \frac{1}{2}at^2 = 0$



Use: ISOLATE(D-AT²/2,T)

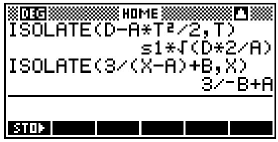
The result (shown right) needs a small amount of interpretation.

The answer is supposed to be $T = \pm\sqrt{\frac{2D}{A}}$.

I think we can safely assume that you realize that the 'T=' is missing (for you to fill in if needed), but there is also a strange symbol 'S1' that needs explaining. This is supposed stand for a ± sign. (You know, 'S' for sign.) Considering that the ± sign is actually available through the **CHARS** screen it is a little difficult to see why they did this, but…

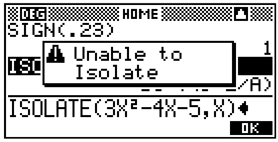
Eg. 2 Make X the subject of the formula $B = \dfrac{-3}{(X - A)}$.

Using: ISOLATE(3/(X-A)+B,X)
we get: 3/-B+A



which is equivalent to: $X = \dfrac{-3}{B} + A$

The ISOLATE function is very useful within its limitations, but it will not deal with every type of formula. For example:



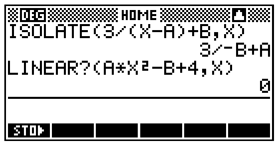
See also: The Solve aplet, FNROOT, QUAD

LINEAR?(expression,var.name)

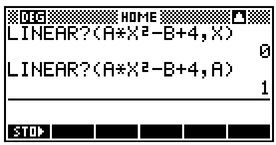
This is another of those functions which is probably aimed more at the programmer than at the normal user. It is designed to test whether a supplied expression is linear or non-linear in the variable you specify, returning zero for non-linear and 1 for linear.

Eg. Suppose we use the expression $AX^2 - B + 4$

If X is the variable and A and B are both constants (say A=4, B=5) then the expression $AX^2 - B + 4$ would become $4X^2 - 5 + 4$ which would be non-linear. Thus LINEAR? returns zero (right).



On the other hand, if X were one of the constants (say X=6) and A were the variable, then the expression $AX^2 - B + 4$ would become $A \times 6^2 - 5 + 4$ or $36A - 1$, which is linear. Thus LINEAR? would return 1.



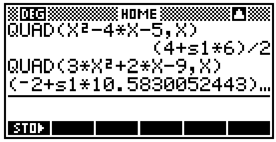
Clearly the main use for this is going to be when a programmer does not know in advance what function the user is going to type in.

See also:

QUAD(expression,var.name)

This is a function specifically designed to find the roots of a quadratic equation. It uses the quadratic formula $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ to do this *and gives both possible answers by using the 'S1' formal variable to represent the ± symbol*.
The quadratic must be entered as an expression rather than as an equation, and you must also indicate which variable is the one being solved for. This is so that you could have an equation such as $Px^2 + Qx - 5 = 0$ where P and Q were memory values, and still be able to tell it to solve for X rather than for P or Q.

Eg. Solve $x^2 - 4x - 5 = 0$
Use QUAD(X2-4X-5,X)
Answer: (4+S1*6)/2



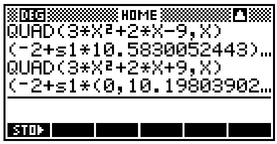
It is now up to you to interpret this as:

$$x = \frac{4 \pm 6}{2}$$
$$= \frac{4+6}{2} \text{ or } \frac{4-6}{2}$$
$$= 5 \text{ or } -1$$

Probably the easiest way to do this, particularly in the second case which involves a long decimal expression, is to use the up arrow key to move up to the expression, copy it and then delete the S1* from it, leaving just (4+6)/2. Pressing **ENTER** would evaluate this to 5 and you could then copy the (4+6)/2 expression and change the + to a - to get the other solution of -1.

An easier way altogether is probably to use the Solve aplet instead. Alternatively, since the Solve aplet requires that you have some guess prepared in advance, you might use the Function aplet and, after graphing, use the *FCN* tool to find the x intercepts.

Note: The Quad function does have one distinct advantage over other methods, in that it will give a complex number solution to quadratics for which the discriminant is negative. This may well make it worth using in problems where a complex answer is acceptable. Complex numbers are expressed on the HP38G in the form (a, b) representing $a + bi$. Thus the answer to the second quadratic shown above would represent $\dfrac{-2 \pm \sqrt{-112}}{6}$ with the $\sqrt{-112}$ written as a complex number.



See also: FNROOT, LINEAR?

<u>QUOTE(var.name)</u>

Intended for use mainly by programmers. When creating a program, one sometimes wants to store a function such as X^2-4 into one of the functions F1(X)…F9(X). This can be done using the STO➢ command, but it turns out that if you do this inside a program then the X doesn't get entered. Instead, the current contents of memory X (a number) is entered in its place. The QUOTE function is there to fix this.

For example, a programmer might use QUOTE(X) ^{2}-4➢F1(X) to ensure that the letter X was used instead of the contents of memory X when entering X^2-4 into F1(X). An easier way is to use single quotes: X ^{2}-4Æ➢F1(X).

A somewhat contrived example of a non-programmer's use of this function can be found on page 24 where the use of functions from other aplets in the HOME view is being discussed.

See also: ----

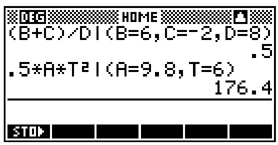
<u>The '|' function</u>

<u>expression|(va1r=value,var2=value,…)</u>

This is called the 'where' function. It is used to evaluate formulae, of the type when one would say "Evaluate ….., <u>where</u> a = 5, b = 4 etc".
The formula must be in the form of an expression rather than an equation. You should enter the equation first, then the 'where' symbol (which supplies its own bracket) and then the values of all the variables in the expression. Any not supplied are evaluated using values currently stored in the memory for that letter.

Eg. 1 Evaluate $a = \frac{b+c}{d}$ <u>where</u> b = 6, c = -2 and d = 8

Use: (B+C)/D|(B=6,C=-2,D=8)
Answer: 0.5

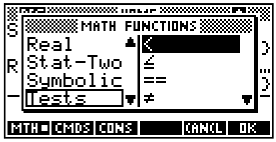


Eg. 2 Using the formula $d = \frac{1}{2}at^2$, find the distance d which an object would fall under Earth's gravity of 9.8 m/sec^2 in a time of 6 seconds.

Use: .5AT^2 |(A=9.8,T=6)
Answer: 176.4 metres

See also: ISOLATE

The 'Tests' group of functions



These are all functions which are of interest only to programmers, and consequently we will not cover them here.

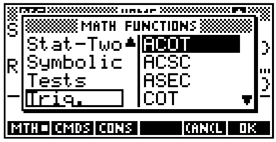
The only time that some of these might be of use is in entering Piecewise defined functions into the **SYMB** view in the Function aplet. This is covered in some detail on page 45.

For those wanting to try a little programming, we will offer this small tip which might save those of you who have never encountered the C language some grief. When using an IF….THEN…. ELSE….. statement, don't use the syntax you may be used to if you know Pascal or Basic, which is IF (A=4) THEN….ELSE….. This will not *test* to see if A has the value 4, it will actually *assign* the value of 4 to A, thereby ensuring that the test will always evaluate as true even if A didn't have the value of 4 before you ran the test! The correct syntax is IF (A==4) THEN….. ELSE….. and this == sign can be found in the Tests group.

Although in many ways the programming language of the HP38G behaves in a similar way to Basic, the internal language programmed into the chip (the BIOS) is written in C and this sometimes pops up in unexpected places if you are not used to the C language.

Programming the HP38G is covered in a small way on pages 117 - 124 but those wanting more detail than is given there must consult the manual (obscure though it is at times). The best method of learning how to program the HP38G is to download an aplet from the Net and dismantle it.

The 'Trigonometric' and the 'Hyperbolic' groups of functions



These two groups of functions cover the Trigonometry functions which are less commonly used and which have consequently not been given their own buttons on the face of the calculator.

Although they (of course) give different results, you use them in exactly the same way as you would the normal SIN, COS and TAN functions, together with their inverse functions (above the buttons) of ASIN, ACOS and ATAN. For the benefit of those who don't know, the inverse operation of trig. functions can be written in two ways.

Eg. If $\sin(30^\circ) = 0.5$,

then we can write either $\sin^{-1}(0.5) = 30^\circ$ (read as "inverse sin")

or $\arcsin(0.5) = 30^\circ$ (read as "arc-sin")

Both of these mean exactly the same thing mathematically, but the *arc-sin* useage is the older, more traditional one. Many of the modern calculators have opted for the other alternative but the HP38G designers chose to stay with *arc-sin*, which was then (as is commonly done) abbreviated to ASIN.

On the face of the calculator you will find:

Function	Inverse function
SIN (sine)	ASIN (arc-sine)
COS (cosine)	ACOS (arc-cosine)
TAN (tangent)	ATAN (arc-tangent)

In the Trig. group of functions you will find:

Function	Inverse function
COT (cotangent)	ACOT (arc-cotangent)
CSC (cosec/cosecant)	ACSC (arc-cosec)
SEC (secant)	ASEC (arc-secant)

In the Hyperb. group of functions you will find (amongst other things):

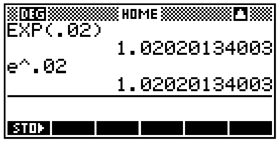
Function	Inverse function
SINH (hyperbolic sine or "shine")	ASINH (arc-hyp.sine)
COSH (hyperbolic cos or "cosh")	ACOSH (arc-hyp.cos)
TANH (hyperbolic tant)	ATANH (arc-hyp.tan)

These 'hyperbolic' functions are used mainly in engineering applications.

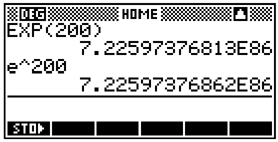
Some further functions are available in the Hyperbolic group of functions. They are duplicates of functions available on the face of the calculator but give more accurate answers. They would primarily be of use to those people, such as architects and engineers, for whom full accuracy is paramount. These functions are:

EXP(num)

This function gives a more accurate answer than does the button labelled **e^** which appears above the + sign on the calculator. As you can see on the right, the difference is normally not detectable even to 12 significant figures.

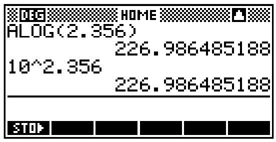


The difference only becomes apparent for very large values (as you can see on the right) and is, even then, hardly earth-shattering.



ALOG(num)

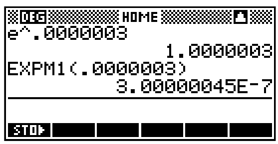
This function provides the same result as the button labelled **10^** on the keyboard above the * key. It is another function giving greater accuracy than the one it 'replaces'. As with the others, this greater accuracy would never be required in a school setting.



EXPM1(num)

This function is designed to be more accurate when anti-logging very small values close to zero. It gives the value not of e^x but of $e^x - 1$ (*EXPM1: exp minus 1)* You may wonder how this is an advantage, since you must then add 1 to obtain the correct answer, but a look at the screen opposite will show you.

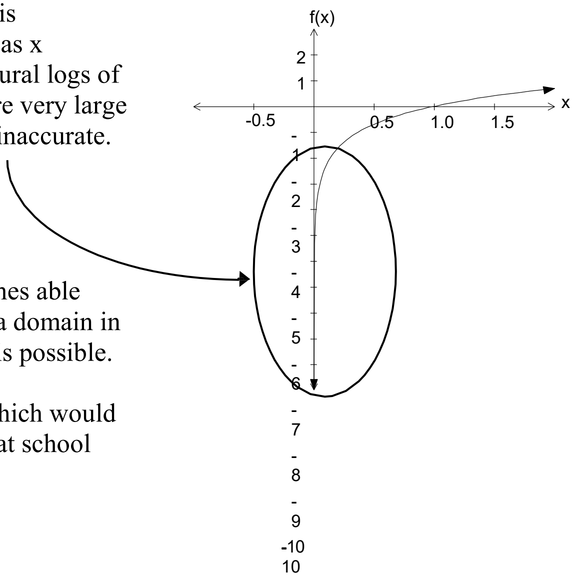
As you can see, the normal keyboard function **e^** gives an answer to $e^{0 \cdot 0000003}$ of 1·0000003. This gives the impression (since it doesn't show a full 12 significant digits) that it is an exact value.



In fact the true answer is 1·000000300000045…. but the final digits have been lost in the rounding off to 12 sig. figures. By giving an answer of $e^x - 1$, the leading 1 is lost, freeing the calculator to drop the first 6 zeros by changing to scientific notation, and thus give an answer which shows the final ….0045 rather than dropping it. As you might imagine, this would not normally be needed in schools!

LNP1(num)

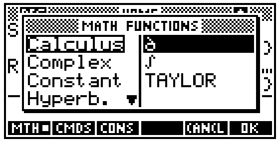
Since the ln(*x*) function is asymptotic to the y axis as x approaches zero, the natural logs of numbers close to zero are very large negatives, and possibly inaccurate.



"LNP1"="ln plus 1"
By finding the natural log of $x + 1$ rather than of x , the function becomes able to do its calculations in a domain in which greater accuracy is possible.

This is not something which would normally be of concern at school level.

The 'Calculus' group of functions



This group consists of three functions, two of which are discussed in detail in the chapter dealing with the Function aplet.

The functions are:	(i) the integrate, or $\int$ function, discussed on pages 44.
	(ii) the differentiate, or ∂ function, discussed on pages 39.
and,	(iii) the TAYLOR function, discussed below.

There is neither the space nor the reason to go into Taylor polynomials too deeply at this point. If you go on and study mathematics at University level, then you will undoubtedly encounter them at some point in your studies, at which point this function will become useful.

Briefly, a Taylor polynomial allows you to approximate the graph (values) of a more complex function via a simpler function, a polynomial.

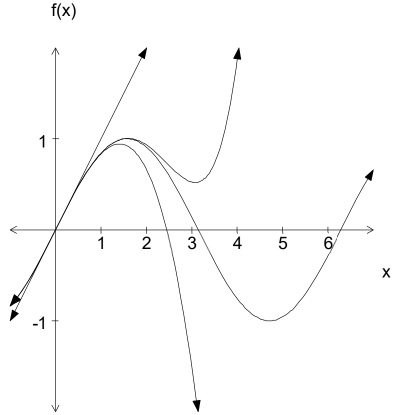
For example, the complex (relatively speaking) function of SIN(X) can be approximated by the polynomial given below:

$$\sin(x) = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + ...$$
$$= x - \frac{1}{6}x^3 + \frac{1}{120}x^5 - \frac{1}{5040}x^7 + ...$$

This can be seen more clearly in the graph on the right, which shows the $y = \sin(x)$ function, together with successive approximations of : $y = x$, followed by $y = x - \frac{1}{6}x^3$, followed by

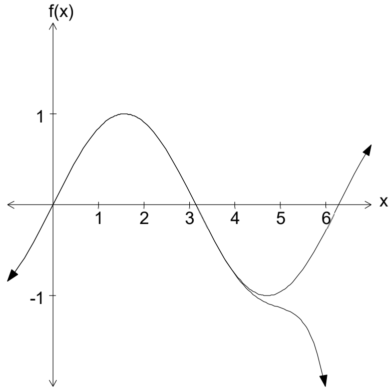
$y = x - \frac{1}{6}x^3 + \frac{1}{120}x^5$. As you can see,

while the first approximation is not very good, the match becomes closer and closer as you include more terms from the Taylor polynomial.



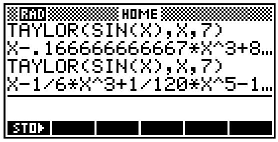
The graph on the right shows the Taylor polynomial taken to another 3 terms and, as you can see, the fit is beginning to be quite accurate.

You may wonder why anyone would bother with this when they can obtain a value for sin(x) simply by pressing the appropriate button on their calculator but, if so, then you have clearly never wondered just how the calculator gets its values in the first place!

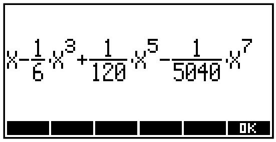


Suppose we wanted to find $\sin(30^\circ)$. The calculator converts this value of 30° to radian measure and then substitutes this into the Taylor polynomial for sin(x) (which is built in at the factory by the designers). It follows the terms of the Taylor polynomial until the successive terms being added and subtracted are so small that they are not affecting the answer, and then displays this result as $\sin(30^\circ)$. Because the factorial on the bottom of the fraction increases in size much faster than the x^n terms do, it is guaranteed that the terms will eventually become small enough to be disregarded. Understanding this process may begin to give you a healthy respect for the speed of today's calculators! In fact, modern calculators use even faster shortcuts but the general idea is the same.

The screen shot on the right shows the calculator deriving the Taylor polynomial for sin(x) up to the 7^{th} power.

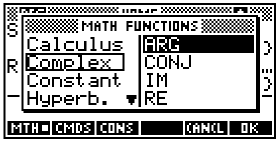


The first is calculated with HOME **MODES** set to Standard, the second with HOME **MODES** set to Fraction 4. The screen shot below shows the fractional polynomial in more detail after highlighting it and pressing the *Show* key.



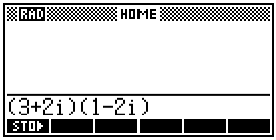
Note that if the function you apply the TAYLOR function to is already a polynomial, then you will simply get the same function back.
Thus TAYLOR((X-1)^5*(2X+1),X,6) will give the same result as you would get from POLYFORM((X-1)^5*(2X+1),X). The drawback of using TAYLOR is that it is much slower, and you must specify the highest power expected. If you used TAYLOR((X-1)^5*(2X+1),X,5) instead of ….,X,6) for example, the last term of + $2x^6$ would be omitted, whereas POLYFORM does not need this additional input.

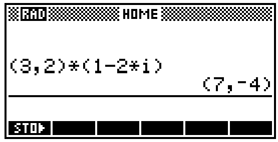
The 'Complex' group of functions



Complex numbers on the HP38G can be entered in either of two ways. The first way is to write them in the same way as they are commonly written in mathematical workings: $a + bi$. The other way is as an ordered pair: *(a,b).*

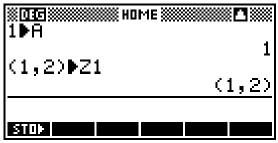
For example, $(3 + 2i)(1 - 3i)$ could be entered into the calculator exactly as it is written there, with the '*i*' obtained using the A..Z key, hitting the blue 2nd function key first to get a lowercase *i*. This option is shown on the right. The screen underneath shows how, as soon as you press **ENTER**, the calculator immediately converts this form into the other of entry, which is as an ordered pair. As you can see, the calculator is sometimes a little inconsistent in its conversions.





Complex numbers can be used with all trigonometric and hyperbolic function, as well as with some real-number and keyboard functions. When in doubt, try it.

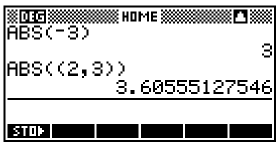
Just as real numbers can be stored into the alphabetic memories A to Z, there are 10 special memories Z1,Z2..Z9,Z0 which are provided to store complex numbers.



In addition to the trig functions, there are four functions in the Complex group plus two others, one (SIGN) from the real group and one (ABS) on the keyboard that take complex arguments and give a very useful result.

<u>*ABS(real or complex)*</u>

The absolute function, which is found on the keyboard above the **-X** key, returns the absolute value of a real number.



Eg. ABS(-3) returns a value of 3.

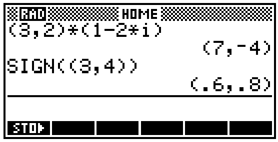
When you use the absolute function on a complex number $a + bi$ it returns the magnitude of the complex number $\sqrt{a^2 + b^2}$.

<u>*SIGN(real or complex)*</u>

This function is normally part of the Real group (see page 128 - 135) but is very

useful with complex numbers. If given a complex number *(a,b)*, SIGN will return another complex number which is a unit vector in the direction of *(a, b)*.

i.e. SIGN(A,B) returns $\left(\frac{a}{\sqrt{a^2+b^2}}, \frac{b}{\sqrt{a^2+b^2}}\right)$.

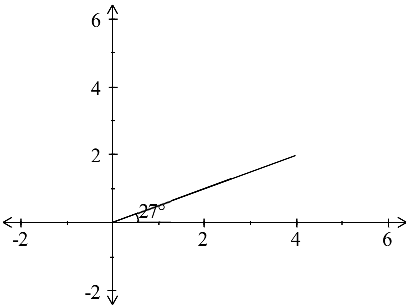


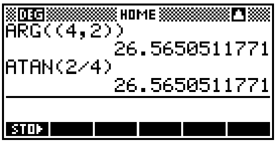
This is very useful, not just in complex numbers, but also in vector problems.

See also: SIGN (Real group),IM,REAL,ARG,CONJ

<u>*ARG(complex or vector)*</u>

This function returns the size of the angle defined by regarding the complex number as a vector. For example, as shown right, ARG(*4+2i*) would be 26·565° . The same information can, of course, be obtained by completing the right triangle and using trig (as shown in the screen shot).





The reason for the double brackets is that <u>every</u> function used by the calculator uses brackets (hence the outer pair) but so too do complex numbers (hence the inner pair). Using ARG(a+bi) instead avoids this.

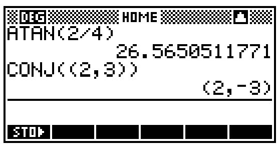
Note: The manual gives the argument of ARG as *(r, θ)*, as if it should be supplied in polar format rather than in the form $a + bi$ or *(a,b)*. ***This is incorrect***.

<u>*CONJ(complex)*</u>

This function returns the complex conjugate of the complex number given to it.

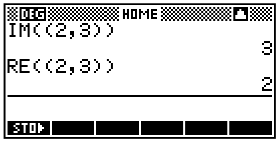
Eg. If $z = 2 + 3i$, then find the complex conjugate $\bar{z}$.

Answer (right): $\bar{z} = 2 - 3i$



See also: IM,ARG,RE

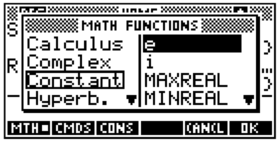
IM(complex) and RE(complex)



These functions return the imaginary and real parts of the complex number supplied.
If you enter $a + bi$ then IM((a,b)) = b.
RE((a,b)) = a.

See also: CONJ,ARG,RE

The 'Constant' group of functions



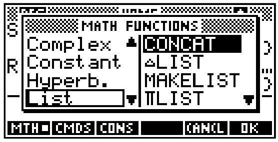
These 'functions' consist of a set of commonly occurring constants.

Two of them, MAXREAL and MINREAL are only of use to programmers. They consist of the largest and smallest numbers respectively with which the calculator is capable of dealing, and are there as a check to ensure that calculations within a program have not overflowed the capacity of the calculator.

The other three, π, i, and e, are far more easily obtained in other ways.

The first, π, is available via a button on the face of the calculator above the 3 key. The second, i, is easily obtained as a lowercase letter through the **A..Z** button, pressing the blue 2nd function key first to get lowercase. The third, e, is available in two ways. If you want it as a function (as in $e^{3.4}$) then the e^ function is above the + key. On the other hand, if you need the numerical value of e (as in $\frac{2e}{3}$) then you can use the e^ key in the same way and then just hit the DEL key to get rid of the unneeded ^ symbol.

The 'List' group of functions

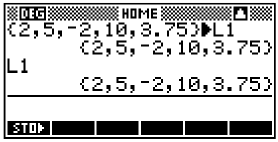


A list in the HP38G is the same mathematically as a set. As with a set, it is written as a series of numbers separated by commas and enclosed with a pair of curly brackets.

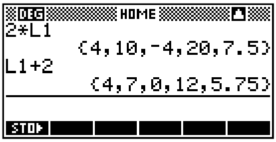
Eg. {2,5,-2,10,3.75}

Using the HOME view these lists can be stored in special list variables. There are ten of these L1,L2,..L9,L0.

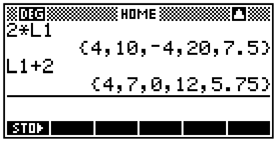
Eg. {2,5,-2,10,3.75}➤L1



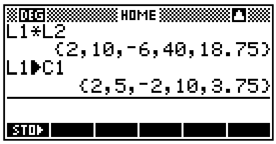
Typing L1 and then **ENTER** will then retrieve the list (see right). Lists can also be multiplied by a constant and have a constant added to them (see below)



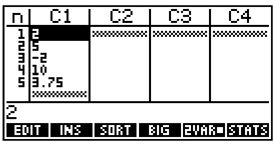
If we store another list of the same length into L2, then the two lists can be multiplied together. The resulting list is obtained by multiplying each element in the first list by the corresponding element in the second list.



Many of the normal mathematical functions also work on lists of numbers by performing the operation on each individual element.



The column variables C1,C2..C9,C0 in the Statistics aplet are identical to list variables and can be used as extra storage if you need more list variables. The statistical variables have the additional advantage, of course, that they can be graphed in the Statistics aplet and that all the usual statistical measures are available. To transfer a list variable to a statistics variable, just store one into the other (see right). As you can see in the second view, the list has been transferred to C0. Pressing '*Stats*' would now give the usual statistical measures for the newly created column.

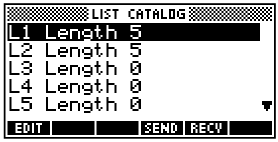


There are also a number of special functions available for list variables which are contained in the List group of functions in the MATH menu. These will be discussed at the end of this section.

The List Catalogue

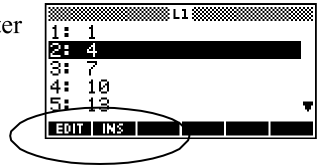
In addition to being able to manipulate Lists in the HOME view, there is also a special 'List Catalogue' provided which allows easier entering and editing of lists. If you look above the 7 key you will see a label of LIST which gives you access to this catalogue (obviously you have to press the BLUE key first).

When you enter this catalogue you will see the screen on your right (or something similar). The catalogue shown right indicates that there are currently two lists in use, both of length 5.



Pressing the DEL key when on one of these lists will delete that list, clearing the memory it uses. Pressing BLUE CLEAR (above the DEL key) will clear all lists. In both cases a query message pops up asking whether you are sure you want to do this.

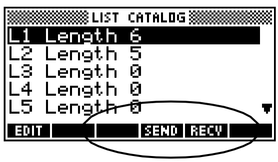
If you press the button under '*Edit*' then you will enter a special editing screen which allows you to change individual values, delete values (using the DEL key) and insert new elements into a list. If you press the '*Ins*' key with the highlight in the position shown, then
the new number you type in is inserted before the 4, with all the elements below shifted down one position to make room.



Having entered the editing screen, you may be wondering how to exit, since no key is apparently provided for this. The answer is that you just press BLUE LIST again to return to the catalogue level (or else press HOME if you've finished altogether).

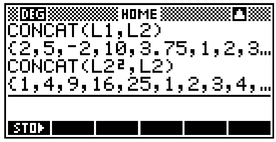
Changing of individual elements of a list can also be done in the HOME view, if not quite so easily. As we saw earlier, typing L1 and pressing ENTER will display an entire list in the HOME view. If you want to see just (say) element 3, then typing L1(3) will display just that one element (see right). As you can also see in the screen shot right, you can change just one element using the store command. It is not possible to insert an extra element in the HOME view, except in that you could add an element to the end of a list using the CONCAT function discussed on the next page.

Lists can also be sent from one HP38G to another using the infra-red link with the aid of the two buttons labelled '*Send*' and '*Recv*' (see right). The procedure is exactly the same as that for sending aplets from one calculator to another, which is discussed on pages 104 - 124.



CONCAT({list})

This function concatenates two lists - appending one on to the end of the other in the order that you specify.



Eg. L1={2,5,-2,10,3.75}
L2={1,2,3,4,5}

CONCAT(L1,L2)= {2,5,-2,10,3.75,1,2,3,4,5}

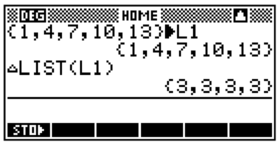
CONCAT(L1,{5})➤L1 would add another element of value 5 onto the end of list L1, storing the resulting longer list back into L1.

ΔLIST({list})

This function produces a list which contains the differences between successive values in the supplied list. The resulting list has a length one less than the original.

Eg. L1={1,4,7,10,13}

ΔLIST(L1)={3,3,3,3}



MAKELIST

This function produces a list of the length that you specify using a rule of your choice.

The syntax is: MAKELIST(*expression, variable name, start , end, increment*)

where	*expression*	is the mathematical rule used to generate the numbers.
	variable name	is the letter (X, Y etc) that is to be used in the expression (any other letters will be taken as constants).
	start	is the first value that *variable name* is be given.
	end	is the largest value that *variable name* is to take.
and	*increment*	is the amount that *variable name* should be incremented by.

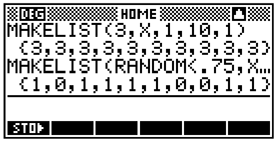
Eg. 1 MAKELIST(X^2,X,1,10,2)➤L1
produces { 1, 9, 25, 49, 81 } as X goes from 1 to 3 to 5 to …
and stores the result into L1.

Eg. 2 MAKELIST(RANDOM,X,1,10,1) produces a set of 10 random numbers, while MAKELIST(INT(45*RANDOM)+1,X,1,6,1) will choose your Lotto numbers for you. The X in these cases serves only as a counter.

Eg. 3 MAKELIST(3,X,1,10,2) produces {3,3,3,3,3,3,3,3,3,3}.

The MAKELIST function can also be used to simulate observations on random variables.

For example, suppose we wish to simulate 10 Bernoulli trials with p = 0.75. We can use the fact that a test like (X<4) or (Y>0.2) returns a value of either 1 (if the test is true) or 0 (if the test is false).



Thus: MAKELIST(RANDOM<0.75,X,1,10,1) will return a list of 1's and 0's corresponding to the simulated Bernoulli trials.

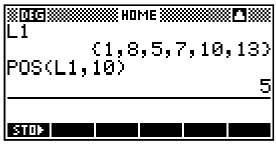
Various examples of this process are given in the 'Tips and Tricks' section which immediately follows the section on Univariate Statistics (pages 73,74).

πLIST({list})

This function returns the product of all the elements of a list.

Eg. πLIST({2,3,5}) would return a value of 30.

POS({list},num)



This function conducts a search of a list. It returns the position in the list of the first occurrence of the number you specify (see example right). It is probably of more use to programmers.

If the number specified is not in the list it returns zero. If the value occurs in more than one place then only the first position is reported. The value specified can be either a number (as shown) or a variable or an expression to be evaluated.

SIZE({list})

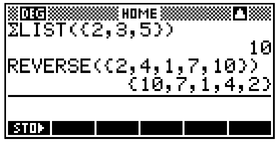
This function returns the size of the list specified. Since normal users would probably know anyway, and could find out easily via the list catalogue, this is clearly another of those functions which are of more use to programmers (who won't know when they write their program just how long a list you will ask it to deal with when you eventually run the program).

ΣLIST({list})

This function returns the sum of all the elements of a list.

Eg. ΣLIST({2,3,5}) would return a value of 10.

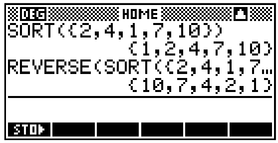
REVERSE({list})



This function reverses the order of all elements in a list.

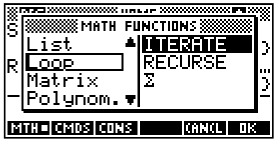
Eg. REVERSE({2,4,1,7,10}) would return {10,7,1,4,2}

SORT({list})



This function returns a list that is sorted into ascending order. If you want the list in descending order instead then use REVERSE(SORT(list)).

The 'Loop' group of functions



This is an interesting group of functions that may be of use for students studying discrete functions and sequences.

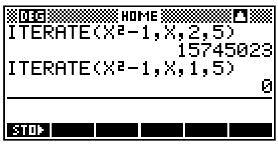
ITERATE(expression,var.name,strt,num.iter.)

This function evaluates an expression a specified number of times, starting with a supplied initial value an using the answer to the previous evaluation as the value for the variable in the next evaluation.

Eg. ITERATE(X^2-1,X,2,5) gives an answer of 15745023

This answer is obtained as follows:

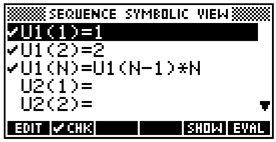
initial value:	X=2 $X^2 - 1 = 3$	first iteration
new value:	X=3 $X^2 - 1 = 8$	second iteration
new value	X=8 $X^2 - 1 = 63$	third iteration
new value	X=63 $X^2 - 1 = 3968$	fourth iteration
new value	X=3968 $X^2 - 1 = 15745023$	fifth iteration
Final answer:	X = 15 745 023	



It will be left as an exercise for you to calculate why the answer to the same iteration with a starting value of 1 gives an answer of zero.

RECURSE

This functions is provided for programmers to let them define functions in the Sequence aplet. For example, typing RECURSE(U,U(N-1)*N,1,2)➢U1(N) seemingly produces no useful result in the **HOME** view, but would produce the result shown right in the **SYMB** view of the Sequence aplet. The resulting sequence is the factorial numbers.



The syntax is:

RECURSE(<seq.name>,<defn of term n>,<1st term>,<2nd term>)

and it really must be STO➢'ed into a sequence such as U1,U2..U9,U0 for it to have any meaning.

Σ (SUMMATION)

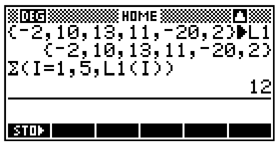
This function offers a way of calculating the results of summation notation problems. The syntax of the function is ordered in the same way as one reads a summation expression (see the examples below).

Eg. 1 $\sum_{i=1}^{5} i^2$ which expands to $1^2 + 2^2 + 3^2 + 4^2 + 5^2$ giving an answer of 55,

can be evaluated using Σ(I=1,5,I²)

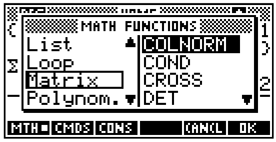
Eg. 2 $\sum_{i=1}^{6} x_i$ where $x_1 = -2$, $x_2 = 10$, $x_3 = 13$, $x_4 = 11$, $x_5 = -20$, $x_6 = 2$

can be evaluated by first defining a list L1 as {-2,10,13,11,-20,2} and then calculating Σ(I=1,6,L1(I))



Note: Although 'i' was used as the summation index in each of the cases above, there is nothing special about this letter. 'i' and 'j' are the letters traditionally used in mathematical problems.

The 'Matrix' group of functions



This very extensive group of functions is provided to deal with matrices.

The scope of functions and abilities covered in this group is in fact vastly greater than would be required by the average school student or teacher. In many cases the explanation of what the function is used for would occupy many pages to no real useful gain. Consequently many of the functions will be covered only by commenting "See Official Manual".

A detailed set of examples for the more commonly used functions is given in the chapter titled "Using Matrices with the HP38G" on pages 90 - 96.

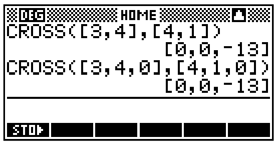
<u>COLNORM</u> See Official Manual

<u>COND</u> See Official Manual

<u>CROSS([vector],[vector])</u>

This function finds the cross product of two vectors. Vectors for this function are written as single row matrices.

For example, a = (3,4,0) or $\begin{pmatrix} 3 \\ 4 \\ 0 \end{pmatrix}$ would be written as (3,4,0).



<u>DET(matrix)</u>

This function finds the determinant of a square matrix.

Eg. If $A = \begin{bmatrix} 2 & 3 \\ -1 & 5 \end{bmatrix}$ then find det(A).

Ans: det (A) = 2x5-3x(-1)
= 13

See also: INVERSE, RREF

<u>DOT([vector],[vector])</u>

This function returns the dot product of two vectors. Vectors for this function are written as single row matrices.

For example, $a = (3,4)$ or $\begin{pmatrix} 3 \\ 4 \end{pmatrix}$ would be written as (3,4).

See the chapter "Using Matrices with the HP38G" for a fully worked example of this function (pages 90 - 96).

EIGENVAL See Official Manual

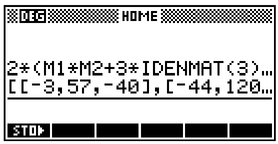
EIGENVV See Official Manual

IDENTMAT(size)

This function creates an n x n square matrix which is an identity matrix (1's on the diagonal, zero elsewhere). For example, IDENTMAT(4) would produce a 4x4 identity matrix for use or storage.

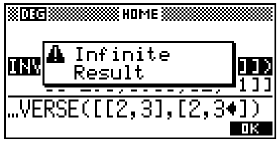
Eg. Suppose A, B and C are 3 x 3 matrices already stored in the Matrix catalogue as M1, M2 and M3 respectively, and you wish to evaluate $2(AB + 3) + C$.

Evaluating 2(M1*M2+3)+M3 will give an error message (see right) because the term '3' is not a matrix. This may well be the correct result.



However, by rewriting '3' as 3I (where I is the 3x3 identity matrix) the result becomes possible. This is shown in the second screen shot, where 2(M1*M2+3)+M3 has been rewritten as 2(M1*M2+3*IDENTMAT(3))+M3.

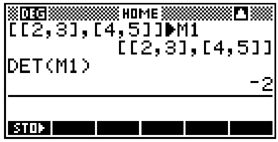
INVERSE(matrix)



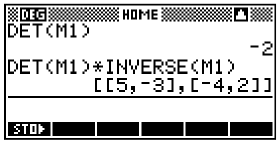
This function produces the inverse matrix of an n x n square matrix, where possible. A fully worked example of the use of an inverse matrix to solve a 3 by 3 system of equations is given on page 91, 92 of the chapter "Using Matrices with the HP38G".

An error message is given (see right) when the matrix is singular (det. zero).

Note: A common mathematical habit is to write the inverse matrix as a fraction (one over the determinant) multiplied by a matrix, so as to avoid decimals and fractions within the inverse matrix. The HP38G does not do this. If you want the matrix with the determinant factored out, then evaluate DET(matrix) first, record the fraction and then evaluate DET(matrix) * INVERSE(matrix) to obtain the non-fractional matrix.



i.e. $A = \begin{bmatrix} 2 & 3 \\ 4 & 5 \end{bmatrix} \Rightarrow A^{-1} = \frac{1}{-2} \begin{bmatrix} 5 & -3 \\ -4 & 2 \end{bmatrix}$



Remember that the inverse matrix is not just the matrix, but the fraction times the matrix!

See also: RREF, DET

LQ See Official Manual

LSQ See Official Manual

LU See Official Manual

MAKEMAT See Official Manual

QR See Official Manual

RANK See Official Manual

ROWNORM See Official Manual

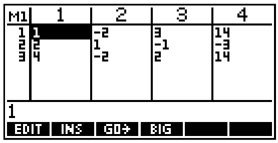
RREF(matrix)

This function takes an augmented matrix of size n by n+1 and transforms it into reduced row echelon form, with the final column containing the solution.

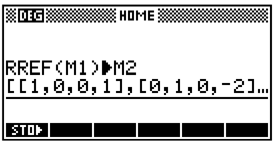
Eg. The system of equations
$$\left.\begin{array}{r} x-2y+3z=14 \\ 2x+y-z=-3 \\ 4x-2y+2z=14 \end{array}\right\}$$

is written as the augmented matrix
$$\left[\begin{array}{ccc|c} 1 & -2 & 3 & 14 \\ 2 & 1 & -1 & -3 \\ 4 & -2 & 2 & 14 \end{array}\right]$$

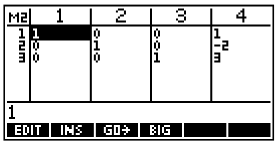
which is then stored as a 3x4 real matrix M1.



We now use the function RREF to change this to reduced row echelon form and store it as M2.

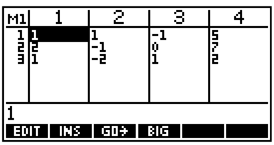


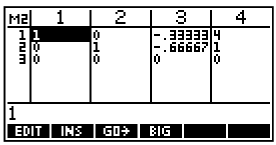
This gives the final result shown in the matrix M2 on the right, giving a solution of (1, -2, 3).



The big advantage of the RREF function is that it will still work with singular matrices. For example, the set of equations shown below left has an infinite number of solutions and the RREF result shows this by its final line of zeros.

$$\left.\begin{array}{r} x+y-z=5 \\ 2x-y=7 \\ x-2y+z=2 \end{array}\right\}$$





See also: INVERSE, DET.

SCHUR See Official Manual

SIZE See Official Manual

SPECNORM See Official Manual

SPECRAD See Official Manual

SVD See Official Manual

SVL See Official Manual

TRACE See Official Manual

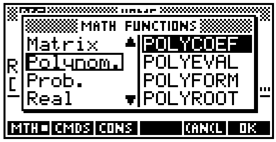
TRN(matrix)

This function returns the transpose of an n x m matrix.

For example, if $M1 = \begin{bmatrix} 2 & 3 \\ 1 & -2 \\ 0 & 4 \end{bmatrix}$ then TRN(M1) would return $\begin{bmatrix} 2 & 1 & 0 \\ 3 & -2 & 4 \end{bmatrix}$

An example of the use of this function is given on page 95 of the chapter "Using Matrices with the HP38G".

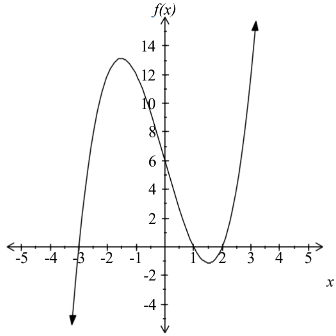
The 'Polynomial' group of functions



This group of functions is provided to manipulate polynomials.

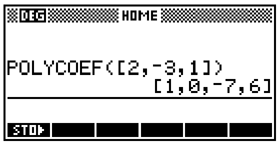
We will use the following function to illustrate some of the tools in the Polynomial group:

$$f(x) = (x-2)(x+3)(x-1) = x^3 - 7x + 6$$



<u>*POLYCOEF([root1,root2,...])*</u>

This function returns the coefficients of a polynomial with roots x_1, x_2 , x_3 ,... The roots must be supplied in vector form, which for the HP38G means putting them in square brackets.

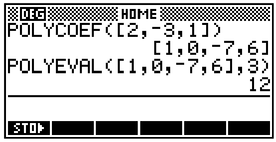


The function $f(x)$ above has roots 2, -3 and 1.
The screen shot right shows the function correctly giving the coefficients as 1, 0, -7 and 6 for a final polynomial of $f(x) = x^3 - 7x + 6$.

See also: POLYEVAL, POLYFORM, POLYROOT

POLYEVAL([coeff1,coeff2,...],value)

This function evaluates a polynomial with coefficients as specified at the point specified. Note that the coefficients must be in square brackets, followed by the value of x (not in brackets).



The function $f(x) = x^3 - 7x + 6$ has the value 12 at x = 3.

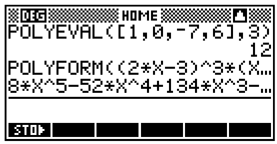
Note: If you are evaluating more than one point it is probably more efficient to enter the function into the **SYMB** view of the Function aplet. You can then either use the **NUM** view to find the function values required, or else simply type F1(3), F1(-2) etc. in the **HOME** view.

See also: POLYCOEF, POLYFORM, POLYROOT

POLYFORM(expression,var.name)

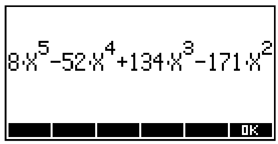
This is the most powerful of the polynomial functions. It allows algebraic manipulation and expansion of an expression into a polynomial. The expected parameters for the function are firstly the expression to be expanded, and secondly the variable which is to be the subject of the resulting polynomial. If the expression contains more than one variable then any others are treated as constants.

Eg. 1 Expand $(2x-3)^3(x-1)^2$

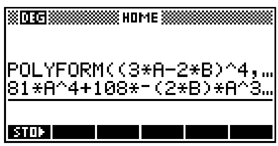


Result: $8x^5 - 52x^4 + 134x^3 - 171x^2 + 108x - 27$

The resulting polynomial is shown both as it appears in the **HOME** view and as it appears after pressing the '*Show*' button. Once it appears in the '*Show*' window, of course, it can be scrolled right and left to see the missing terms.



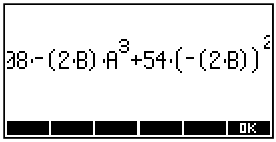
Eg. 2 Expand $(3a-2b)^4$



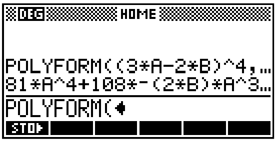
This function contains two variables, A and B, which must be expanded separately. The first expansion, treating A as the variable, is done using the expression POLYFORM((3A-2B)^4,A) (see right).

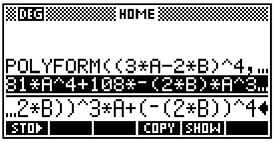
Continued over…

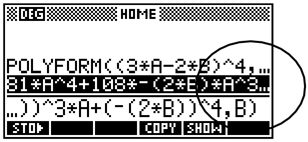
As you can see if you examine the view after pressing '*Show*', the expansion of the expression in terms of A has been done, but the terms involving B are not fully evaluated.



The solution to this is to use POLYFORM again. Use the **MATH** menu to fetch the POLYFORM function to the edit line, then move the cursor up to the partially evaluated expression that was the result of the previous POLYFORM. Copy it into the edit line and add a comma, a B and an end bracket. Pressing **ENTER** will now evaluate the terms involving B.

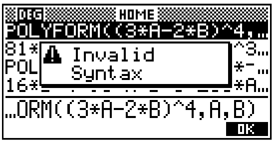






After pressing **ENTER** the for the second evaluation, the result is shown right (after pressing '*Show*').

Note: According to the official manual this double use of POLYFORM should not be necessary. The explanation of the POLYFORM function implies that the function can evaluate in more than one variable at one time, meaning that POLYFORM((3A-2B)^4,A,B) should produce the final result we saw in one step. In fact, all this produces is an error message (see left).



See also: POLYCOEF, POLYEVAL, POLYROOT

POLYROOT([coeff1,coeff2,…])

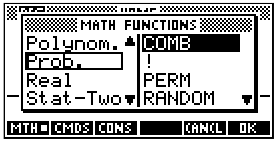
This function returns the roots of the polynomial whose coefficients are specified. The coefficients must be input as a vector in square brackets.

Eg. Using our earlier function of $f(x) = (x-2)(x+3)(x-1) = x^3 - 7x + 6$ we can enter the coefficients as [1,0,-7,6].

As you can see in the screen shot, the roots of 2, -3 and 1 have been correctly found.

See also: POLYCOEF, POLYEVAL, POLYFORM

The 'Probability' group of functions

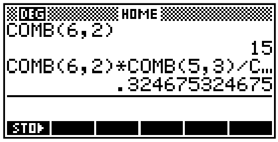


This group of functions is provided to manipulate and evaluate probabilities and probability distribution functions (p.d.f.'s).

<u>*COMB(n,r)*</u>

This function gives the value of ${}^nC_r$ using the formula ${}^nC_r = \dfrac{n!}{(n-r)!r!}$.

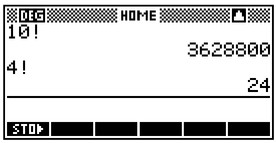
Eg. Find the probability of choosing 2 men and 3 women for a committee of 5 people
from a pool of 6 men and 5 women.



$$p = \frac{\binom{6}{2}\binom{5}{3}}{\binom{11}{5}} = 0.3247$$

Note: The reason for the single 'COMB(6,2)' above the main calculation is to save time. Rather than using the **MATH** menu for every entry of the COMB function, you can enter it once and then '*Copy*' it repeatedly, changing the parameters.

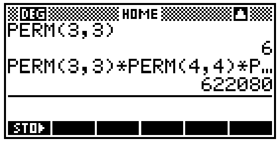
<u>*The ! function*</u>



The factorial function finds the number of possible permutations of a collection of objects.

Eg. Find the number of 'words' that can be formed from the letters FRED.
No. of words = 4! = 24

PERM(n,r)

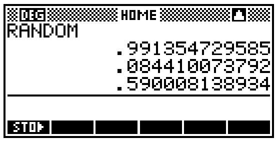


This function gives the value of ${}^{n}P_{r}$ using the formula ${}^{n}P_{r} = \dfrac{n!}{(n-r)!}$.

Eg. How many ways can 3 Maths, 4 English, and 6 German books be arranged on a shelf if all the books from a subject must be together?

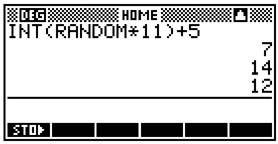
Ans: $\left({}^{3}P_{3}\times{}^{4}P_{4}\times{}^{6}P_{6}\right)\times 3!$

RANDOM



This function supplies a random 12 digit number between zero and one. If you want a series of random numbers, just keep pressing **ENTER** after the first one.

Eg. Produce a set of random integers between 5 and 15 inclusive.



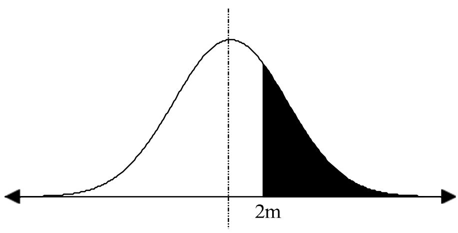
Use the expression INT(RANDOM*11)+5
The RANDOM*11 produces a range from 0 to 10.999999. This is then dropped down to the integer below, giving a range of integers 0,1,2,3,...,10. The final adding of 5 gives the correct range.

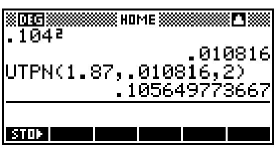
UTPN(mean,variance,value)

This function, the 'Upper-Tail Normal Probability', gives the probability that a normal random variable is greater than or equal to the value supplied. Note that the variance must be supplied, NOT the standard deviation.

Eg. 1. Find the probability that a randomly chosen individual is more than 2 metres tall if the population has a mean height of 1.87m and a standard deviation of 10.4cm

$$\bar{x} = 1.87m,\ \sigma = 0.104m$$
$$\Rightarrow \sigma^2 = 0.010816$$



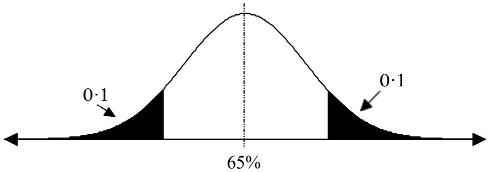


Ans: P(height>2m) = 0.1056

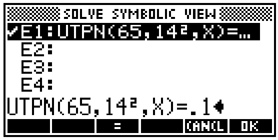
Eg. 2. The population of Year 12 Applicable Mathematics students had a mean exam score of 65% and a standard deviation of 14%. What two scores will cut off the top and bottom 10% of students?

i.e. Find x_0 such that

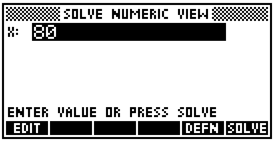
$$P(x > x_0) = 0{\cdot}1$$

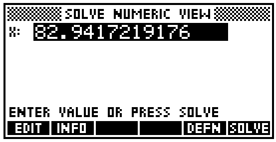


Using the Solve aplet (below right)
we can reverse the direction of the UTPN function.



Enter the expression to be solved for into the **SYMB** view (right), then switch to the numeric view. Enter a guess of 80% (without the % sign!) and then press the '*Solve*' button.





The second value could be found by using the symmetry properties of the Normal Distribution, but it is probably just as fast to go back to the **SYMB** view, change the 0.1 to 0.9 and then re-Solve. Remember that an '*Edit*' button is provided in the **SYMB** view to allow you to change the expression without having to retype it completely.

Final answer… 47.06% and 82.94% are the cut offs.

<u>UTPC(degrees,value)</u>

This is the Upper-Tailed Chi-Squared Probability function. It returns the probability that a χ^2 distribution with the supplied number of *degrees* of freedom is greater than the *value* supplied.

UTPF(numerator,denominator,value)

This is the Upper-Tailed Snedecor's F Probability function. It returns the probability that a Snedecor's F distribution with *numerator* degrees of freedom (and *denominator* degrees of freedom in the F distribution) is greater than the supplied *value*.

UTPT(degrees,value)

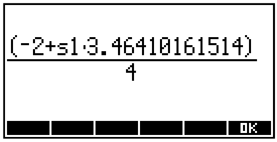
This is the Upper-Tailed Student's t Probability function. It returns the probability that a Student's t distribution with the supplied number of *degrees* of freedom is greater than the supplied *value*.

Some Further Worked Examples

The examples which follow are intended to illustrate the ways in which the calculator can be used to help solve some typical problems. In some cases more than one method is shown.

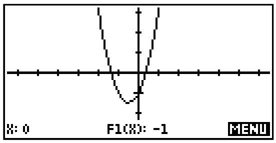
Eg. 1 Find the x intercepts of the quadratic equation $g(x) = 2x^2 + 2x - 1$

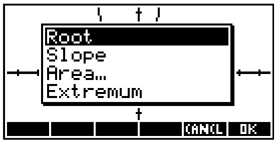
Method 1: Use the QUAD function in **HOME**.



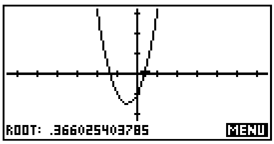
Result: Shown right, using the '*Show*' button in the bottom view. The advantage of doing it this way is that the answer is given in the same form that you would see it if you used the Quadratic formula. Just '*Copy*' the result, edit and square the decimal part to find the value of the discriminant. The 'S1' is the calculator's version of the ± sign. Just '*Copy*' the result and remove the S1 to obtain the positive solution, replacing the + with a - to obtain the other. This method is only of use if the question said "Show working" because it doesn't give the answer directly.

Method 2: Use the Function aplet.

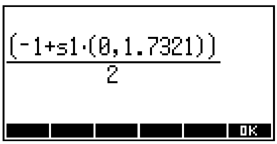




Result: Shown right. Enter the function into the **SYMB** view, use the **VIEWS** button and choose 'Decimal'. If the axes don't suit, then use the '*Zoom*' options. Now use the '*FCN*' option of '*Root*' to find the two roots. One result is shown.



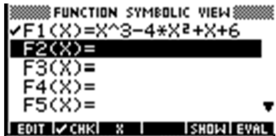
Eg. 2 Find the complex solutions to the complex equation $f(z) = z^2 + z + 1$



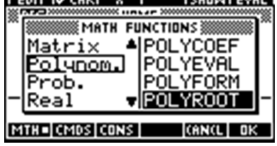
Result: This is best done with the QUAD formula mentioned in example 1, since it is capable of giving complex results. This is shown above, rounded to 4 dec. pts. It's up to you of course to realize that (0,1.7321) is $\sqrt{3}i$. The 'S1' means ±.

Eg. 3 For the function $f(x) = x^3 - 4x^2 + x + 6 \ldots$

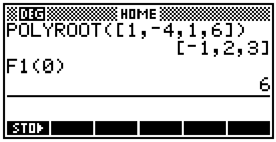
(i) find the intercepts.
(ii) find the turning points.
(iii) draw a sketch graph showing this information.
(iv) find the area under the curve between the two turning points.



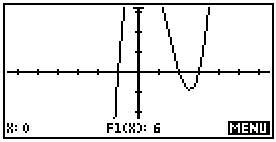
Step 1. Enter the function into the SYMB view of the Function aplet, so that it is available for use.

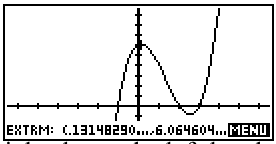


Step 2. Use the POLYROOT function to find the roots. This function is in the MATHS menu in the 'Polynom.' group.

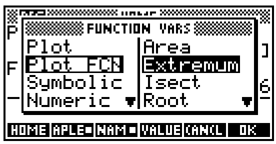


The results show that the x intercepts are $(-1,0),(2,0)$ and $(3,0)$. The y intercept is found by evaluating F1(0) in the HOME view giving the point (0,6).

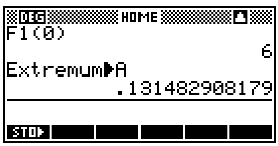




Step 3. Switching to the **PLOT** view via **VIEWS** - Decimal, you will find that the function does not display as well as it could. Since it is the y axis that is not displaying enough, we will use the 'Y-Zoom Out' option in the '*Zoom*' menu after first setting the Zoom factors to 2 rather than 4 (which is too drastic). Now use the 'FCN' pop-up menu to find the 'Extremum' (both left and right). The snapshot right shows the left-hand turning point of (0.131,6.065).



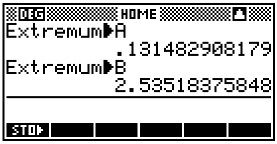
Step4. Because I know that part (iv) of the question requires me to re-use these extremum values in an integration (which I would like to be as accurate as possible), I am going to 'save' the extremum value just found. I change into **HOME** and store it as shown in memory A. Rather than typing the word Extremum, you can retrieve it from the **VAR** menu. Hit **VAR**, then '*Aplet*' at the bottom of the screen.

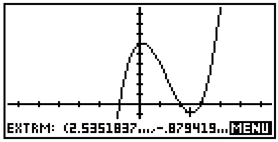


Move to the 'Plot FCN' menu and choose 'Extremum' from the list.

Note: You MUST store the first before finding the second extremum, if you want to use this trick. The Extremum variable always stores the last one found. If you want the y coordinate, just evaluate F1(Extremum).

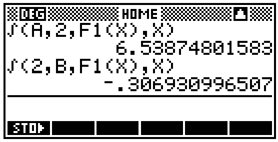
Now use the FCN - Extremum tool again to find and store the x coordinate of the second turning point into memory B. Remember that you can use the '*Copy*' key in **HOME** and just change A to B.

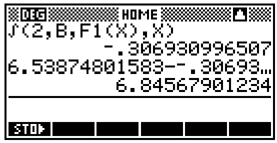




Step 5. The **PLOT** view shows that part of the area we require for part (iv) is negative, so we need to know the x intercept between the two turning points. Fortunately we know from Step 2 that it is the point (2,0). If we did not know this already, then we could use the '*FCN'* menu again, retrieving this time from the **VAR** menu the variable called 'Root' and perhaps storing that into memory C.

We will evaluate the integral in the **HOME** view where you can use the accurate values you stored in Step 4. It needs to be done in two parts and added (well - subtracted actually to reverse the sign of the negative part). This is shown right, with the '*Copy*' key having been used to add the values.



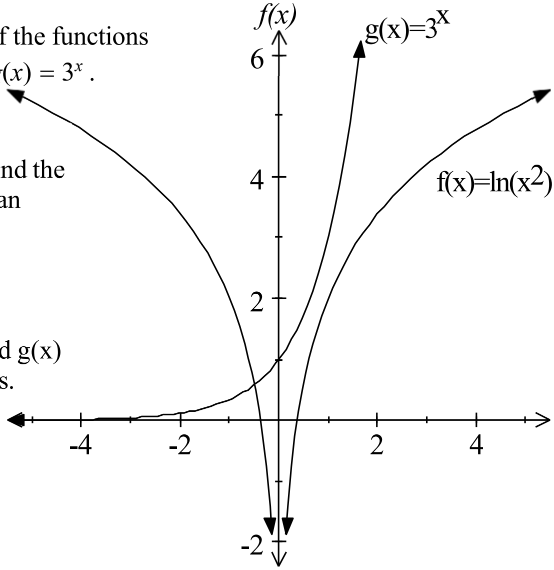


Eg. 4 Shown below is a graph of the functions $f(x) = \ln(x^2) + 2$ and $g(x) = 3^x$.

(i) Showing all working, use the Newton-Raphson method to find the positive x intercept of f(x) to an accuracy of 4 dec. places.

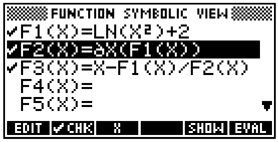
(ii) Showing all working, use the Bisection method to find the point of intersection of f(x) and g(x) to an accuracy of 2 dec. places.

(see next page for solution)



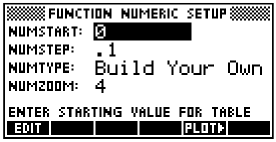
(i) We will use an initial estimate for the positive root of $x_0 = 0{\cdot}5$.

Step 1. Set up the **SYMB** view to match the one shown right. The first entry of F1(X) is the function, the second F2(X) is the derivative of F1(X). The third entry of F3(X) is the Newton- Raphson iteration to produce the next estimate for the root.

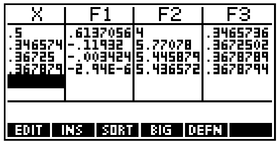


Note: You can use the '*Eval*' key on F2(X) if you want to, but it is not necessary.

Step 2. Switch to the **NUM**eric **SETUP** view and change the 'NumType:' to Build Your Own.

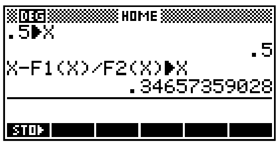


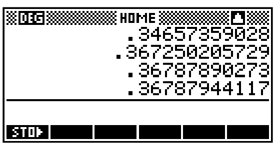
Step 3. Change to the **NUM** view and enter the initial estimate of x = 0.5 Read off the next estimate from the F3 column and enter it into the X column as the next estimate. Continue this process until the required degree of accuracy is attained. This occurs in the screen shot when the next value in F3 matches (to 4 d.p.) the one fed in to get it.



Step 4. Record your results in a written table in order to satisfy the requirement to "show all working".

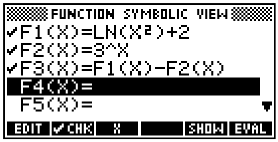
Note: If there is no requirement to show working, then the same result can be obtained more quickly in the **HOME** view once the functions F1(X) and F2(X) have been set up in the **SYMB** view. Just use 0.5➢X to store the initial estimate into memory X. Then use the expression X - F1(X)/F2(X)➢X to calculate the next estimate and to immediately store it into X, replacing the initial estimate. To continue calculating estimates now, simply press **ENTER** repeatedly.



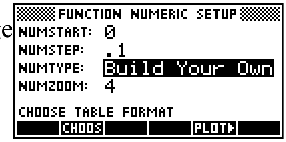


(ii) Inspection of the graph puts the intersection in the interval between x = -0.4 and x = -0.7

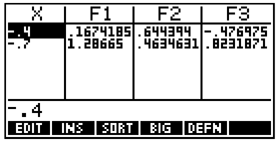
Step 1. Using the Function aplet, set up the functions shown right in the **SYMB** view.



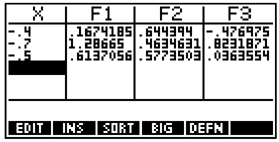
Step 2. Switch into the **NUM**eric **SETUP** view and change the 'NumType:' to Build Your Own.



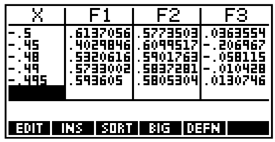
Step 3. Change into the NUM view and enter the initial boundary values of -0.4 and -0.7 Clearly there is an intersection within this interval, since $f(x) - g(x)$ is positive on one side and negative on the other.



Step 4. The mid-point is -0.55, but the values of F3(X) seem to show that the intersection is closer to -0.4. Hence use x = -0.5 as the next point. The intersection is now trapped between -0.5 and -0.4



Step 5. The next point to check will be -0.45. Continuing this process, we can eventually find the point of intersection to the required degree of accuracy. The view on the right shows that the intersection is trapped in the interval between x=-0.50 and x=-0.495 and this means that it will round off to x=-0.50 (2 d.p.). Since the question said to show all working, you would need to record the values shown in the **NUM** view in a table of your own.

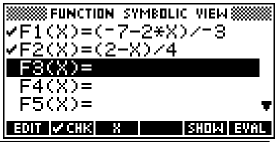


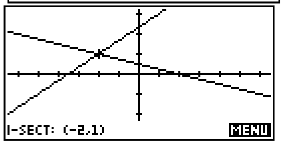
Eg. 5 Solve the simultaneous equations below.

$$\left.\begin{aligned} 2x - 3y &= -7 \\ x + 4y &= 2 \end{aligned}\right\}$$

First method - graphical

Re-arrange the functions into the form y = …… and store them into F1(X) and F2(X) in the **SYMB** view of the Function aplet. Switch to the **PLOT** view and use the '*FCN*' - Intersection tool to find the point of intersection.



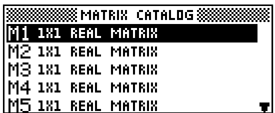


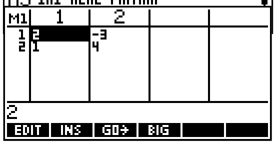
Second method - using a matrix

Step 1. Rewrite $\begin{aligned} 2x - 3y &= -7 \\ x + 4y &= 2 \end{aligned}$ as $\begin{bmatrix} 2 & -3 \\ 1 & 4 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} -7 \\ 2 \end{bmatrix}$

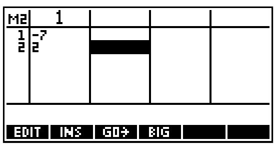
This means that $\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} 2 & -3 \\ 1 & 4 \end{bmatrix}^{-1} \times \begin{bmatrix} -7 \\ 2 \end{bmatrix}$

Step 2. Switch into the Matrix Catalogue (**BLUE MATRIX**). Position the highlight on M1 and press '*New*' and choose a new Real matrix. Enter the matrix shown right.





Press **BLUE MATRIX** to change back to the catalogue and create M2 as shown below right.



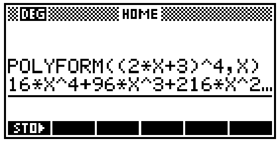
Step 3. Change into the **HOME** view and enter the calculation M1^-1*M2. The result is the (x,y) coordinate of the solution.

Eg. 6 Expand the expressions below.

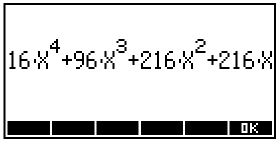
(i) $(2x+3)^4$

(ii) $(3a-2b)^5$

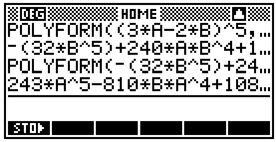
(i) Use POLYFORM((2X+3)^4,X) to expand the polynomial. Use the '*Show*' key to examine the result.

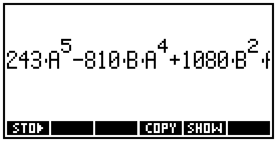


Result: $16x^4 + 96x^3 + 216x^2 + 216x + 81$



(ii) Use POLYFORM((3A-2B)^5,B) to expand the polynomial as a function of B. Then use the polynomial function again, '*Copy*' ing the result from the first expansion and expanding this time as a function of A. The '*Show*' key can then be used to view it, using the left and right arrows to scroll the screen left and right.





Result: $243a^5 - 810a^4b + 1080a^3b^2 - 720a^2b^3 + 240ab^4 - 32b^5$

Eg. 7 A particle P is moving in a straight line so that its velocity *v* (in metres/sec) at any time *t* (in seconds, $t>0$) is given by the equation below.

$$v = 3t^2 - 4t + 1$$

(i) Find the time(s) when the velocity is zero.

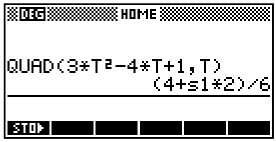
(ii) Find the velocity at the time when the acceleration is zero.

(iii) If the particle P passes through the origin O at time t = 2, then find an equation for the displacement *d* (in metres) from the origin.

(iv) Find the distance travelled by the particle in the first two seconds.

Note: *Some of the work following could be done much more easily on paper, but the point is to show how the calculator can be used, so that you can solve harder ones that way.*

(i) Find the time when the velocity is zero.

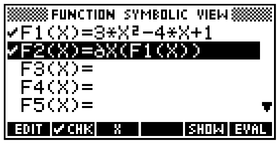


Step 1. Solve the quadratic by any method. I will use the QUAD function in this case. The answer needs to be split into two, giving

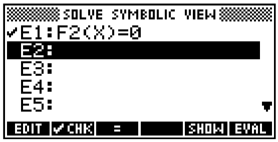
$(4 + 2) / 6 = 1$ and $(4 - 2) / 6 = \frac{1}{3}$.

Result: P is stationary at t = 1 and t = $\frac{1}{3}$.

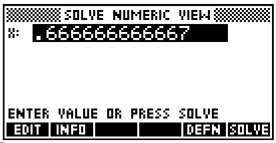
(ii) Find *v* when accel. is zero.



Step 1. Acceleration is $\frac{dv}{dt}$, so I will use the Function aplet to differentiate. The Function aplet works with X, not with T, so use $F1(X)=3X^2\text{-}4X+1$.
Pressing '*Eval*' gives $a = 6t - 4$ for F2(X).

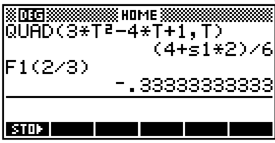


Step 2. Switch to the Solve aplet and enter the equation F2(X) = 0 into the **SYMB** view. Switch to the **NUM** view and press '*Solve*', giving an answer of t=0.66666667 or 2/3.



Step 3. Now calculate the velocity for that *t* using F1(X) in the HOME view.

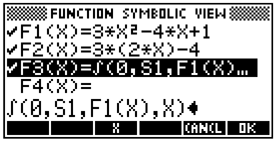
Result: $v = \frac{-1}{3}$.

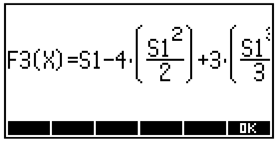


(iii) Find an equation for *d*, given that *d=0* when *t=2*.

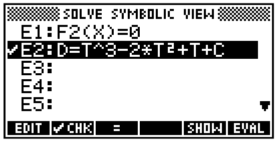
Step 1. Change back into the Function aplet and integrate F1(X) using the system variable S1 to ensure that the integration is done algebraically. Pressing the '*Eval*' button gives the result partially visible below right, which needs to be simplified down to the equation:

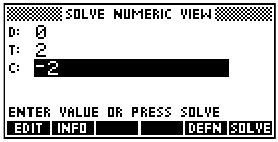
$$d = t^3 - 2t^2 + t + c$$





Step 2. Switch back to the Solve aplet and enter this formula in to the **SYMB** view. Change to the **NUM** view and solve for C, first setting T to 2 and D to 0. This gives a final equation of:



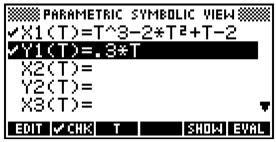


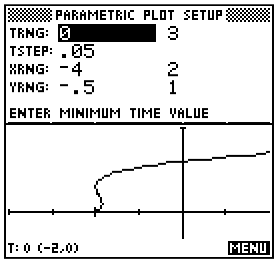
Result: $d = t^3 - 2t^2 + t - 2$

(iv) Find the distance travelled in the first 2 seconds.

Step 1. Use the Parametric aplet to view the motion of the particle to see whether it doubles back during the first two seconds. Enter the motion equation as X(T) and enter Y(T)=0.3T. This second equation moves the particle up the y axis as it traces out its path, thereby making it easier to view.

I'm interested in the first 2 seconds only, so I'll also restrict TRng: to 0 to 3. The final plot makes it plain that it doubles back *twice* in the first two seconds.



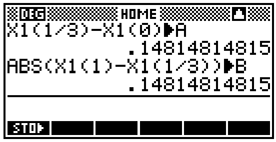


Step 2. The '*FCN*' tools to find extremum are not available in the Parametric aplet, so we'll have to use our brain and remember that the turning point is when the derivative (the velocity) is zero, and that we found the velocity to be zero in part (i) at t = 1 and t = $\frac{1}{3}$. Alternatively, you could transfer the equation to the Function aplet as F4(X)=X^3-2X²+X-2 and use the '*FCN*' tools there.

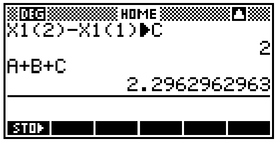
Either way, the distance travelled is given by:

$$\text{dist.} = \left(d(1/3) - d(0)\right) + \left|\left(d(1) - d(1/3)\right)\right| + \left(d(2) - d(1)\right)$$

This can be evaluated in the **HOME** view. See right, where I have evaluated each expression separately, storing them into memories A, B and C. The final answer is then A+B+C.



Result: Distance = 2.296 metres.



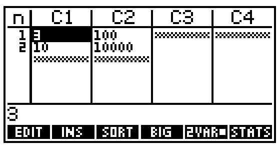
Eg. 8 A population of bacteria is known to follow a growth pattern governed by the equation $N = N_0 e^{kt} \quad ; t \geq 0$. It is observed that at t = 3 hours, there are 100 colonies of bacteria and that at t = 10 hours there are 10 000 colonies.

(i) Find the values of N_0 and of *k*.

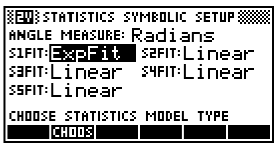
(ii) Predict the number of bacteria colonies after 15 hours.

(iii) How long does it take for the number of colonies to double?

(i) Find N_0 and *k*.

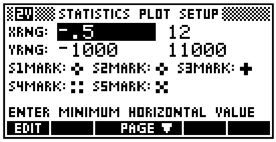


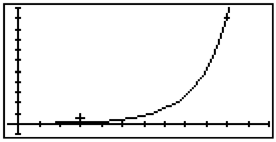
Step 1. Start up the Statistics aplet, set it to '*2VAR*' and enter the data given. Change to the SYMB SETUP view and specify an Exponential line of best fit for the data.



Step 2. Change to the **PLOT SETUP** view and adjust it so that it will display the data. (This is not really needed, since the line of best fit is what we need and it will be calculated even if the data doesn't show.) YTick is set to 1000 incidentally.

Now change to the **PLOT** view and press '*FIT*' (if not already set). Wait while the line draws.



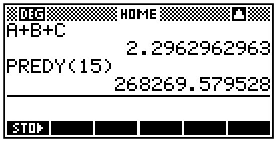


Step 3. Change to the SYMB view, move the highlight to the equation of the regression line and press '*Show*'. Rounded to 4 dec. places, this gives an equation of:

$$N = 13{\cdot}8950e^{0{\cdot}6579t}$$

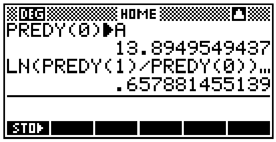
(ii) Predict N for t = 15 hours.

Step 1. Change to the **HOME** view and use the PREDY function.



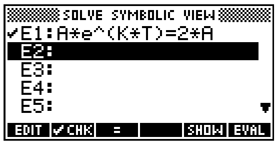
Result: 268 269 colonies.

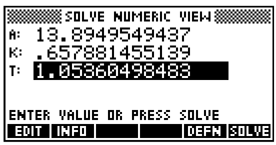
(iii) Find t so that $N = \frac{1}{2}N_0$.



Step 1. Store N_0 into memory A and k into K, so that I don't have to re-type them. (Re-type them if you're not sure of the algebra I've used.)

Step 2. Switch to the Solve aplet and enter the equation to be solved. Changing into the **NUM** view, you should find the values of A and K already defined, so move the highlight to T and press '*Solve*'.





Result: Doubling time is 1.0536 hours.

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