



In this issue

- Reviews of the latest TI Software Apps including:
 - ◆ Cellsheet™
 - ◆ Probability Simulator
 - ◆ Datalogging
 - ◆ Inequality Graphing
- Using the TI-83 Plus as a sundial!

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GENERAL INFORMATION: If you have general questions about using a product, to order products, or before returning a product for service:

CSC – Customer Service Centre

e-mail: ti-cares@ti.com

Phone: 020 8230 3184

Fax: 020 8230 3132

Write to: Texas Instruments CSC • Sitel Central Europe
Woluwelaan 158 • 1831 Diegem • Belgium

EDUCATIONAL INFORMATION: For information on integrating hand-held technology and workshop ideas contact:

Melanie Horsburgh, Educational Marketing Manager

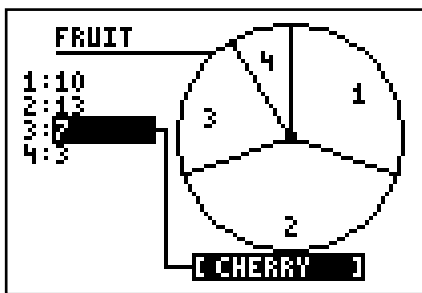
e-mail: mhorsburgh@ti.com

Write to: Texas Instruments • 800 Pavilion Drive • Northampton • NN4 7YL

CellSheet™ The spreadsheet!!

The accessibility of hand-held computing technology in the form of a graphical calculator has raised students' achievements in mathematics. Now you can take this one step further and add spreadsheet technology to your calculator. CellSheet is a fully functioning spreadsheet for the TI-83 Plus, TI-89 and TI-92 Plus.

The importance of spreadsheet technology is recognised in the National Curriculum. For instance in *Handling Data at Key Stage 3* teachers are expected to offer pupils the opportunity to engage in "... tasks focused on using appropriate ICT [for example, spreadsheets, ...], using calculators correctly and efficiently, ...". At *Key Stage 4 (Higher) in Number and Algebra* pupils should be taught to "... plot graphs of (functions) ... using a spreadsheet ...; recognise the characteristic shapes of ... functions ...", and "... use relevant statistical functions on a calculator or spreadsheet." The *National Strategy in Mathematics for Key Stage 3* has the following as a key objective for year 8 "Construct, ... using ICT: pie charts for categorical data; bar charts and frequency diagrams for discrete and continuous data; simple line graphs for time series; simple scatter graphs ..."

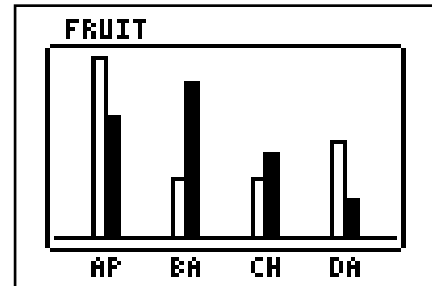


Students can now concurrently appreciate the functionality of their calculator and appropriately engage in use of spreadsheets. Teachers will appreciate not having to face the organisational disadvantages of being compelled to use the ICT suite to engage in a mathematical activity involving spreadsheets.

With CellSheet in your calculator, press the **APPS** key and select the CellSheet option. You will be into an environment which is familiar from a computer. Numbered rows and lettered columns are standard in CellSheet.

QUA	A	B	C
1	APPLE	15	10
2	BANANA	5	13
3	CHERRY	5	7
4	DANSON	8	3
5			
6			
B3: 5			[Menu]

Note that you can display qualitative data on your calculator and in a choice of appropriate forms:



Pie or Bar charts have been available only on the TI-73. Use text characters to describe each category (here the student collected data on types of fruit that different groups enjoyed eating.) The usual **TRACE** facility is available to enable the graph to be explored and allow pupils the opportunity to interrogate the display.

In addition to entering qualitative and quantitative data in cells, CellSheet enables you to create formulae – making full use of the functionality of the calculator. The processes of cutting, copying, pasting, using absolute and relative references into specified ranges are fully supported. All the available special features associated with CellSheet are readily available using the "soft keys", these are the five keys on the top row of the calculator. **[GRAPH]** (also known as F5) is the main MENU – it pops into view when it is available.

S01	A	B	C
1			
2			
3			
4			
5			
6			
A1:			[Menu]

Optimisation is a valuable mathematical task for students to explore and a spreadsheet is a useful vehicle to facilitate this. One such task is "Determine the shape of a right-angled triangle with hypotenuse of length 13 such that the area of the triangle is a maximum." The sheet below has the beginnings of the problem set up in which column A contains the length of one of the two other sides, and column B contains the appropriate formulation using Pythagoras theorem for the remaining side.

S01	A	B	C
1	X	SIDE	AREA
2		1	
3			
4			
5			
6			
B2: =√(13²-(A2)²)			

CellSheet™ The spreadsheet!!

continued

The sheet is completed with a simple formula for the area of a right-angled triangle inserted into cell C2. All formulae can be copied and pasted as appropriate. Any CellSheet can be saved with a descriptive name e.g. MAXTRL1 and the first few characters of the name will appear in the top left on screen. There is no need to subsequently save the sheet, all changes are automatically saved under the same named CellSheet in the RAM part of the calculator's memory.

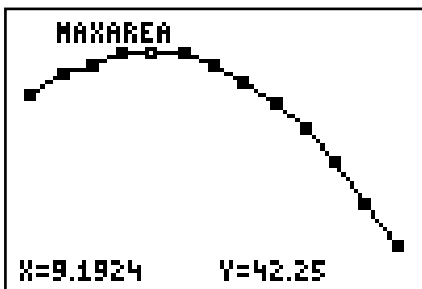
MAX	A	B	C
1	X	SIDE	AREA
2	1	12.961	6.4807
3	2	12.845	12.845
4	3	12.649	18.974
5	4	12.369	24.739
6	5	12	30
C2: =A2*B2/2			[Menu]

A full formulation of the problem being explored might produce something like the above. Explore the problem numerically using the cursor to navigate the spreadsheet entries. Or, explore it graphically – all within CellSheet. The graphing (chart) options are available from 'Menu'.

```

LINE CHART
XRange:A2:A14
YRange1:C2:C14
YRange2:
YRange3:
Title:MAXAREA
AxesOn AxesOff
DrawFit Draw
    
```

Change the entry in cell A2 and the incremental formula in the rest of column A to engage in a decimal search. This yields the following graph where the maximum area is shown to be 42.25 and the length of one side of the triangle is 9.1924.



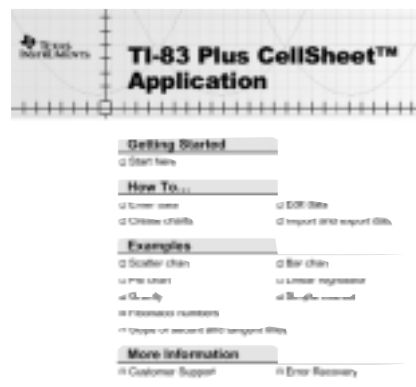
The formula bar in the spreadsheet can be switched to show values rather than formulae. Then the numerical approach reveals a multi-decimal version of the value. Clearly, this helps the student's interpretation of the display. The maximum area is clearly visible along with the associated lengths of the triangle. Students will identify that it is an isosceles triangle.

MAX	A	B	C
2	9.192	9.1928	42.25
3	9.1921	9.1927	42.25
4	9.1922	9.1926	42.25
5	9.1923	9.1925	42.25
6	9.1924	9.1924	42.25
7	9.1925	9.1923	42.25
C6: 42.249999999986			[Menu]

This article merely scratches the surface of its power and potential, it merely wets your appetite to delve deeper into spreadsheets on a calculator, in particular, the Texas Instrument's CellSheet. You can discover more by visiting the TI web site – for the TI-83 Plus calculator visit the following:
<http://education.ti.com/product/tech/83p/APPS/cellsheet.html>



This will not only tell you about the CellSheet App but also give you the opportunity; for a modest outlay, to download it to your TI-83 Plus. To download you need to click APP, then CellSheet and enter the "shop" to obtain the APP. Return and a click later and you can download the electronic guidebook.

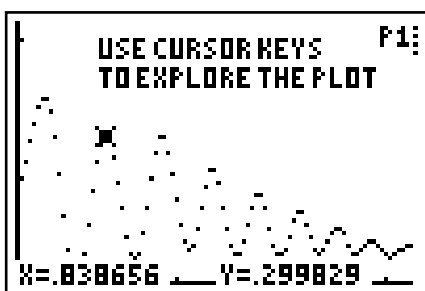


Datalogging Software

A variety of software can be used with the calculator based datalogging system and this brief guide offers a tour of the applications and programs available. The software is considered under the two headings of **Hand-held**, where the calculator and datalogger (CBL 2™ or CBR™ Ranger) are self contained in terms of data capture and analysis, and **PC** based where data is uploaded from the calculator or datalogger to a spreadsheet or specialist package such as TI InterActive!™. Hand-held software may be transferred from calculator to calculator or may be downloaded from various web sites in which case TI-GRAPH LINK™ software is required.

1. HAND-HELD

- Comes as applications (APPS), program groups or programs either in the form of suites, for example, **CBL™/CBR**, **DataMate™**, **CHEMBIO** and **PHYSICS** or in the form of 'single-use' software such as **DaRotary**, used to collect data with rotary motion sensors. This software is available for a variety of calculators including TI-73, TI-82, TI-83, TI-83 plus, TI-89 and TI-92. In addition, a large number of bespoke offerings are available including Roger Fentem's excellent **Bounce** program which is used with a Ranger and does not require a CBL 2.



- The **CBL/CBR** application suite comes loaded on a TI-83 Plus and is very handy for use with a Ranger as no CBL 2 is required. It also provides a useful gauge feature. Like all applications, CBL/CBR is stored in the Flash ROM area of the calculator, and if removed from the calculator can be downloaded FREE from the TI-Education site.

```

PROBE: [ ] Light
      [ ] Volt Sonic
TYPE: Bar Meter
MIN: -10
MAX: 10
UNITS: Volt
DIRECTNS: [ ] Off
GO...
    
```

- The **DataMate** suite, which comes already loaded onto a CBL 2, runs as an application on the TI-83 Plus and as a group of programs on all other calculators. The CBL 2 detects the appropriate calculator so, when the calculator is put into receive mode and the **TRANSFER** button on the datalogger is pressed, the correct version is transferred.

A faster version of DataMate for the TI-83 Plus will be available in the Autumn. The CBL 2 also has Flash upgrade capability, and the current version of the operating system (1.03) including DataMate 1.11 is available from the TI site.

```

CH 1: TEMP(C)    30.2
CH 2: TEMP(C)    23.8
CH 3: TEMP(C)    19.7

=====
MODE: TIME GRAPH-100
=====
1:SETUP      4:ANALYZE
2:START      5:TOOLS
3:GRAPH      6:QUIT
    
```

The three sensors supplied with the CBL 2 (temperature, light and voltage) are 'recognised' automatically by DataMate when plugged into the datalogger; other sensors are also 'auto-ID' or can be selected from the sensor menu. (The DataMate version for TI-82, however, supports only a limited number of sensors.) The *Quick Set Up* feature on the CBL 2 can be used to collect data without a calculator being attached; up to four auto-ID sensors can be used at the same time, the Start/Stop button being used to control the sampling period. At the end of sampling, the CBL 2 is attached to the calculator, the DataMate application started and the **Retrieve Data** option chosen from the **Tools** menu.

- The DataMate versions for TI-83 Plus, TI-89 and TI-92, but not those for TI-73, TI-82 and TI-83, allow experimental set ups and data to be stored in the 600 K Flash memory of the CBL 2. In addition, the **DataDir** program, available FREE from the Vernier site for all calculators except the TI-82, allows programs and, if appropriate, applications also to be stored. These 'hard drive' features of the CBL 2 clearly serve to enhance the 'stand alone' capability of the technology.
- The **CHEMBIO** and **PHYSICS** suites, available FREE from the Vernier site as applications or program groups, are still widely used for datalogging, supporting all of the Vernier sensors. The sequence of tasks is possibly more 'linear' than DataMate, the user being taken through screen by screen:

```

***MAIN MENU***
1:SET UP PROBES
2:COLLECT DATA
3:VIEW GRAPH
4:VIEW DATA
5:FIT CURVE
6:RETRIEVE DATA
7:QUIT
    
```

```

SELECT PROBS
1: TEMPERATURE
2: PH
3: PRESSURE
4: COLORIMETER
5: VOLTAGE
6: CONDUCTIVITY
7: MORE PROBES
  
```

```

***MAIN MENU***
1: SET UP PROBES
2: COLLECT DATA
3: VIEW GRAPH
4: VIEW DATA
5: FIT CURVE
6: RETRIEVE DATA
7: QUIT
  
```

```

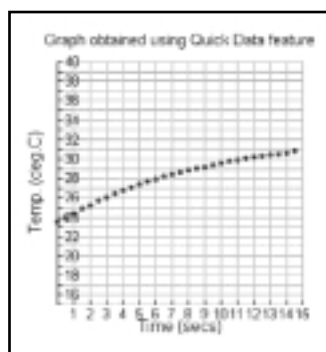
DATA COLLECTION
1: MONITOR INPUT
2: TIME GRAPH
3: TRIGGER/PROMPT
4: TRIGGER
5: SINGLE POINT
6: RETURN
  
```

This selection of screen shots shows how the user is guided through **SET UP PROBES** to **TIME GRAPH** data collection. These suites are not loaded onto the CBL 2™ and do not support auto-ID sensors, so committed users may be waiting for the appearance of the faster version of DataMate in the Autumn.

2. PC BASED

- Using TI-GRAPH LINK™ software, available FREE from the TI web site or from TI resource disks (supplied with calculators and dataloggers), applications, programs, data lists and so on can be exchanged between calculator and PC (or MAC®). Calculator screen shots, like the ones used in this article, can be uploaded, and lists can be saved on the PC in calculator format or converted to text files to be used in spreadsheets. The connecting cable needed for TI-GRAPH LINK is now being supplied with calculators. **TI-Connect™**, a successor to TI-GRAPH LINK, will be available by the end of 2001; this will be a powerful piece of FREE software designed to manage all aspects of calculator/computer connectivity. Preview details can be found on the TI web site.

- Data from calculators (but not the TI-73 or TI-82) can also be transferred to a PC using **TI Interactive!™**, a purchased software package, where it can be analysed using the list editor, spreadsheet, grapher and other tools, and the data and graphs incorporated into very smart looking reports. Screen shots can also easily be incorporated into these reports using the 'one click' icon.



In addition, TI InterActive! has a *Quick Data* feature, supporting a variety of sensors, which allows **direct connection** with a CBL 2 or Ranger for data capture and the display of real time graphs.

Useful Web Sites

TI Education

<http://education.ti.com/uk>
<http://education.ti.com/product/prselect.html>



Vernier

<http://www.vernier.com>



Oxford Educational

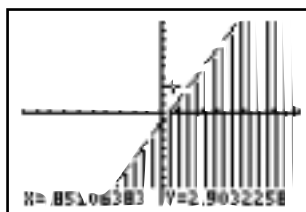
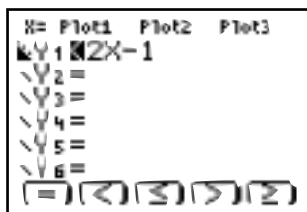
For purchase of calculators, dataloggers, sensors and TI InterActive!
<http://www.oxford-educational.co.uk>



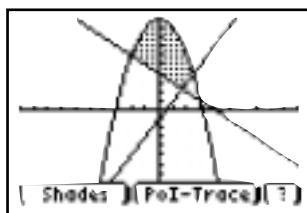
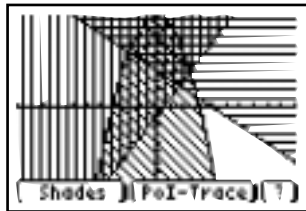
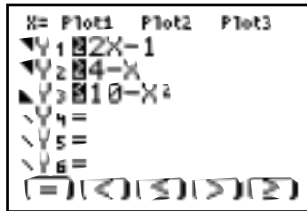
Inequality Apps – A Review

Having downloaded this App, I spent a frustrating half-hour trying to make it work successfully, before swallowing my male pride and reading the instruction manual. Unlike most Apps and programs, **Inequality Graphing** can be left running in the background, whilst other calculations are performed.

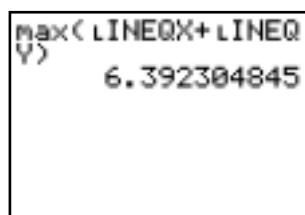
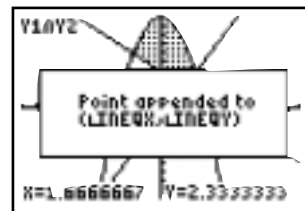
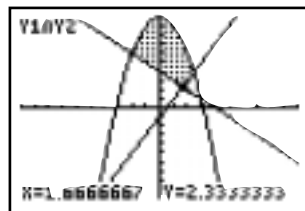
At a basic level, the App makes it easy to represent most explicit inequalities. Inequalities are input by entering the "y=" menu and, using one of the inequality signs on the function keys, changing the " = " sign to the appropriate inequality. When the graph is plotted the appropriate area is shaded in.



It is possible to enter several inequalities and to view the area of intersection by changing the shades option once the graph is drawn. However there is no option to shade the "unwanted region, which is unfortunate for those of us who prefer to use (or teach) this.

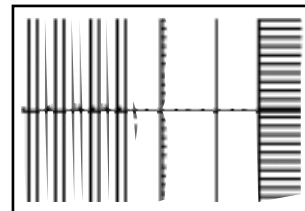
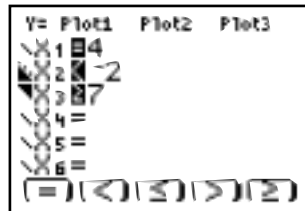


With more than one equation or inequality plotted, the App can also calculate all the points of interest (intersection) shown on the screen. These can be then added to a list for further calculation such as maximum or minimum values.



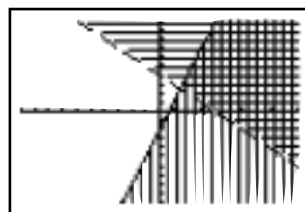
The maximum value of $x + y$ for intersection points

One of the useful additional features that the App has is the "x=" editor which allows both equations and inequalities of the form "x=K" to be entered. K has to be a constant, and any variables entered here (such as y) are evaluated to produce a vertical line.

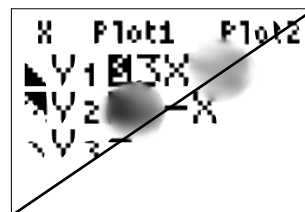


In terms of teaching, the App could be used to check inequalities drawn by hand in class or to set up challenges to reproduce given screens (possibly with some hints where necessary).

Can you produce this screen using inequalities?



Here is a hint!

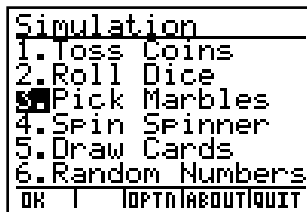


The App does not provide any teaching activities directly, but is a useful addition the graphing capabilities of the TI-83 Plus.



Probability Simulator for the TI-83 Plus

Having written the article "Rolling a die an awful lot of times!" in TI-Time for Summer 2001, I was interested to look at the **Probability Simulator** Apps for the TI-83 Plus, downloadable to Flash ROM via the computer. The program can be selected through the **APPS** button, and when loaded gives the following menu:



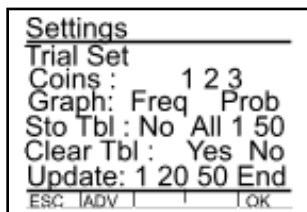
Before working through these simulations I felt it important to consider WHY I would want to use them. In my case as a Key stage 3 and 4 teacher I would want them to generate data to compare with a consideration of the theoretical outcome, usually based on

equiprobability. I would also like to have available a method for considering an unfair trial. Of course the major factor is 'in the long run'. There must be a way of generating a large amount of data in a reasonable time and being able to analyse it easily.

My comments on the simulations will bear these factors in mind. On the menu above **OPTN** allows you to set a Random Seed value.

Toss Coins:

On entry the default screen for one coin is set with a histogram.



SET allows you to:

- Set the number of coins – 1, 2 or 3;
- Decide whether the graph shows frequencies or probability;
- Chose how the graph is updated – 1 is good for showing the fluctuations.

ADV allows you to change the 'fairness' of the coin. Note that for 2 or 3 coins the bias will be the same for each. Press **OK** to get back to the histogram.

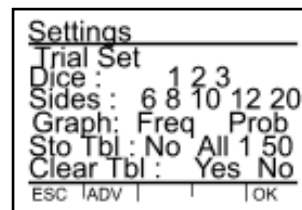
Press **TOSS** to start the simulation with one throw. The base line then changes to allow 1 throw, 10 throw or 50 throws. Whilst you can repeat the process endlessly, I should like to see these changed. There is no point in a simulation of 1 or 10 throws – you could do this with a real coin! I should like to see much larger numbers, or the facility to enter your own number (as in my program in the last magazine). Much larger numbers enable you to discuss 'in the long run' and enable you to suggest a sample size which makes calculations of the theoretical frequencies simple. For example with one die a sample size of a multiple of 6, for two dice a multiple of 36 and so on.

When you have the sample size that you want, you can get either the frequencies or probabilities (according to what you have set) by using the **left** and **right** arrows. It took me some time to find this facility as the *Probability Users' Manual* was not then available from the web site at first, and there is no indication within the program itself of how to access this.

Although there is a facility to save the data I did not find this useful as it simply itemises each throw.

For coins the data is easy to get from the screen using the arrows on the histogram, since there are only at most 4 columns for 3 coins. With the dice simulation it is much more tedious – throwing three six-faced dice would produce columns from 3 to 18 (i.e. total score) which cannot be displayed on the screen at the same time. 3 twenty faced dice would be out of the question on a split screen! Therefore I should like to see a facility to obtain the cumulated data on the screen without the graph.

Roll Dice:



SET enables you to:

- Select 1, 2 or 3 dice, with the total score being calculated;
- Select the number of sides for the die.

What happened to the tetrahedron (4 sides)? This would be more useful than 10, 12 and 20. All the important statistical concepts could be obtained from 4 and 6, particularly at the age when this appears in the latest key stage 3 document.

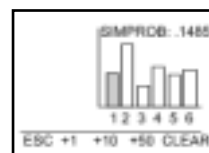
Side	Wght	Prob
1	1	.1667
2	1	.1667
3	1	.1667
4	1	.1667
5	1	.1667
6	1	.1667

ESC | | | | | OK

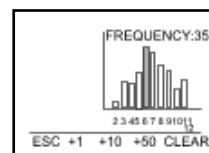
Again **ADV** allows you to vary the weighting and hence the fairness of the die. By changing the Wght figure the program recalculates the probabilities.

How would we use this in the classroom? Since it is transparent – easy to change – it might be best to work in pairs, with one pupil setting a calculator up and then the other using it and from the (large) sample obtained hypothesising about the nature of the bias. The first pupil could be briefed to make a fairly large bias and could also be briefed not to allow the second person to use the **ADV** key to get the answer before obtaining the sample!

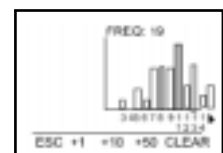
Final frequencies/probabilities can be obtained by using the **left** and **right** arrows on the graph: each of the following having a sample size of 201.



One die screen



Two dice screen



Three dice screen
(all 6-faced die)

As can be seen the 3 dice screen cannot display all the columns at one go. (these are 6 faced dice, imagine the problem with 3 twenty faced dice!) My suggestion here is to stick to the 4 and 6 faced dice, since these will give us all we need whilst enabling pupils to work out the theoretical probabilities easily.

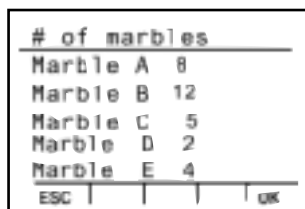
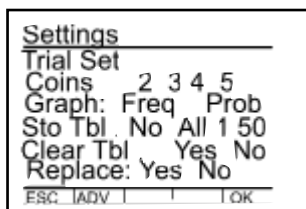
.....continued

Probability Simulator for the TI-83 Plus

continued

Pick Marbles:

This program enables us to pick up to 5 types of marbles (colours etc.) with similar variations to the first two programs. By using **ADV** we can set the number of each type of marble with the important addition of being able to chose 'with or without replacement'.



In the example above, with replacement, the number of each marble set is reflected in the sample of 51. If without replacement the total number of throws in this case would be 31 since we start with 31 marbles. The message **NO MORE**

MARBLES is given. In the case of Marbles the itemised list would be useful with "No replacement" to discuss such questions as which type of marble you would expect to be used up first, and why.

Spin Spinner:

Enables us to set the number of sections and their weighting. The process is similar to the first two and so I will not go through it again.

Draw Cards:

Can only draw one card at a time and I could not justify its use in our curriculum.

Random Numbers:

You can set the range of the numbers, 1 to 6 numbers within the range 0-99, and dictate if repeat numbers are allowed or not. No doubt pupils (and teachers) would be interested in its ability to generate lines for the National Lottery. There does not seem to be a facility of summing up individual number's recurrence, other than by hand, and since one can only select a line at a time this could be tedious.

This is a new set of programs and clearly they will be amended in the light of experience. I have suggested how I might use it and what additional features I would like, and would be interested in other teachers' reactions after use in the classroom.

A 9 page document *Probability Simulation User's Manual* can be downloaded from the web-site, but there is a need for a companion document with suggestions for suitable examples for classroom use.

Jaiwant Timotheus, Holly Lodge High School, Smethwick

TI-83 Plus Probability Simulator

The Probability Simulator is one of a range of new Apps for the TI-83 Plus. It is available from the TI website, and is also supplied with the new TI-83 Plus *Silver Edition*.

The simulator offers six options: **Toss Coins; Roll Dice; Pick Marbles; Spin Spinner; Draw Cards** and **Random Numbers**. Each of the options has an animation to go with it. If you choose to roll dice, for example, you will see the dice appear from the left hand side of the screen, spin in the air and then 'land', displaying their score. Along the bottom of the screen, the various menu buttons allow you to choose to roll the dice another time, or ten times, or fifty times.

Also on screen you will find a frequency or probability graph. Along the horizontal axis there are the different scores or options available, and the vertical axis represents the frequency or experimental probability. The vertical scale automatically recalculates the scale each time an experiment is carried out, but does not display any markings to tell the user the scale being used. This can be a little confusing at times.

One of the great strengths of the simulator is that it allows you to change many of the settings. You can choose between 1, 2 or 3 coins, and decide their weightings. You can choose whether your dice have 6, 8, 10, 12 or 20 sides. The animations change accordingly, and you can again choose the

weightings. The fact that the animations change is particularly helpful in developing a mental image of what the experiments represent. For example, when you choose the marbles, you can choose how many there are of each type in the bag, and whether or not they are being replaced. The animation will also show the chosen marble being put back into the bag, or staying on the screen, depending on the option selected. I could see myself asking a class to spot the differences in the animations and then encourage them to think about how this might affect the mathematics.

There seems to me to be many ways that the Probability Simulator can be used in the classroom. Using a TI Viewscreen™ and a Teacher Calculator, you could set up the calculator beforehand and then choose marbles, pick cards or whatever. Questions such as, how many marbles are there in the bag? How can you be sure? How many experiments do we need to carry out? could generate a lot of mathematical thought.

The values generated by the simulator can also be exported as a list and then statistically analysed in more detail after you have closed the Probability Simulator App.

The simulator allows the teacher to expose pupils to a wide variety of probability experiments with very little organisational hassle.

T³ – Teachers Teaching with Technology™



T³ Scotland

T³ Scotland delivers Hand-held Technology Courses that are:

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- Delivered by current classroom teachers
- Designed to meet the needs of Scottish teachers
- High quality content developed in Scotland

FLEXIBLE OPTIONS – half day, one day, two day, summer school

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- Get help with introducing new technology into mathematics teaching

For more information about T³ Scotland courses, please contact **Ian Forbes**:

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Moray House Institute of Education
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Holyrood Road
Edinburgh
EH8 8AQ

T³ England, Wales and Northern Ireland

T³ in England, Wales and Northern Ireland is offered in partnership with the Mathematical Association and co-ordinated by their Professional Development Officer, **Rosalyn Hyde**.

The following courses are now offered:

- Mathematics at Key Stages 3 and 4
- Data Handling in Maths and Science for Secondary Schools
- Numeracy and Transition at Key Stages 2 and 3
- Data Handling in Science at Key Stage 3

The recently published draft National Numeracy Strategy for Key Stage 3 makes it clear that graphics calculators have a key role to play in teaching and learning at Key Stage 3. All T³ materials are written by experienced educators in line with the National Numeracy Strategy, National Curriculum and G.C.S.E. criteria. Training sessions are hands-on workshops given by trainers experienced in using hand-held technology in the classroom. The courses cover basic operation of the calculator and data loggers, ideas and materials for use in the classroom across the attainment targets, practical help in managing the use of ICT in teaching

and learning, and the impact of technology on teaching. We are also able to offer short introductory sessions for teachers, as well as longer courses in a variety of formats.

A key part of our strategy for training and supporting teachers in using hand-held technology is to work in collaboration with Local Education Authorities. An important way forward for this partnership is for T³ to train a team of local teachers to become trainers in their L.E.A. Those authorities already working in partnership with T³ have been able to select an appropriate focus for their area from the list of available courses, to select teachers to act as trainers and to plan a strategy to develop the appropriate use of hand-held technology in their area.

If you are interested in more details, please contact **Rosalyn Hyde**:

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Southampton
SO16 6QW

Calculator clock

This article describes how to set out an analemmatic sundial on your TI-83 Plus, and use it to tell the time (providing the sun is shining!). It can also be adapted for the TI-73 and TI-83, but the angled screen of the latter needs compensating to make it level.

An analemmatic sundial has a vertical gnomon, (the part of a sundial that casts the shadow) which is conveniently provided by a rod or person that casts the correct shadow when put on the appropriate position for the time of year.

An analemmatic sundial does not have hour lines, but rather hour points, on the circumference of a horizontal ellipse.

There is also a central scale on which various days are marked to show where to place the gnomon.

A picture of an analemmatic sundial designed for the *Williamson Park* at Lancaster is shown below. A person standing on the appropriate position for the time of year provides the vertical gnomon. Schools can set out their own analemmatic sundials in the playground, and advice on this can be obtained from the author. The project makes a nice piece of cross-curricular work with science.



Since this work was first described at The Mathematical Association's annual conference at Lancaster (April 2001), it is fitting that the latitude (54.05°N) and longitude (2.78°W) of Lancaster be used in the calculations here. The sundial is adjusted for its longitude, so that a later mental adjustment is not needed. The work described uses the lists and statistical plot functions.

Enter the data for the hour points into L1. To do this, use the sequence function from the LIST OPS. The screen shots may help you through the procedure.

```
NAMES [ ] MATH
1:SortA(
2:SortD(
3:din(
4:Fill(
5:seq(
6:scnSun(
7:List(
```

This sequence produces the data to give the positions for the hour points from 4 am (8 hours before 12 noon) to 8 pm, and is adjusted for longitude 2.78°W by subtracting 2.78 x 4/60, the 4/60 being

```
seq(A-2.78*4/60,
A, -8, 8, 1)+SEQ1
(-8.185333333 -...
```

the 4 minutes per degree converted to hours. It takes the sun 4 minutes to travel though 1 degree of longitude, hence this adjustment.

To put this data into List 1, move the cursor onto L1 at the top of the list so L1= shows at the bottom, then 2nd LIST SEQ1 pastes the sequence into the list.

Now the *x* and *y* coordinates of the sundial are calculated using

$$x = r \sin(15(t - 4q/60))^\circ$$

$$y = r \sin \theta \cos(15(t - 4q/60))^\circ$$

where θ is the angle of longitude (2.78°) and θ is the angle of latitude (54.05°). If you want to use it on a site east of the Greenwich meridian, change the subtraction to addition. If we choose 2*r* to be the length of the major axis of the ellipse, the minor axis has the length 2*r*sin θ . On the ground taking *r* as 2 metres gives a good size sundial. Hence we work with this so the data in the lists can be used to mark out the sundial on the ground in metres. θ and θ can be obtained from an Ordnance Survey map or gazetteer.

The values of $t - 4\theta/60$ for *t* from -8 to 8 have already been calculated and put into L1.

Make sure that you are working in degrees before executing this step! Move the cursor onto L2 and enter 2sin(15L1) as shown.

```
L1  [ ] L3  2
-8.185
-7.185
-6.185
-5.185
-4.185
-3.185
-2.185
L2=2sin(15L1)
```

Press ENTER to obtain this screen.

```
L1  [ ] L2  L3  2
-8.185 -1.904
-7.185 -1.998
-6.185 -1.998
-5.185 -1.915
-4.185 -1.779
-3.185 -1.481
-2.185 -1.083
L2()=-1.68151128...
```

Now move the cursor onto L3, type 2sin(54.05)cos(15 L1) and press ENTER to obtain the screen shown here.

```
L1  [ ] L2  L3  3
-8.185 -1.682 0.777
-7.185 -1.998 -0.963
-6.185 -1.998 -0.785
-5.185 -1.915 -0.625
-4.185 -1.779 -0.467
-3.185 -1.481 -0.288
-2.185 -1.083 -0.1212
L3()=-.876582582...
```

The coordinates have been calculated, and can now be plotted on the screen. Select the STAT PLOT and set it up to show a scatter plot with L2 as the *x* coordinates and L3 the *y* coordinates as shown here.

```
Plot2 Plot3
On Off
Type: [ ] L<
Xlist:L2
Ylist:L3
Mark: [ ]
```

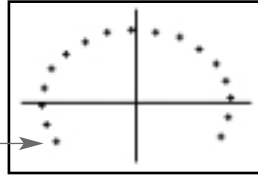
Press GRAPH and the sundial appears! To fit it in nicely to the screen, use the following window.

```
WINDOW
Ymin=-2.35
Ymax=2.35
Xscl=[ ]
Ymin=-1.05
Ymax=2.85
Xscl=0
Xres=1
```

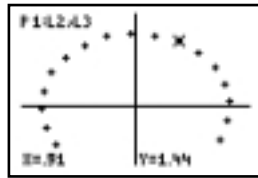
Calculator clock

continued

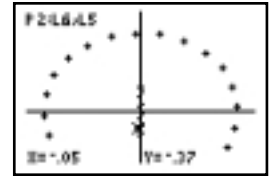
The points mark the positions of 4 am to 8 pm hour marks in an anti-clockwise direction. The y -axis points true north, the x -axis points east.



With the **MODE** set to 2 decimal places, and using the **TRACE** function the coordinates of the hour markers can be shown. The one shown here is for 2 pm GMT. In British Summer Time it will be 3 pm.



Press **GRAPH** and the central scale also appears! On the screen shown here, the **TRACE** function is used to show where, on the central scale, the gnomon should go on 1st February. Using the cursor, the position for any month can be found.



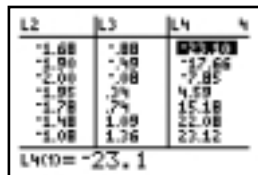
All that remains is to make a gnomon, and fix it in place. A staple, straightened out at one end provides a suitable device. Another is a 1-inch panel pin. To fix it in position a small piece of Blu-tack is ideal and this can be used to hold the staple on the top corner of the screen under the lid when not in use.

A central scale is needed to indicate where the gnomon is placed. This indicates where the gnomon should be placed (or observer should stand) according to the time of year. The scale is calculated on the values of the sun's declination for 2000. The declination varies from year to year, coming back very closely to what it was every four years. The variation is not enough to make a significant difference in the reading of the shadow time. The sun's declination, in degrees, is shown here for the first of each month.

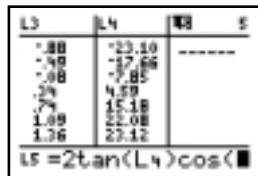
Month	Jan	Feb	Mar	Apr	May	Jun
Declination	-23.10	-17.66	-7.85	4.59	15.18	22.08
Month	Jul	Aug	Sep	Oct	Nov	Dec
Declination	23.12	18.15	8.39	-3.34	-14.83	-21.92

To calculate the displacement of the gnomon from the centre use displacement = $r \tan d \cos \theta$ where d = declination of the sun, found from the table above.

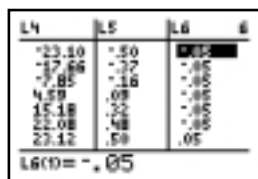
Here the sun's declination has been entered in L4.



And the calculation for the displacement, $2 \tan(L4) \cos(54.05)$ in L5. To mark these around the north/south axis in order, the January to June displacements will be plotted on the left-hand side of the y -axis, the July to December on the right-hand side.



To do this, the x -coordinates are -0.05 for the first six months, 0.05 for the next six months.

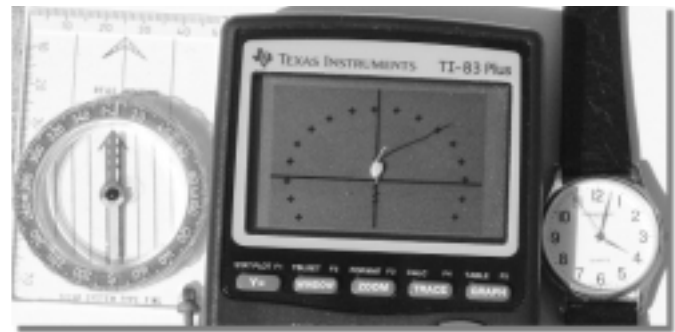


Set up **PLOT2** as shown.



To use the sundial, orientate the y -axis due north (if using a compass, remember to adjust for magnetic north), put the gnomon in the correct position for the time of year, and read off the time!

The picture below shows my TI-83 Plus, orientated in a true north direction, showing the time as just before 3 pm. (In British Summer Time the mark closest to north will be the 1 pm mark. In Greenwich Mean Time it will be the noon mark) on 30 May.



Remembering that if you have a watch, but no compass, if you orientate the TI-83 Plus to show the correct time, it will then have the y -axis pointing north. Hence you are never lost with a TI-83 Plus!

Sundial purists will be aware that the 'equation of time' needs to be taken into consideration to obtain the true time. However, due to the brevity of this article that has been omitted here. Further details can be obtained from the author on receipt of a stamped addressed envelope.

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