Scientific Programmable
Operating Instructions

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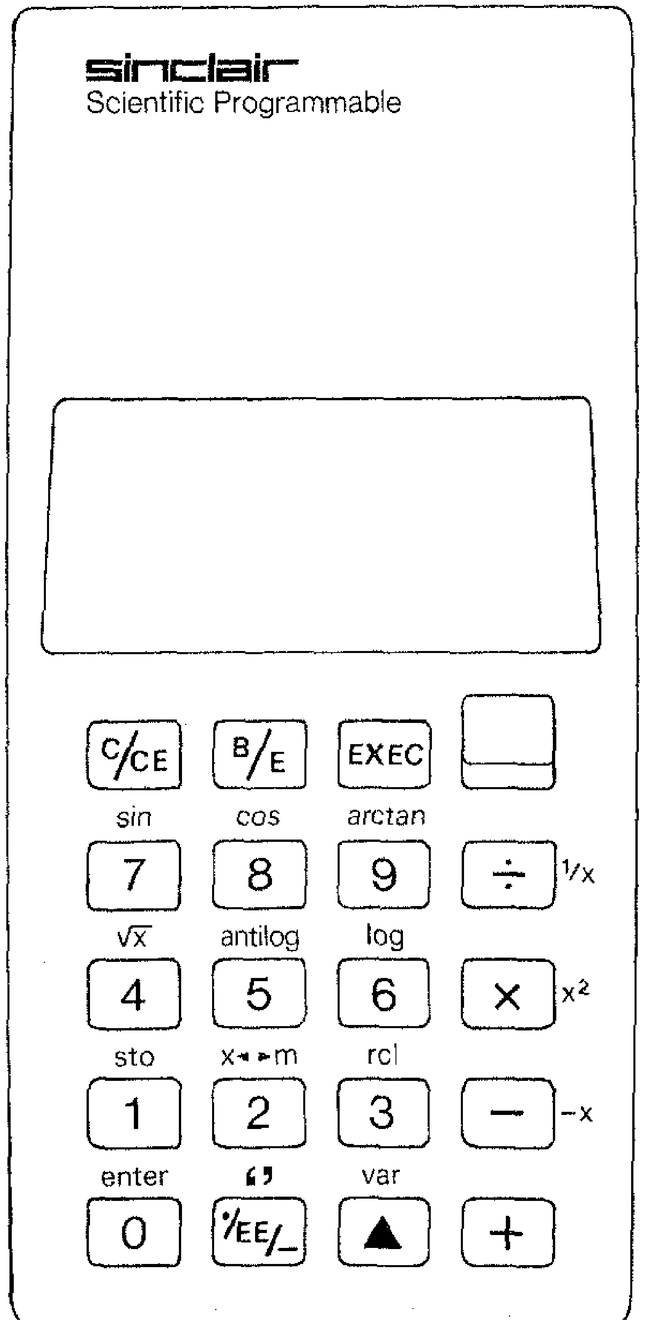

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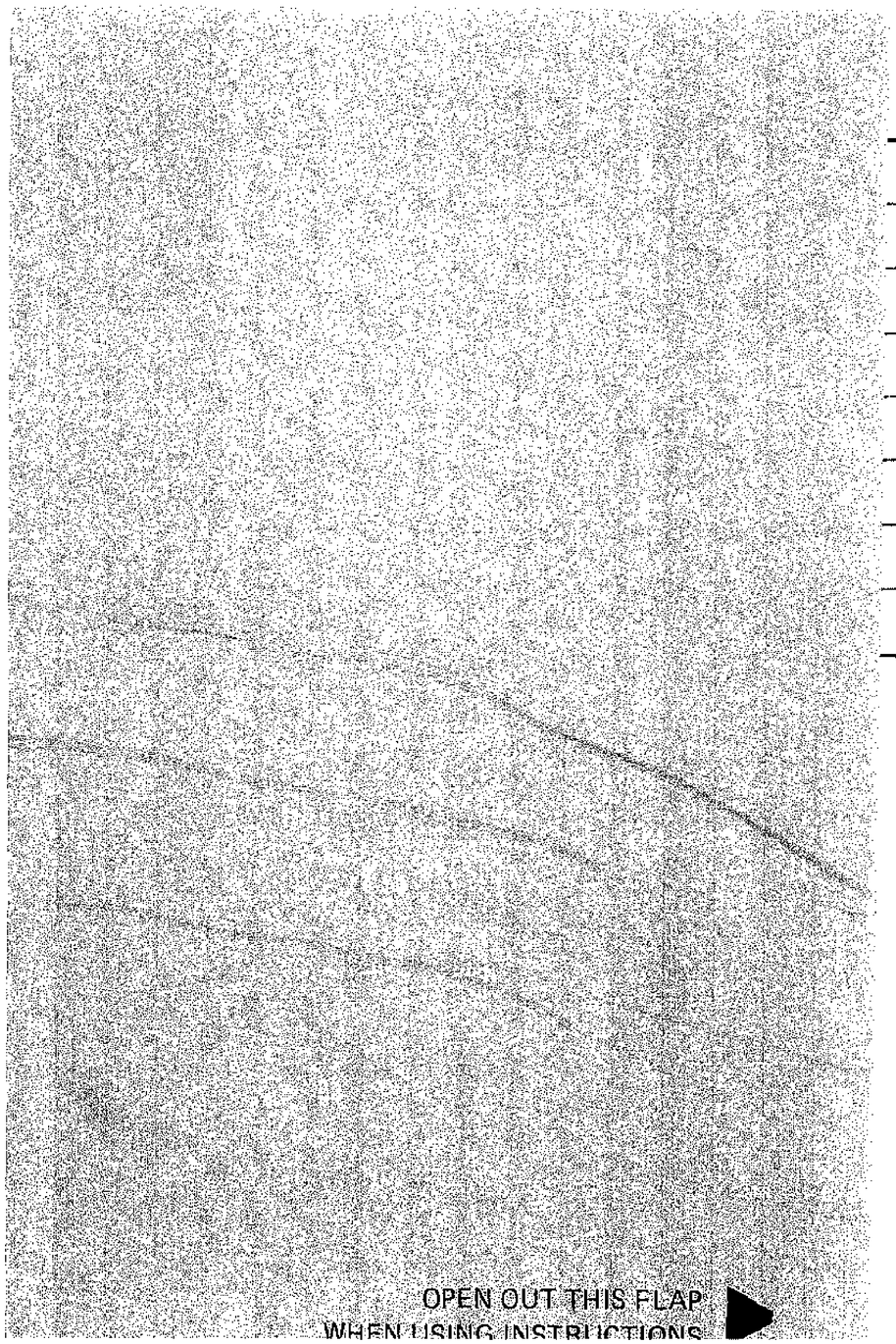

Introduction

Pocket calculators have changed the lives of businessmen. They've made normal commercial calculations easier, faster, more accurate and more available than anyone could have imagined a few years ago.

But for engineers, mathematicians, and scientists, whether they're students or hard-working professionals, commercial pocket calculators hardly dent the problems of handling figures.

The scientific pocket calculators were a break-through. Scientific notation enormously increased the range of numbers which could be handled. Logs and trig functions available at a key-stroke dispensed with time-consuming four-figure tables.

But even these scientific calculators couldn't progress calculations in the way that a computer can progress them. Every operation on a number entered into the calculator demanded further key-strokes.

Only a calculator which can be programmed like a computer can make a real dent in the problems of repetitive and interative calculations, with their need to carry out the same more or less complex operations on a series of variables.

The Sinclair Scientific Programmable is the first mains/battery calculator in the world to offer a self-contained programming facility combined with true scientific functions at a price within the reach of the general public.

It allows the operator to enter a standard program or a program of his own devising, and this way to execute a complex calculation simply by entering variables when required.

It makes the repetitive evaluation of formulae, or the solving of equations, or integration by the iterative process a matter of minutes, rather than hours.

THE SINCLAIR SCIENTIFIC PROGRAMMABLE

FUNCTIONS AND FEATURES

24-STEP KEYBOARD-ENTRY PROGRAM FACILITY

The Scientific Programmable is programmed directly through the keyboard. A program of up to 24 steps can be entered simply by keying in a sequence of instructions corresponding to the calculation to be programmed. It is stored ready to operate on any numbers entered. The program can be stopped at any point for variables to be entered.

Switching off the machine automatically clears the program.

SCIENTIFIC NOTATION

5 digit mantissa, 2 digit exponent, both signable. Number entry can be in scientific notation or fully-floating decimal point: all results are automatically displayed in scientific notation.

SCIENTIFIC FUNCTIONS

Directly available: sine, cosine, arctangent (all in radians); $\log_{10}$, antilog$_{10}$ (10^x).

Immediately derivable: arcsine, arccosine, tangent; degree conversion; $\log_e$.

PERMITTED ARGUMENT RANGE:

Logs (base 10)—all positive numbers

Antilogs (base 10)—numbers between -99 and 99

$\sqrt{\ }$ —all positive numbers

Sin and Cos—between 0 and $\frac{\pi}{2}$ radians

Arctan—numbers between 0 and 49.991—results in radians.

MATHEMATICAL FUNCTIONS

x^2, $\frac{1}{x}$; sign change, $\sqrt{x}$

ARITHMETIC FUNCTIONS

$+, -, \times, \div$.

POST-FIXED OPERATORS

Ideal for complex full-flow chain calculation.

MEMORY

3 separate functions: store, recall and exchange.

'UPPER AND LOWER CASE' OPERATION

The keyboard layout is very simple: most keys have two or more functions, instantly selectable. The outcome is a very wide range of functions (including programming) available from just 19 keys.

MAINS/BATTERY OPTION

An AC mains adaptor is supplied with the Scientific Programmable, and should be used where possible. A disposable 9 V cell allows the calculator to be used wherever AC facilities are not available, but is intended only for occasional use, not for continuous operation.

1 CONTROLS

C/CE Key This key is used to clear the machine (but not the memory) or to clear an incorrect entry.

Used after an operator, i.e. when a calculation has been completed, it will clear the machine completely, e.g.:

ENTER	DISPLAY SHOWS
3	3.
+	3.0000
4	4.
×	1.2000 1
C/CE	0.0000

Used after entry of an incorrect number, but before the next operator, it clears only the incorrect entry:

ENTER	DISPLAY SHOWS	
3	3.	
+	3.0000	
5	5.	— incorrect entry
C/CE	3.0000	
4	4.	
×	1.2000 1	(= 3 × 4)

After a new program has been stored, depressing C/CE takes the machine out of the 'program learn' mode and clears the display ready for number entry, either for the entry of data into program, or for carrying out normal keyboard calculations.

0 to 9 The ten digits are used to enter numbers, including exponents.

·/EE/− During number entry this key will cause a decimal point to be entered in the mantissa when first used. If used for a second time during entry of the same number it will cause subsequent digits to be entered in the exponent range of the number. If used a third time it will change the sign of the exponent.

+ − × ÷ The four function keys are used for the basic arithmetic functions.

▲ This key is used to select the upper case functions.

B/E (Begin/End) When learning a program the calculation sequence should be preceded and terminated by this key.

EXEC This key is used to execute (and to continue the execution of) a program.

2 NUMBER REPRESENTATION AND ENTRY

Number entry

Numbers may be entered in either floating point format or scientific (exponent) notation. If no exponent is entered it is assumed to be zero. The digits will appear from the right of the display and unwanted leading zeros will be suppressed, except that a single zero will automatically be placed before the decimal point when a fractional mantissa is entered. This leading zero limits accuracy when entering a fractional number to four significant figures. If five are required the number must be entered in scientific notation. The decimal point key is also used both to enter an exponent and to change the sign of an exponent when necessary. During exponent entry only the last two digits entered will be accepted. This can be used to correct an error during exponent entry.

Examples

NUMBER		KEY SEQUENCE	DISPLAY
59		5 9	5 9.
34.2		3 4 . 2	3 4.2
16,000,000		1 . 6 . 7	1. 6 7
	or	1 6 . . 6	1 6. 6
.000001		1 . . . 6	1. − 6
.23		. 2 3	0. 2 3
1.2×10^{-42}		1 . 2 . . 4 2	1. 2 − 4 2

In each case where the decimal point has been used for a second time it has caused subsequent digits to be entered into the exponent. Where used for a third time it has made the exponent negative. If at any stage during the entry of a mantissa an error is made, press C/CE and begin entering the number again.

Display of Results.

Numbers are represented by a signed, five digit mantissa and a signed, two digit exponent.

The result of a calculation is always displayed in standardised scientific notation. That is, the decimal point is automatically positioned after the first digit of the mantissa and the exponent is given the value necessary to represent accurately the magnitude of the result. So, for example, the result of adding 6,000 and 7,000 would be displayed as 1.3000 with an exponent of 4:-

1 . 3 0 0 0 4

Reverse Polish Notation

Each of the four arithmetic operators (+ − × ÷) is used **after** the number to which it refers. The first number of any sequence of arithmetic calculations should be followed by an "enter" instruction. (The upper case function on the zero key).

So to calculate 10 − 6, for example, the sequence is:-

KEY SEQUENCE	DISPLAY	COMMENT
10	10.	
▲	10.	Select upper case
Enter (0)	1.0000	10 is entered
6	6.	
−	4.0000	Answer

KEY	DISPLAY	COMMENT
2	2.	
▲		Select upper case
Enter (0)	2.0000	2 is entered
3	3.	
÷	6.6666 − 1	Answer

Chain calculations can be performed in the same way. For example:

[(2 + 3) ÷ 8 + 4] × 2

is keyed in as

2 ▲ Enter (0) 3 + 8 ÷ 4 + 2 ×

The operator always follows the number, and produces a result (this is why the machine has no "equals" key).

Reciprocals, Squares, Sign Change.

The four arithmetic functions normally operate on two numbers. The application of three of these functions to single numbers has been specially programmed to give three additional convenience functions.

÷	Applied to a single number gives $\frac{1}{x}$
×	Applied to a single number gives x^2
−	Applied to a single number gives $-x$

For example, to find the reciprocal of 23, the sequence would be:-

KEY SEQUENCE	DISPLAY	COMMENT
23	23.	
▲		Upper case
Enter (0)	2.3000 1	23 is entered
÷	4.3478 − 2	Result is $\frac{1}{23}$ ≈ 0.043478

These three functions can be applied to the result of any calculation sequence as well as to a number just entered.

For example, to calculate $\frac{1}{3^2 + 4^2}$

KEY SEQUENCE	DISPLAY	COMMENT
3	3.	
▲		Upper case
Enter (0)	3.0000	3 is entered
×	9.0000	3 is squared
▲		
Sto (1)	9.0000	9 goes into the Memory
▲		
Enter (0)		Sets up machine for new number entry after use of memory function. See page 8
4	4.	
▲		
Enter (0)	4.0000	
×	1.6000	4 is squared
▲		
Rcl (3)	9.0000	9 is recalled from memory
+	2.5000	$25 = 9 + 16$
÷	4.0000 – 2	$0.04 = 1/(3^2 + 4^2)$

Entry Sequence

In each of these examples the entry sequence uses ▲ Enter (0). An alternative is to press C/CE, which clears the display and working registers (but not the memory). Any number can then be keyed in followed by +, which adds the new number to the previously displayed result (zero).

Thus the following sequences are equivalent: each could be used to multiply 3 × 2.

USING C/CE	USING Enter (0)
C/CE	3
3	▲
+	Enter (0)
2	2
×	×

3 SCIENTIFIC FUNCTIONS

By using ▲ followed by number keys 4 thru 9 the functions log (base 10), antilog ($=10^x$), $\sqrt{x}$, sin, cos and arctan are obtained.

Log Evaluates the common logarithm (base 10) of the number currently displayed. The acceptable argument range is all positive numbers.

Antilog. Evaluates the antilogarithm (10^x) of the number displayed. Argument range :- $-99 < x \leq 99$.

$\sqrt{x}$ Evaluates the square root of the number displayed. The acceptable argument range is $0 \leq x \leq 9 \times 10^{99}$.

Sin and Cos The sine or cosine of the number displayed will be evaluated The argument must be expressed in radians and lie between 0 and $\pi/2$.

Arctan The arctan will be evaluated for numbers between 0 and 49.9 (which gives a result equivalent to 88.85°). The result will be expressed in radians.

Arcsin, Arccos, Tan These functions are not directly available on the machine but can easily be derived from the following formulae:-

1. Arcsin

$$\text{Arcsin } x = \text{Arctan } \left[\frac{x}{\sqrt{1 - x^2}}\right]$$

This can be keyed in as: Enter × ÷ 1 − √ ÷ Arctan

2. Arccos

$$\text{Arccos } x = \text{Arctan } \left(\frac{1}{x}\sqrt{1 - x^2}\right)$$

This can be keyed in as: Enter × ÷ 1 − √ Arctan

3. Tan

$$\text{Tan } x = \sqrt{\frac{1}{\cos^2 x} - 1}$$

This can be keyed in as: Enter Cos × ÷ 1 − √

A program can be written to provide any one of these functions as a single keystroke operation. The writing of programs is covered in Section 5.

Execution time on these programs is very quick—actually faster than some machines which offer Arcsin, Arccos, and Tan as single functions.

4 USING THE MEMORY

There are three memory functions.

Sto	copies the number displayed into memory register without affecting the display. Any previous contents of the memory register will be overwritten.
rcl	copies the contents of the memory register to the display. The memory register will be unaffected. The previous result will remain within the machine as it would if the recalled number had been entered from the keyboard.
x < > m	exchanges the contents of the display and the memory register.

Following any of the memory operations the remaining content of the display behaves as if it were a number which had been keyed in but **not** entered.

This is to enable sequences of the following type to be performed:-

KEY SEQUENCE	DISPLAY	COMMENT
C/CE	0.0000	
2	2.	
+	2.0000	
3	3.	
▲	3.	
Sto (1)	3.	3 is stored in memory.
×	6.0000	

If the contents of the display following the Sto instruction behaved like a number which had been both keyed in **and** entered, then the final × instruction would square the 3, not perform the required multiplication of 2 × 3.

This means that if it is necessary to follow a memory operation with a new number entry, an "Enter" instruction or an operator **must** follow the memory instruction and precede the new number entry—just as an "Enter" instruction or operator must follow a number which has been keyed in.

For example, suppose we wish to recall the number 3 from the memory and add the number 4 to it, the correct sequence is:-

KEY SEQUENCE	DISPLAY	COMMENT
▲		
rcl (3)	3.0000	3 is recalled from memory
▲		
Enter (0)	3.0000	Machine is now set up for new number entry
4	4.	4 is keyed in
+	7.0000	

If the Enter instruction had been omitted, the machine would not have accepted the new number 4. However, the "enter" instruction is not required where the recalled number is to be used on a previous result, e.g.

4	4.	4 is keyed in
▲		
rcl (3)	3.0000	3 is recalled from memory, no 'enter' instruction required.
+	7.0000	

This procedure is very simple to operate provided you remember that the display after a memory operation behaves **like a number which has been keyed in but not entered.**

5 PROGRAMMING

The Sinclair Scientific Programmable is able to remember a sequence of up to 24 keystrokes or steps. Such a sequence is referred to as a program. Once a program has been stored in the calculator it can be repeatedly executed, using different data.

PROGRAM ENTRY

To store a program, begin with B/E. This will clear out any existing program and also clear all the registers including the memory. Within a program the keys C/CE, B/E and EXEC may not be used. All the other keys are used in the normal way subject to the following conditions:-

1. Upper case functions such as SIN, LOG etc., do not need to be preceded by ▲
2. The only numbers that can be entered as part of a program are integers (no decimal point or exponent). To indicate to the machine that you wish to enter a number and not an upper case function, numbers stored as part of a program must be preceded by ❛❛ (the upper case function on the ·/EE/– key) and terminated by ❛❛.
3. VAR, which will be automatically stored as part of a program when ▲ (VAR) is used, will cause execution of a program to stop at that point, enabling a displayed result to be observed or a number to be entered. Always terminate a program with VAR to display the result.

Once entry of a program is completed C/CE must be depressed, this will take the machine out of the 'program learn' mode and clear the display ready for number entry. It is not necessary to press B/E at the end of program entry. Doing so merely inhibits the machine against entry of further program steps, pressing C/CE after the final 'variable' key is entirely satisfactory in completing a program entry.

During entry of a program the number of steps so far entered is displayed in the exponent slot, this must not exceed 24. If an error is made during program entry the B/E key should be depressed twice and the whole program entered again.

Example: A program to evaluate $\sqrt{A^2+2B^2}$

KEY	FUNCTION		Display shows
B/E		begin program; assume A has been keyed in.	0.
0	Enter	upper case function is ENTER	0. 1
×	x^2	multiply without entering new number squares A.	0. 2
1	STO	upper case function is STO. A^2 is placed in memory register.	0. 3
0	Enter	sets up machine for new data entry	0. 4
▲	VAR	*stop* to enter the variable B	0. 5
0	Enter	ENTER B	0. 6
×	x^2	Square B	0. 7
·/EE/−	❛	*begin entering* number as part of program	0. 8
2	2	enter 2	0. 9
·/EE/−	❜	terminate number	0. 10
×	×	multiply B^2 by 2	0. 11
3	RCL	recall A^2 from memory	0. 12
+	+	add A^2 and $2B^2$	0. 13
4	√	take square root of $A^2 + 2B^2$	0. 14
▲	VAR		0. 15
C/CE	CLEAR	clears machine for first variable entry	0.0000

To find $\sqrt{3^2 + 2\times5^2}$ using the above program

3		3.
EXEC		9.0000
5		5.
EXEC	RESULT	7.6811

To find $\sqrt{\frac{1}{3}^2 + 2.\frac{1}{4}^2}$

1		1.
▲		1.
enter (0)		1.0000
3		3.
÷	(result = 1/3)	3.3333 − 1
EXEC		1.1111 − 1
1		1.
▲		1.
enter (0)		1.0000
4		4.
÷	(result = 1/4)	2.5000 − 1
EXEC continue execution		4.8591 − 1
		Result = 0.48591

Note that before continuing execution of the program a calculation can be carried out, the result of which will be entered by the program as B. Fractions could have been entered as 0.3333 and 0.25. A program will remain available for execution until another program is stored, or until the calculator is switched off.

All normal functions of the calculator, including the memory register, may be used while a program is stored, even though that program may not be executed for long periods of time.

NOTE:- Upon depressing the EXEC key the machine executes the section of a program between two 'variable' instructions. If more than one 'variable' keystroke is entered in a program, care must be taken to ensure that execution of the program with the previous data is completed before new data is entered, since there is no automatic way of returning to the start of a program. For example, if a program contains three 'variable' instructions EXEC must be depressed a total of three times to complete the program. Therefore, if after entering the first piece of data and depressing EXEC it is realised that the data was in error, the EXEC button must be depressed twice more before the program can be run again with the correct data.

Some applications

Program to convert degrees to radians: $R = \frac{D}{57.3}$

KEY	FUNCTION	COMMENTS
B/E	BEGIN	Begin storing program
0	ENTER	assumes that the display contains the value of the angle in degrees
·/EE/–	‘	begin number entry
5	5	
7	7	
3	3	
·/EE/–	’	End entering conversion factor
÷	÷	
·/EE/–	‘	
1	1	
0	0	
·/EE/–	’	
×	×	Multiply by 10 to scale conversion factor
▲	VAR	Stop (*display shows 0. 13*)
C/CE	CLEAR	End storing program

With this program sin 30° would be evaluated as follows:-

KEY SEQUENCE	DISPLAY SHOWS	COMMENTS
30	30.	
EXEC	5.2356– 1	30° in radians
▲	5.2356– 1	
Sin	5.0000– 1	= Sin 30°
Or to evaluate Cos 45°		
C/CE	0.0000	
45	45.	
EXEC	7.8534– 1	45° in radians
▲	7.8534– 1	
Cos	7.0717– 1	Cos 45°

Similarly, programs can be used to evaluate natural logarithms (base e) and e^x; to evaluate the tangent function and to evaluate arcsin and arcosine.

Solving equations by iterative methods To solve an equation such as Cos x = x, would normally require a graphical solution or, with a non-programmabel calculator, extensive trial and error.

With a programmable calculator, however, advantage can be taken by iterative solutions such as Newton's Method.

Newton's Method states that increasingly more accurate solutions to an equation f(x) = 0 are generated by the formula:

$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)}$ where f'(x) is the first derivative of f(x). Thus by starting with an arbitary guess of the solution, repeatedly executing this formula will rapidly yield the answer correct within the accuracy limits of the machine.

To solve cos x = x

$f(x) = \cos x - x = 0$

$$\therefore x_{n+1} = x_n - \left[\frac{\cos x_n - x_n}{-\sin x_n - 1}\right]$$

rearranging this becomes:

$$\frac{x_n \sin x_n + \cos x_n}{\sin x_n + 1} \quad \textit{or} \quad \frac{x_n + \sqrt{\frac{1}{\sin^2 x_n} - 1}}{\frac{1}{\sin x_n} + 1}$$

Program: assume x_n is in display.

KEY	FUNCTION	COMMENTS
B/E	B/E	
1	sto	store x_n in memory
7	sin	*form sin* x_n
×	x^2	square
÷	$\frac{1}{x}$	*reciprocate* $\left(\frac{1}{\sin^2 x_n}\right)$
·/EE/–	’	
1	1	
·/EE/–	‘	
–	–	subtract
4	√	form $\sqrt{\frac{1}{\sin^2 x_n} - 1}$
3	rcl	
+	+	add x_n
2	x<>m	*Recall* x_n *to display* and place $x_n + \sqrt{\frac{1}{\sin^2 x_n} - 1}$ in memory
7	sin	form sin x_n

KEY	FUNCTION	COMMENTS
÷	$\frac{1}{x}$	reciprocate
·/EE/−	6	
1	1	
·/EE/−	9	
+	+	add 1
		reciprocate
÷	$\frac{1}{x}$	$\left(\frac{1}{\frac{1}{\sin\ x_n}+1}\right)$
3	rcl	
×	×	multiply by contents of *memory*
▲	var	display result
(display shows 0. 22)		$\left(\frac{x_n+\sqrt{\frac{1}{\sin^2 x_n}-1}}{\frac{1}{\sin\ x_n}+1}\right)$
C/CE	clear	

Execution: enter 1 (any arbitrary first value within the range of the sin function, i.e. $< \pi/2$ will do)

depress	*Exec*
”	”
”	”
”	”

Display is now alternating between .73905 and .73906. This is the correct solution for x in radians.

Integration by reduction formula

To find the integral of $\sin^n\theta\ d\theta$ between limits 0 and $\frac{\pi}{2}$

$$I_n = \int_0^{\pi/2} \sin^n\theta d\theta = \int_0^{\pi/2} \sin\ \theta\ \sin^{n-1}\theta d\theta$$

Integrating by parts

$$I_n = \left[-\cos\ \theta\ \sin^{n-1}\theta\right]_0^{\pi/2} + (n-1)\int_0^{\pi/2} \cos^2\theta\ \sin^{n-2}\theta d\theta$$

$$= 0 + (n-1)\int_0^{\pi/2} (1-\sin^2\theta)\ \sin^{n-2}\theta d\theta\ (n\geq 2)$$

This can be written as $(n-1)(I_{n-2}-I_n)$

hence $I_n = \frac{n-1}{n} . I_{n-2}$

or $\int_0^{\pi/2} \sin^n\theta d\theta = \frac{n-1}{n}\int_0^{\pi/2} \sin^{n-2}\theta d\theta$

Thus by successive operations of the formula until $n-2 = 1$ (n odd) or $n-2 = 0$ (n even) a solution can be obtained since $\int_0^{\pi/2} \sin\ \theta d\theta = 1$ and $\int_0^{\pi/2} \sin^0\theta d\theta = \pi/2$

It is therefore necessary to repeatedly evaluate $I_{m+2} = \frac{m+1}{m+2} I_m$ until $m+2=n$.

Program

At the beginning of each execution, I_m is in the memory and m in the display.

KEY	FUNCTION	COMMENT
B/E	Begin	
O	Enter	
·/EE/−	6	
1	1	
·/EE/−	9	
+	+	Form m+1
2	x < > m	I_m to display, (m+1) to memory
3	rcl	Recall (m+1)
×	×	Form $I_m \times (m+1)$
2	x < > m	Exchange
0	enter	
·/EE/−	6	
1	1	
·/EE/−	9	Enter 1
+	+	Form (m+1) + 1 (= m + 2)
2	x < > m	
3	Rcl	
÷	÷	Form $\frac{I_m \times (m+1)}{(m+2)}$
2	x < > m	*Exchange: we now have $I_{(m+2)}$ in memory* and (m+2) in display
▲	Var	Display m + 2 (display shows 0. 19)
C/CE	CLEAR	

Execution

For n even

Key Sequence	Display
3.1416	3.1416
▲	3.1416
Enter (0)	3.1416
2	2
÷	1.5708
▲	1.5708
Sto (1)	1.5708
C/CE	0.0000
EXEC	2.0000
EXEC	4.0000
etc	
.	
.	
.	
▲	
rcl (3)	recall I_m

For n odd

Key Sequence	Display
1	1
▲	
Sto (1)	1.0000
EXEC	3.0000
EXEC	5.0000
.	
.	
▲	
rcl (3)	recall I_m

Calculator care

Although Sinclair calculators are built to a high standard of reliability a limited number are, of course, returned with various faults. Amazingly, about one third of these machines turn out not to be defective at all and have been sent back either because the battery needed replacement, or because the user failed to understand some aspect of the machine's operation.

We list below some of the reasons for which machines are returned.

1. **Batteries**
   If you have a problem with your calculator, first check that the battery is OK—or try operating it on the mains adaptor.
2. **Display blanks out**
   This can result from—a) pressing an execute button when the machine has no program or no data, or b) attempting to carry out a scientific function on a number which is outside the argument range for that function. Switch the machine off and switch on again to clear this condition.
3. **Number fails to enter following use of memory function**
   Check memory section, page 8.
4. **Incorrect number entry**

Service

If at any time your calculator requires service please send it to one of the following:
U.K.: Sinclair Radionics Ltd., Calculator Service Department, Edison Road, St. Ives, Huntingdon, Cambs., PE17 4HJ.
U.S.A.: Sinclair Radionics Inc., 375 Park Avenue, New York 10022.
Otherwise contact your Sinclair dealer or distributor for details.

Guarantee

The Sinclair Scientific Programmable is guaranteed against defects arising in normal use, for a period of 1 year from the date of purchase.

Should any problem arise, UK owners should return the calculator direct to Sinclair Radionics Ltd., Calculator Service Department, Edison Road, St. Ives, Huntingdon, Cambs., PE17 4HJ, carefully packed, postage prepaid.

Please enclose a letter with the calculator, stating clearly your name and address; the date and place of purchase; and the nature of the fault.

Please use the space below to record the relevant details for your reference.

Date of purchase 28.11.78

Place of purchase By Mail

Owner's name and address.