Novus 4525
Scientist PR
Operations Guide
Made in America, with pride, 
by National Semiconductor

All the advanced electronics in this Novus calculator are manufactured by National Semiconductor Corporation, a world leader in the design and production of solid-state electronic components. National is a multi-national, NYSE-listed company that's demonstrated unparalleled growth over the last six years.

Your Novus calculator is built in the USA. That's because American technology — and specifically the know-how of National Semiconductor — is the key to this product's quality, reliability and computation "horsepower." No other manufacturer can equal National's ability to produce rugged, performance-packed components in the large volumes that result in quality products with small price tags.

The same National Semiconductor electronics have helped take Americans to the moon and back, and are the critical "guts" of high-performance products ranging from life-saving medical equipment to consumer products such as color tv's and digital watches.

You now own one of the world's most technically-advanced consumer products. We hope you'll be as proud to use it as we were to make it.
Getting Started

Turn your Novus Scientist on with the switch on the left side of the calculator. The calculator is automatically cleared and the display should now show 0. If it does not, check to see if the battery needs recharging by connecting the Novus AC charger.

AC Charger

Your Novus Scientist is powered by rechargeable batteries. A dot will illuminate (●) on the extreme left side of the display as a low-battery indicator. Although calculations can still be made while the low-battery indicator is on, the battery should be charged as soon as possible. Continued use on a weak battery may result in inaccurate answers. To charge the batteries connect the Novus AC Charger to the jack on the top left side of the machine. A typical full charge takes five hours. You can operate your calculator while the charger is connected. BE SURE THE CALCULATOR IS TURNED OFF BEFORE CONNECTING THE AC CHARGER.

Display

The Novus Scientist displays an 8-digit mantissa and a 2-digit exponent. The calculator will accept and display any positive or negative number between \(-1 \times 10^{-99}\) and \(9.9999999 \times 10^{99}\). Any result larger than \(9.9999999 \times 10^{99}\) will result in an overflow indicated by displaying 8 mantissa digits of the result with the two least significant digits of the 3-digit exponent. Computed results between the range of 0.1 and 99999999 are displayed in floating point format. Results smaller than 0.1 or larger than 99999999 are automatically converted to scientific notation format.

Automatic Display Shutoff

To save battery life, the Novus Scientist shuts off all but the most significant digit of the mantissa if no key has been pressed for approximately 30 seconds. No data has changed and to restore the display without changing its contents, touch \(\text{CHS}\) twice.

Reverse Polish Logic and the Stack Principle

The Novus Scientist uses Reverse Polish logic with four registers called X, Y, Z and T. A register is an electronic element used to store data while it is being displayed, processed or waiting to be processed. The four registers are arranged in a "stack" as follows: (To avoid confusion between the name of a register and its contents, the registers in this diagram and the diagrams in Appendix A are represented by capital letters X, Y, Z and T and the contents of the registers by lower case letters x, y, z and t).
The display always shows the contents (x) of register X. See Appendix A for diagrams showing what happens to the stack for each operation of the Novus Scientist.

**Keying In and Entering Numbers**

To enter the first number in a 2-function calculation, key in the number and touch \[\text{ENT}\]. If your number includes a decimal point, key it in with the number. If a decimal is keyed in more than once in a number entry, the calculator will use the last decimal keyed in. You do not have to key in the decimal in whole numbers.

To enter a negative number, key in the number and touch \[\text{CHS}\].

**Scientific Notation**

Any number can be entered into the Novus Scientist in scientific notation—that is, as a number (mantissa) multiplied by 10 raised to a power (exponent). The exponent indicates how many places the decimal point should be moved. If the exponent is positive, the decimal is moved to the right. If the exponent is negative, the decimal is moved to the left. For example: 1200 can be entered as \(1.2 \times 10^3\). Key in: \(1.2 \text{ EE } 3\), the display shows: 1.2 03. Note: The last two digits on the right side of the display are used to indicate exponents.

Very large and very small numbers must be entered in scientific notation. For example: 134,000,000,000,000 (written \(1.34 \times 10^{14}\)) must be keyed in: \(1.34 \text{ EE } 14\); display shows: 1.34 14. To enter a negative exponent, touch \[\text{CHS}\] after keying in the exponent. Example: .000000000034 (written \(3.4 \times 10^{-11}\)) must be keyed in: \(3.4 \text{ EE } 11 \text{ CHS}\), display shows: 3.4 ~ 11.

If \[\text{EE}\] has not been preceded by a mantissa entry, the \[\text{EE}\] depression is ignored.

**Correcting Mistakes**

To clear a wrong number entry, touch \[\text{C}\]. Touching \[\text{C}\] clears the X register (display) and drops the stack down.

To correct a wrong exponent entry, just key in the correct exponent. If more than two numbers are keyed in after touching \[\text{EE}\], the calculator retains the last two numbers keyed in as the exponent.

To correct a wrong mantissa entry after \[\text{EE}\] has been touched, touch \[\text{EE}\] (decimal). This will clear the display to 0 and allow re-entry of the mantissa and exponent.
Keyboard Layout

1. Low voltage indicator when lit.
2. On/Off switch.
3. Mantissa
4. AC charger jack
5. LOAD/STEP/RUN switch
6. Number entry keys
7. Enter key
8. Clear key
9. Memory function keys
10. Enter exponent key
11. Basic function keys
12. Change sign key
13. Log function keys
14. Power and root key
15. Trig function keys
16. Pi entry key
17. Inverse trig function key
18. Program control keys
19. Square root, reciprocal and exchange keys
20. Start, halt, skip, del keys
21. Enter exponent key
22. Memory function keys
23. Roll stack key
24. Basic function keys
25. Change sign key
26. Enter exponent key
27. Memory function keys
Keyboard Callouts

arc  Touched before sin, cos or tan computes the inverse sine, cosine or tangent (in degrees), respectively, of the number in the display.

sin  Computes the sine of the angle (in degrees) in the display.

cos  Computes the cosine of the angle (in degrees) in the display.

tan  Computes the tangent of the angle (in degrees) in the display.

$\pi$  Enters $\pi = 3.1415927$ into the display (X register), and raises stack.

log  Computes the common logarithm of the number in the display.

$10^x$  Computes the common antilogarithm of the number in the display. (Raises 10 to 'x' power).

ln  Computes the natural logarithm of the number in the display.

$e^x$  Computes the natural antilogarithm of the number in the display. (Raises $e = 2.7182812$ to the 'x' power).

$y^x$  Raises 'y' to the 'x' power.

$\sqrt{\text{ }}$  Computes the square root of the number in the display.

$1/x$  Computes the reciprocal of the number in the display. (Divides 1 by 'x').

$x\leftrightarrow y$  Exchanges the number now in the display with the number last in the display.

MR  Recalls the contents of memory to the display (X register), and raises stack.

MS  Stores the number in the display in memory.

ROLL  Moves the contents of register X to register T, the contents of register Y to register X, the contents of register Z to register Y and the contents of register T to register Z.

EE  Instructs the calculator to accept the next number keyed in as an exponent of 10.

CHS  Changes the sign of the number in the display.

ENT  Enters the number in the display (x register) into a working register (y register).

$\div$  Divides 'y' by 'x'.

$\times$  Multiplies 'y' by 'x'.

$-$  Subtracts 'x' from 'y'.

$+$  Adds 'x' to 'y'.

$\text{C}$  Clears contents of display (x register) and rolls stack down.

See page 8 for explanation of program control keys.
Performing Calculations

In addition to the separate memory, there are four locations where numbers can be kept for operations. These locations are called registers and in the Scientist these have been combined into an automatic stack. The Novus Scientist uses the four-level stack along with Reverse Polish logic to allow calculations according to mathematical hierarchy.

Mathematical Hierarchy and Reverse Polish Logic

Hierarchy is a term for the rules of mathematics referring to the order of performance of operations on numbers. Those rules are:

1. Do the problem left to right.
2. Do all operations within parentheses, if any, first.
3. Perform operations in the following order:
   a. raising to powers, taking roots, trig, log and reciprocal functions,
   b. multiplication and division,
   c. addition and subtraction.
4. Repeat steps 1 through 3 until the calculation is complete.

Example: The equation \((3^3 + 2)^4 + \sin 30/\sqrt{25}\) is solved according to the rules of hierarchy as follows:

1. \(3^3 = 27\).
2. \(2 + 27 = 29\).
3. \(29 \times 4 = 116\).
4. \(\sin 30 = .5\)
5. \(\sqrt{25} = 5\).
6. \(.5 + 5 = .1\)
7. \(116 + .1 = 116.1\)

Following these three steps, you can calculate the example equation \((3^3 + 2)^4 + \sin 30/\sqrt{25}\) using Reverse Polish logic as follows:

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ENT</td>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>(\sqrt{\cdot})</td>
<td>26.999981*</td>
<td>(3^3)</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>(+)</td>
<td>28.999981</td>
<td>((3^3 + 2))</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>(\times)</td>
<td>115.99992</td>
<td>((3^3 + 2)^4)</td>
</tr>
<tr>
<td>30</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>(\sin)</td>
<td>0.5000002</td>
<td>(\sin 30)</td>
</tr>
<tr>
<td>25</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>(\sqrt{\cdot})</td>
<td>5</td>
<td>(\sqrt{25})</td>
</tr>
<tr>
<td>(\div)</td>
<td>0.1</td>
<td>(.5 + 5)</td>
</tr>
<tr>
<td>(+)</td>
<td>116.09992</td>
<td>((3^3 + 2)^4 + \sin 30/\sqrt{25})</td>
</tr>
</tbody>
</table>

Calculation is complete and performed according to the rules of hierarchy.

*Note: The actual results which occur when performing special functions must be rounded off to the third to sixth place for greater accuracy. The inaccuracy (e.g. \(3^3 = 26.999981\) instead of 27) of answers occurs because extra guard digits and rounding techniques are not employed during calculations in order to simplify the technical design of your calculator.
One-Factor Calculations
The one-factor functions are listed below. These function keys operate on the displayed entry or result, that is, the indicated trig, log or other special operation is performed automatically when you depress one of these keys:

Examples:
\[ \sin 30^\circ = 0.5 \]
Key in: 30 \( \sin \); display shows 0.5000002
\[ \cos^{-1} 0.5 = 60 \]
Key in: 0.5 \( \cos \); display shows 60.000454
\( \sqrt{ } \)
Computes the square root of the number in the display.
Example: Key in: 2 \( \sqrt{ } \); display shows 0.5.
\( \ln \)
Computes the natural logarithm of any positive number in the display.
\( e^x \)
Computes the natural antilog of the number in the display by raising 'e' (2.7182812) to the power in the display.
\( \log \)
Computes the common logarithm of any positive number in the display.
\( 10^x \)
Computes the common antilog of the number in the display by raising 10 to the power in the display.
\( \sin \)
Computes the sine of the angle (in degrees) in the display.
\( \cos \)
Computes the cosine of the angle (in degrees) in the display.
\( \tan \)
Computes the tangent of the angle (in degrees) in the display.
\( \text{arc} \)
Touched before \( \sin \), \( \cos \), or \( \tan \), computes the arc sine, arc cosine or arc tangent (in degrees), respectively, of the number in the display.

Two-Factor Calculations
Functions involving more than one variable are performed by keying in the first factor and depressing \( \text{ENT} \), keying in the second factor and depressing \( \times \) for multiplication, \( \div \) for division, \( y^x \) for raising \( y \) (value entered on \( \text{ENT} \)) to the power keyed in as the second entry.

Examples:
\[ 15 - 3 = 12 \]
Key in: 15 \( \text{ENT} \) 3 \( \div \); display shows 12
\[ 12 \div 4 = 16 \]
Key in: 12 \( \text{ENT} \) 4 \( \div \); display shows 16
\[ 10 \div 2 = 5 \]
Key in: 10 \( \text{ENT} \) 2 \( \div \); display shows 5
\[ 6 \times 5 = 30 \]
Key in: 6 \( \text{ENT} \) 5 \( \times \); display shows 30
\[ 4^3 = 64 \]
Key in: 4 \( \text{ENT} \) 3 \( y^x \); display shows 64.000033
*See note, page 6.*

Chain Calculations
The stack automatically lifts calculated answers when you complete a calculation and drops during calculations involving both the X and Y registers as illustrated on page 20-22. This automatic stack lift and drop allows you to retain intermediate results without re-entering numbers. Many calculations can be approached by keying in numbers in left to right order.

Example:
\[ (2 + 3) \times (4 + 5) = 45 \]
Key in: 2 \( \text{ENT} \) 3 \( + \) 4 \( \text{ENT} \) 5 \( + \) \( \times \)

Memory
\( \text{MS} \)
Stores the number in the display in memory (register M).
\( \text{MR} \)
Recalls the contents of memory (register M) to the display (register X).

To clear memory, key in: 0 \( \text{MS} \).
Programming

The addition of "learn mode" programming to the already powerful Novus Scientist provides the user with a unique time saving approach to the evaluation of long equations or those which require iterative solutions.

"Learn-mode" programming is essentially automatic key pressing. One of the benefits of the "learn-mode" programmer is its inherent simplicity in developing and using a program. Effective use of the programmer does not require any special skills or knowledge of programming languages. If you can use the calculator, you can use the programmer!

The basic technique of "learn-mode" programming is that the programmer remembers the sequence of key depressions used to solve a problem. Therefore, to program the calculator, all the user must do is solve the problem correctly once with the programmer in LOAD mode. Even if mistakes are made, when the proper corrections are made the programmer will learn the corrections and yield the proper solution.

Programming Function Keys

LOAD/STEP/RUN Switch
LOAD — Allows loading of program steps into the program storage area.
STEP — Executes one step of a stored program for each touch of start.
RUN — Permits execution of programs by use of the start or skip keys.

Programming Keys

start The start key has functions in both the LOAD and RUN modes.
In LOAD mode, touching start will erase all previously stored information in the program storage area, write a START code and mark the beginning of the first program. In the RUN mode, touching start begins execution of the first program. If the programmer is stopped at a HALT code (explained below), touching start continues the program to the next HALT or to the end of the program. After reaching the end of a program, the programmer always returns to the START code at the beginning of the first program.
skip The skip key has functions in both the LOAD and RUN modes. In the LOAD mode, touching skip marks the beginning of programs other than the first. It writes a SKIP code for each subsequent program. In RUN mode, touching skip causes the programmer to jump from the beginning of a program, or from a HALT point, to the beginning of the next program and begin execution of that program. Execution continues to the first HALT or to the end. If only one program is stored and the programmer is stopped at a HALT, touching skip will jump over the remaining part of the program and start execution at the beginning of the program. This feature may be used to create a "loop" within the main program. When only two programs are stored, touching skip effectively executes the second program and touching start executes the first. When more than two programs are stored, a HALT code must be programmed in somewhere in all programs except the first. To execute the second program, touch skip, to execute the third program, touch skip twice, to execute the nth program, touch skip n-1 times.

halt The halt key functions only in the LOAD mode and is used to insert a HALT code in the program sequence. In RUN mode, when the programmer encounters a HALT code, it stops the playback of the program and returns control of the calculator back to the user. halt is usually used as a pause in the program
execution to allow the reading of an intermediate result and/or to input a variable for further processing. Normally, **start** is used to leave the HALT condition and continue execution of the program, but it will also allow branching to the next or subsequent programs if **skip** is touched.

**del**

The **del** key (delete) functions only in the LOAD mode and is used for editing the program. Its purpose is to remove entries from the program memory. Touching **del** always starts with the last program step entered and removes one entry each time it is touched. It is essentially a backspace key. Using the **del** key can cause the error alarm to come on if an attempt is made to delete a START or SKIP code. When a SKIP code is deleted, the alarm means that an entire program has been removed. Touching **del** again will turn off the error alarm and delete the last step of the program preceding the deleted SKIP. If the alarm does not go off with the next touch of **del**, it means that the START code is the only code left in the program memory and all programs have been cleared. The START code cannot be deleted. If a SKIP code is deleted accidentally, re-entering **skip** will reinitiate that program.

**Error Alarm**

The programmable Scientist has a program memory capacity of 100 steps. If more than 100 program steps are entered, or if a SKIP code is deleted, or an attempt is made to delete a START code, an error alarm consisting of all decimal points will be displayed. For example, (.1.2.3.4.5.....) would indicate an error alarm.

**Entering Variables**

With the LOAD/STEP/RUN switch in RUN position, when the program encounters a HALT code, control of the calculator is returned to the user. A variable can be entered for further processing at that time. A variable consists of any number entry key (0-9), **CHS** or **π**. Touching **start** after the variable has been entered continues the program from the HALT code.

**Entering Constants**

With the LOAD/STEP/RUN switch in LOAD position, keying in any number entry key (0-9), **CHS** or **π** WITHOUT preceding the number with a HALT code enters the number in the program as a constant. This constant will be automatically keyed in and used each time the program is run.

**Programmer Control Operations**

The following table summarizes the operations of the programming switch and keys.

<table>
<thead>
<tr>
<th>KEY</th>
<th>LOAD MODE</th>
<th>RUN MODE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>start</strong></td>
<td>Clears program area and writes START code.</td>
<td>Starts first program or continues from a HALT.</td>
</tr>
<tr>
<td><strong>skip</strong></td>
<td>Marks beginning of programs subsequent to the first.</td>
<td>Jumps over remainder of a program and begins execution of the next program.</td>
</tr>
<tr>
<td><strong>del</strong></td>
<td>Deletes the last step entered in a program.</td>
<td>No function.</td>
</tr>
<tr>
<td><strong>halt</strong></td>
<td>Writes a HALT code in the program and returns control of calculator to user.</td>
<td>No function.</td>
</tr>
</tbody>
</table>
Desired flow of execution:

Entering Single Programs

The programmable Scientist functions as a calculator while it is being programmed, thus enabling you to use actual data to get a meaningful result as you program. While it is not necessary to use actual data while keying in a sequence of programming steps, doing so for simple, non-iterative programs can be quite helpful. This feature lets you "debug" your program by seeing if the calculated result displayed at the end of programming is the same as your predicted result for the calculations involved. If it is, you have keyed in the program correctly.

Example: Program the Scientist to convert the rectangular coordinates X and Y to polar coordinates R and θ. Using actual variables X = 6 and Y = 8, we can can predict results of:

\[ R = \sqrt{X^2 + Y^2} = \sqrt{6^2 + 8^2} = \sqrt{100} = 10, \]  
\[ \theta = \arctan \frac{Y}{X} = \arctan \frac{8}{6} = \arctan 1.3333333 \approx 53.12998 \]

Desired flow of execution:

<table>
<thead>
<tr>
<th>Switch Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN position</td>
<td>Permits execution of programs by use of [start] or [skip].</td>
</tr>
<tr>
<td>LOAD position</td>
<td>Allows loading of programs into program storage area.</td>
</tr>
<tr>
<td>Switching from LOAD to RUN position</td>
<td>Positions programmer control to begin execution of the first program.</td>
</tr>
<tr>
<td>Switching from RUN to LOAD position</td>
<td>Positions programmer control to begin entering more program steps to the end of the last program entered. Previous program data is not affected. Multiple programs can be added at this point by touching skip.</td>
</tr>
<tr>
<td>STEP position</td>
<td>Executes one step of a stored program for each touch of the start key.</td>
</tr>
</tbody>
</table>

Programming Examples

The following example programs will illustrate the versatility of the programmable Scientist. The following programming symbols will be used to help define the flow of execution of sample programs:

- **Start/Stop Points**
  - [Start/Stop]
- **Procedures**
  - [Procedures]
- **Decisions**
  - [Decisions]
- **Input or Output**
  - [Input or Output]
  - Input (variable or constant data key entry) or Output (displayed results)
Loading the program.

Switch: LOAD position.

<table>
<thead>
<tr>
<th>STEP</th>
<th>KEY ENTRY</th>
<th>DATA ENTRY</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>T</th>
<th>M</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>start</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mark beginning of program.</td>
</tr>
<tr>
<td>2</td>
<td>halt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pause for entry of a variable (X).</td>
</tr>
<tr>
<td>3</td>
<td>ENT</td>
<td>6.</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X.</td>
</tr>
<tr>
<td>4</td>
<td>ENT</td>
<td>6.</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store X in register Z.</td>
</tr>
<tr>
<td>5</td>
<td>x</td>
<td>36.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X².</td>
</tr>
<tr>
<td>6</td>
<td>halt</td>
<td>36.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pause to enter Y.</td>
</tr>
<tr>
<td>7</td>
<td>MS</td>
<td>8.</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Store Y in register M.</td>
</tr>
<tr>
<td>8</td>
<td>ENT</td>
<td>8.</td>
<td></td>
<td></td>
<td>36</td>
<td></td>
<td></td>
<td>Y.</td>
</tr>
<tr>
<td>9</td>
<td>x</td>
<td>64.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Y².</td>
</tr>
<tr>
<td>10</td>
<td>+</td>
<td>100.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X² + Y².</td>
</tr>
<tr>
<td>11</td>
<td>√</td>
<td>10.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>√(X² + Y²).</td>
</tr>
<tr>
<td>12</td>
<td>halt</td>
<td>10.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pause to display R.</td>
</tr>
<tr>
<td>13</td>
<td>x-y</td>
<td>6.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Recover Y.</td>
</tr>
<tr>
<td>14</td>
<td>MR</td>
<td>8.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Recall X.</td>
</tr>
<tr>
<td>15</td>
<td>x-y</td>
<td>6.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Exchange to divide Y by X.</td>
</tr>
<tr>
<td>16</td>
<td>÷</td>
<td>1.33333333</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td>Y/X.</td>
</tr>
<tr>
<td>17</td>
<td>arc</td>
<td>1.33333333</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>tan</td>
<td>53.12998</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td>8</td>
<td>0 displayed. End of program.</td>
</tr>
</tbody>
</table>
Running the program.
Now that the program for converting rectangular coordinates to polar coordinates has been loaded, convert the following rectangular coordinates to polar coordinates:

- $X = 5, Y = 9$
- $X = 7, Y = 4$
- $X = 3, Y = 3$

Switch: RUN position.

### KEY IN | DISPLAY SHOWS
--- | ---
start | 
5 | 5.
start | 25.
9 | 9
start | 10.29563
start | 60.945697
start | 60.945697
7 | 7
start | 49.
4 | 4
start | 8.062257
start | 29.744463
start | 29.744463
3 | 3
start | 9.
3 | 3
start | 4.24264
start | 45.000654

### COMMENTS
- Starts first program and executes to first HALT.
- First $X$.
- Continue program to next HALT.
- First $Y$.
- Continue program to next HALT, $R$ displayed.
- Continue program to end, $\theta$ displayed.
- Start first program.
- Next $X$.
- Continue program.
- Next $Y$.
- Next $R$ displayed.
- Next $\theta$ displayed.
- Start first program.
- Next $X$.
- Continue program.
- Next $Y$.
- Next $R$ displayed.
- Next $\theta$ displayed.

### Entering Multiple Programs
Example: Find the area or circumference of a circle or volume of a sphere of radius $r$, whichever is needed. From Appendix B — Part 3:

- Area of circle = $\pi r^2$,
- Circumference of circle = $2\pi r$,
- Volume of sphere = $\frac{4}{3}\pi r^3$.

It is apparent that no matter which formula is needed, $r$ is going to be used. Thus the programs can be written to store the value of $r$ in memory beforehand. No data is entered during the program.

Desired flow of execution:
Loading the program. Using \( r = 5 \) as a test variable.

<table>
<thead>
<tr>
<th>STEP</th>
<th>KEY ENTRY</th>
<th>DATA ENTRY</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>T</th>
<th>M</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Switch: LOAD position.

1. `start` 5
   - `\pi` 3.1415927
   - `5`

2. `\pi` 3.1415927
   - `5`

3. `ENT` 3.1415927
   - `5`

4. `MR` 3.1415927
   - `5`

5. `ENT` 3.1415927
   - `5`

6. `X` 25
   - `3.1415927`

7. `X` 78.539817
   - `5`

8. `skip` 78.539817
   - `5`

9. `halt` 78.539817
   - `5`

There are more than two programs. Each program subsequent to the first program must have a HALT.

10. `MR` 78.539817
    - `5`

11. `ENT` 78.539817
    - `5`

12. `\pi` 3.1415927
    - `78.539817`

13. `X` 15.707963
    - `78.539817`

14. `2` 2
    - `15.707963`

15. `X` 31.415926
    - `78.539817`

16. `skip` 31.415926
    - `78.539817`

17. `halt` 31.415926
    - `78.539817`

Same as Step 9.

18. `MR` 31.415926
    - `78.539817`

19. `ENT` 31.415926
    - `78.539817`

20. `3` 3
    - `31.415926`

21. `y^2` 124.99984
    - `0`

22. `\pi` 3.1415927
    - `124.99984`

Since no HALT preceded this number entry, it is treated as a constant in the program.
Running the program.

Now that the programs for the area and circumference of a circle and the volume of a sphere of radius \( r \) have been loaded, solve the following problems:

- **Problem 1.** Area and circumference of a circle of radius 7.
- **Problem 2.** Circumference of a circle of radius 9 and volume of a sphere of radius 9.
- **Problem 3.** Area of a circle of radius 6.5 and volume of a sphere of radius 6.5.
- **Problem 4.** Area and circumference of a circle of radius 12.35 and volume of a sphere of radius 12.35.

Switch: **RUN** position.

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>7</td>
<td>( r = 7 ) for Problem 1.</td>
</tr>
<tr>
<td>MS</td>
<td>7</td>
<td>Store radius in memory.</td>
</tr>
<tr>
<td>start</td>
<td>153.93804</td>
<td>Area of circle of ( r = 7 ).</td>
</tr>
<tr>
<td>skip</td>
<td>153.93804</td>
<td>Skip program 1 to start program 2.</td>
</tr>
<tr>
<td>start</td>
<td>43.982296</td>
<td>Circumference of circle of ( r = 7 ).</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>New radius.</td>
</tr>
<tr>
<td>MS</td>
<td>9</td>
<td>Store in memory.</td>
</tr>
<tr>
<td>skip</td>
<td>9</td>
<td>Skip program 1 to start program 2.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>start</td>
<td>56.548668</td>
<td>Circumference of circle of ( r = 9 ).</td>
</tr>
<tr>
<td>skip</td>
<td>56.548668</td>
<td>Skip program 1.</td>
</tr>
<tr>
<td>skip</td>
<td>56.548668</td>
<td>Skip program 2 to start program 3.</td>
</tr>
<tr>
<td>start</td>
<td>3053.6295</td>
<td>Volume of sphere of ( r = 9 ).</td>
</tr>
<tr>
<td>6.5</td>
<td>6.5</td>
<td>New radius.</td>
</tr>
<tr>
<td>MS</td>
<td>6.5</td>
<td>Store in memory.</td>
</tr>
<tr>
<td>start</td>
<td>132.73229</td>
<td>Area of circle of ( r = 6.5 ).</td>
</tr>
<tr>
<td>skip</td>
<td>132.73229</td>
<td>Skip program 1.</td>
</tr>
<tr>
<td>skip</td>
<td>132.73229</td>
<td>Skip program 2.</td>
</tr>
<tr>
<td>start</td>
<td>1150.3467</td>
<td>Volume of sphere of ( r = 6.5 ).</td>
</tr>
<tr>
<td>12.35</td>
<td>12.35</td>
<td>New radius.</td>
</tr>
<tr>
<td>MS</td>
<td>12.35</td>
<td>Store in memory.</td>
</tr>
<tr>
<td>start</td>
<td>479.16357</td>
<td>Area of circle of ( r = 12.35 ).</td>
</tr>
<tr>
<td>skip</td>
<td>479.16357</td>
<td>Skip program 1.</td>
</tr>
<tr>
<td>start</td>
<td>77.597338</td>
<td>Circumference of circle of ( r = 12.35 ).</td>
</tr>
<tr>
<td>77.597338</td>
<td></td>
<td>Skip program 1.</td>
</tr>
<tr>
<td>7890.2338</td>
<td></td>
<td>Volume of sphere of ( r = 12.35 ).</td>
</tr>
</tbody>
</table>
Entering Iterative Programs

At the end of a program, the programmer always positions program control at the beginning of the first program. This feature can be used to do iterative programs. The iterative part of the program is programmed in just once and then executed as many times as needed.

Example: Program the Scientist to find Chi Square ($\chi^2$) for the following data:

<table>
<thead>
<tr>
<th>O_i</th>
<th>2</th>
<th>3</th>
<th>5</th>
<th>7</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>E_i</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Using the equation:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

We can program the equation and use the program $n = 5$ times.

Loading the program.

Since this is an iterative program, "real" variables cannot be used to get a test result at the end of programming. Use a "test" variable of 1 to avoid making logic errors (e.g. division by zero) during programming.

Switch: LOAD position.

<table>
<thead>
<tr>
<th>STEP</th>
<th>KEY ENTRY</th>
<th>DATA ENTRY</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
<th>T</th>
<th>M</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>start</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Enter test variable (1).</td>
</tr>
<tr>
<td>2</td>
<td>ENT</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>Since the first step in the program is ENT, the program will use whatever is in the display for data, thus eliminating the need for a HALT to enter one of the variables ($O_i$).</td>
</tr>
<tr>
<td>3</td>
<td>halt</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pause to enter $E_i$.</td>
</tr>
<tr>
<td>4</td>
<td>MS</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>Store $E_i$ for later division.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>$O_i - E_i$.</td>
</tr>
</tbody>
</table>

Desired flow of execution:

```
START
\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}

i = n

NO

YES

END
```
Running the program.

Figuring \( x^2 \) for the following data:

\[
\begin{array}{cccc}
O_i & 2 & 3 & 5 & 7 & 2 \\
E_i & 4 & 4 & 3 & 5 & 3 \\
\end{array}
\]

Switch: RUN position.

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENT</td>
<td>0.</td>
<td></td>
</tr>
<tr>
<td>ENT</td>
<td>0.</td>
<td>Clear registers X and Y.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>( O_1 ).</td>
</tr>
<tr>
<td>start</td>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>( E_1 ).</td>
</tr>
<tr>
<td>start</td>
<td>1.</td>
<td>( \sum (O_i - E_i)^2 / E_i ). This is the basic program. Continue to re-run it as long as necessary (n = 5 times).</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>( O_2 ).</td>
</tr>
<tr>
<td>start</td>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>( E_2 ).</td>
</tr>
<tr>
<td>start</td>
<td>1.25</td>
<td>Summation with n = 2.</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>( O_3 ).</td>
</tr>
<tr>
<td>start</td>
<td>5.</td>
<td></td>
</tr>
</tbody>
</table>

Looping and Branching

Using the start key to loop, and the skip key to branch, allows an iterative calculation and use of the results of that calculation in subsequent calculations. The following is an example of this technique.

Example: Program the Scientist to find the mean, variance and standard deviation of the following data:

\((2, 7, 3, 5, 2)\).

Using the formulas:

\[
\text{Mean} = \bar{x} = \frac{\Sigma x}{n},
\]

\[
\text{Variance} = \sigma^2 = \frac{\Sigma x^2 - n(\Sigma x/n)^2}{n-1},
\]

\[
\text{Standard Deviation} = \sigma = \sqrt{\sigma^2}.
\]
Desired flow of execution:

START  \[ \begin{array}{c} \text{SUM} \\ X_i \text{ and } X_i^2 \end{array} \] \[ i = n? \] \[ \begin{array}{c} \text{YES} \\ \text{COMPUTE } \bar{X} \\ \text{COMPUTE } \sigma^2 \\ \text{COMPUTE } \sigma \end{array} \] \[ \text{END} \]

Loading the program:
Since this is an iterative program, we will load the stack with a dummy variable \( = 2 \) to avoid making logic errors (e.g., dividing by zero).

<table>
<thead>
<tr>
<th>Switch: LOAD position.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>LINE NO.</th>
<th>KEY ENTRY</th>
<th>DATA ENTRY</th>
<th>REGISTER CONTENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
</tr>
<tr>
<td>2 ENT ENT</td>
<td>start</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 MS</td>
<td>( x_i )</td>
<td>( \Sigma x_i )</td>
<td>n</td>
</tr>
<tr>
<td>2 +</td>
<td>( \Sigma x_i )</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
</tr>
<tr>
<td>3 MR</td>
<td>( x_i )</td>
<td>( \Sigma x_i )</td>
<td>n</td>
</tr>
<tr>
<td>4 x-y</td>
<td>( \Sigma x_i )</td>
<td>( x_i )</td>
<td>n</td>
</tr>
<tr>
<td>5 MS</td>
<td>( \Sigma x_i )</td>
<td>( x_i )</td>
<td>n</td>
</tr>
<tr>
<td>6 C</td>
<td>( x_i )</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
</tr>
<tr>
<td>7 roll</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
<td>x_i</td>
</tr>
<tr>
<td>8 x-y</td>
<td>( \Sigma (x_i)^2 )</td>
<td>n</td>
<td>x_i</td>
</tr>
<tr>
<td>9 roll</td>
<td>n</td>
<td>x_i</td>
<td>x_i</td>
</tr>
<tr>
<td>10 roll</td>
<td>( x_i )</td>
<td>( \Sigma (x_i)^2 )</td>
<td>n</td>
</tr>
<tr>
<td>11 roll</td>
<td>( x_i )</td>
<td>( \Sigma (x_i)^2 )</td>
<td>n</td>
</tr>
<tr>
<td>12 ENT</td>
<td>( x_i )</td>
<td>( x_i )</td>
<td>( \Sigma (x_i)^2 )</td>
</tr>
<tr>
<td>13 ×</td>
<td>( x_i^2 )</td>
<td>( \Sigma (x_i)^2 )</td>
<td>n</td>
</tr>
<tr>
<td>14 +</td>
<td>( \Sigma (x_i)^2 )</td>
<td>n</td>
<td>( \Sigma x_i )</td>
</tr>
<tr>
<td>15 x-y</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
</tr>
<tr>
<td>17 +</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
<td>( \Sigma x_i )</td>
</tr>
<tr>
<td>18 MR</td>
<td>( \Sigma x_i )</td>
<td>n</td>
<td>( \Sigma (x_i)^2 )</td>
</tr>
<tr>
<td>LINE NO.</td>
<td>KEY ENTRY</td>
<td>DATA ENTRY</td>
<td>X</td>
</tr>
<tr>
<td>---------</td>
<td>-----------</td>
<td>------------</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>skip</td>
<td></td>
<td>$\Sigma x_i$</td>
</tr>
<tr>
<td></td>
<td>$x-y$</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>19</td>
<td>MS</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>21</td>
<td>$\div$</td>
<td></td>
<td>$\Sigma x_i/n$</td>
</tr>
<tr>
<td>22</td>
<td>ENT</td>
<td></td>
<td>$\Sigma x_i/n$</td>
</tr>
<tr>
<td>23</td>
<td>$\times$</td>
<td></td>
<td>$(\Sigma x_i/n)^2$</td>
</tr>
<tr>
<td>24</td>
<td>MR</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>25</td>
<td>$\div$</td>
<td></td>
<td>$\Sigma (x_i)^2-n(\Sigma x_i/n)^2$</td>
</tr>
<tr>
<td>26</td>
<td>MR</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>27</td>
<td>$\times$</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>28</td>
<td>$-$</td>
<td></td>
<td>$\Sigma (x_i)^2-n(\Sigma x_i/n)^2$</td>
</tr>
<tr>
<td>29</td>
<td>MR</td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>30</td>
<td>$-$</td>
<td></td>
<td>n-1</td>
</tr>
<tr>
<td>31</td>
<td>$-$</td>
<td></td>
<td>n-1</td>
</tr>
<tr>
<td>32</td>
<td>$\div$</td>
<td></td>
<td>$\Sigma (x_i)^2-n(\Sigma x_i/n)^2$</td>
</tr>
<tr>
<td>33</td>
<td>halt</td>
<td></td>
<td>$\Sigma (x_i)^2-n(\Sigma x_i/n)^2$</td>
</tr>
<tr>
<td>34</td>
<td>$\sqrt{}$</td>
<td></td>
<td>$\sqrt{\Sigma (x_i)^2-n(\Sigma x_i/n)^2}$</td>
</tr>
</tbody>
</table>
Running the program.
Calculate the mean, variance and standard deviation for the following data: (2, 7, 3, 5, 2).

Switch: RUN position.

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0</td>
<td>Clears stack.</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>Clears stack.</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>Clears stack.</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>Clears stack.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>$x_1$.</td>
</tr>
<tr>
<td>start</td>
<td>2</td>
<td>Start program, loop to sum $x$, $x^2$ and $n$.</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>$x_2$.</td>
</tr>
<tr>
<td>start</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>$x_3$.</td>
</tr>
<tr>
<td>start</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>$x_4$.</td>
</tr>
<tr>
<td>start</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>$x_5$.</td>
</tr>
<tr>
<td>start</td>
<td>19</td>
<td>The iteration (looping) part of the program is finished. Branch to the part of the program that uses the data obtained in the interactive part.</td>
</tr>
<tr>
<td>skip</td>
<td>3.8</td>
<td>Program pauses to display $x$.</td>
</tr>
<tr>
<td>start</td>
<td>4.7</td>
<td>Program pauses to display $s^2$.</td>
</tr>
<tr>
<td>start</td>
<td>2.1679483</td>
<td>End of program. Program displays $s$.</td>
</tr>
</tbody>
</table>

1. To clear display before starting program, touch [C] until a zero appears in the display. To clear memory, touch [0 MS].
2. To load a program, move LOAD/STEP/RUN switch to LOAD position.
3. Mark the beginning of the first program with start. Mark the beginning of all subsequent programs with skip. If more than two programs are being stored, all except the first must have a HALT command as part of the program to permit accessing of those programs.
4. To interrupt a program, whether to enter a variable or to display a result, touch halt.
5. To enter a constant, key in the desired number. It becomes part of the program.
6. To enter a variable, key in halt, then the desired number. It does not become part of the program, but is used to "debug" the program.
7. To run programs, move the LOAD/STEP/RUN switch to RUN position.
8. To start the first program, touch start. To start second program, touch skip. To start nth program, touch skip n-1 times.
Error Conditions

In the event of a logic error (e.g., division by zero) the Novus Scientist will display all zeros and decimal points. An error condition is reset by touching C. All registers are cleared to zero. Memory is not affected by error conditions. See Appendix C, Table 1, for a complete table of improper operations.

Appendix A — Stack Diagrams

The following diagrams show what happens to the stack for each operation on the Novus Scientist. Contents of registers are indicated by lower case letters x, y, z and t. Locations are indicated by capital letters X, Y, Z and T. The display always shows the contents of register X. Memory is register M.

<table>
<thead>
<tr>
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<td>x</td>
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f(x): y + x → X
y - x → X
y × x → X
y ÷ x → X
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<td></td>
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<td>X*</td>
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*Note: Calculator conditioned to accept exponent.*

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<td>M</td>
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<td>LOCATION</td>
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<tr>
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<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td>( \ln )</td>
<td>( \log )</td>
<td>0 \rightarrow T</td>
</tr>
<tr>
<td>( \sin, \cos, \tan, e^x, 10^x, \text{arc} ) followed by ( \sin, \cos, \tan )</td>
<td></td>
<td>( t \rightarrow Z \rightarrow Y \rightarrow X \rightarrow \text{lost} )</td>
</tr>
<tr>
<td>( 1/x )</td>
<td>( \sqrt{x} )</td>
<td>( t \rightarrow T \rightarrow Z \rightarrow Y \rightarrow X \rightarrow \text{lost} )</td>
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</table>
Appendix B — Part 1
Some Examples

In the previous sections of this manual is a summary of how the functions of the Novus Scientist work. This appendix demonstrates the versatility of the Scientist in a variety of disciplines.

MATHEMATICS
Real roots of a quadratic equation.
Given the equation $2x^2 + 3x - 4$, find the roots: $x_1$ and $x_2$.

Roots $x_1$ and $x_2$ can be found from the equation:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

where: $a = 2$, $b = 3$ and $c = -4$.

<table>
<thead>
<tr>
<th>STEP</th>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>ENT</td>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>+</td>
<td>-3</td>
<td>2a</td>
</tr>
<tr>
<td>15</td>
<td>MR</td>
<td>4</td>
<td>2a</td>
</tr>
<tr>
<td>16</td>
<td>÷</td>
<td>-2</td>
<td>c/a</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>2.5625</td>
<td>$b^2/4a^2 - c/a = b^2 - 4ac/2a$</td>
</tr>
<tr>
<td>18</td>
<td>√</td>
<td>1.600781</td>
<td>$\sqrt{b^2 - 4ac}/2a$</td>
</tr>
<tr>
<td>19</td>
<td>MS</td>
<td>1.600781</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>+</td>
<td>0.850781</td>
<td>First real root. $x_1 = -b/2a + \sqrt{b^2 - 4ac}/2a$</td>
</tr>
<tr>
<td>21</td>
<td>MR</td>
<td>1.600781</td>
<td>$\sqrt{b^2 - 4ac}/2a$</td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>-0.75</td>
<td>$-b/2a + \sqrt{b^2 - 4ac}/2a$</td>
</tr>
<tr>
<td>23</td>
<td>MR</td>
<td>1.600781</td>
<td>$\sqrt{b^2 - 4ac}/2a$</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>-2.350781</td>
<td>Second real root. $x_2 = -b/2a - \sqrt{b^2 - 4ac}/2a$</td>
</tr>
</tbody>
</table>
Degrees, minutes and seconds to decimal degrees conversion. Convert the following degrees, minutes and seconds to decimal degrees:

56°23'44.5"

<table>
<thead>
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<th>COMMENTS</th>
</tr>
</thead>
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<tr>
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<td>44.5</td>
<td>Seconds.</td>
</tr>
<tr>
<td>ENT</td>
<td>44.5</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>60</td>
<td>60 seconds/minute.</td>
</tr>
<tr>
<td>MS</td>
<td>60.</td>
<td></td>
</tr>
<tr>
<td>÷</td>
<td>0.7416666</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>23</td>
<td>Minutes.</td>
</tr>
<tr>
<td>+</td>
<td>23.741666</td>
<td></td>
</tr>
<tr>
<td>MR</td>
<td>60.</td>
<td>60 minutes/degree.</td>
</tr>
<tr>
<td>÷</td>
<td>0.3956944</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>56</td>
<td>Degrees.</td>
</tr>
<tr>
<td>+</td>
<td>56.395694</td>
<td>Decimal degrees.</td>
</tr>
</tbody>
</table>

Polar to rectangular coordinate conversion. Convert coordinates Θ = 35°, R = 7 to rectangular coordinates.

Using the formula:

\[ X = R \cos \Theta \]  
\[ Y = R \sin \Theta \]

Note: To see X again, touch \( x \)-y.  
See Appendix B - Part 4 for a stack diagram of this example.
What gravitational force does the earth exert on the moon? From Newton's law of universal gravitation,

\[ F = G \frac{m_1 m_2}{r^2} \]

where: \( m_1 \) = mass of the earth \( = 5.98 \times 10^{24} \) kg,  
\( m_2 \) = mass of the moon \( = 7.36 \times 10^{22} \) kg,  
\( r \) = distance from the earth to the moon \( = 3.84 \times 10^8 \) m  
\( G \) = Universal gravitational constant  
\( = 6.67 \times 10^{-11} \) N\( \cdot \)m\(^2\)/kg\(^2\)

therefore:

\[ F = 6.67 \times 10^{-11} \times \frac{5.98 \times 10^{24} \times 7.36 \times 10^{22}}{(3.84 \times 10^8)^2} \]

\[ = 1.99 \times 10^{20} \] newtons.
What is the velocity of a proton (mass $= 1.67 \times 10^{-27}$ kg) which is accelerated through a potential difference of 300 volts?

Since 1 amp is defined as 1 coulomb/second, $12 \text{ A} = 12 \text{ C/s}$. The electron charge $= e = 1.6 \times 10^{-19} \text{ C}$, so a current of 12A corresponds to a flow of:

\[
\frac{12 \text{ C/s}}{1.6 \times 10^{-19} \text{ C/electron}} = 7.5 \times 10^{19} \text{ electrons/sec.}
\]

Using the equation $KE = \frac{1}{2}mv^2$, where $KE = $ kinetic energy of the electron, $m = $ mass of the proton $= 1.67 \times 10^{-27}$ and $v = $ velocity of the electron.

\[
v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 4.8 \times 10^{-17}}{1.67 \times 10^{-27}}} = 2.397 \times 10^5 \text{ meters/sec.}
\]

What is the attractive force between a proton (charge $+e$) and an electron (charge $-e$) in a hydrogen atom where the radius of the electron orbit is $5.3 \times 10^{-11}$ m?
Using Coulomb's law:

$$F = k \frac{Q_1 Q_2}{r^2}$$

where:
- \( k \) = Universal constant = \( 9.0 \times 10^9 \) N-m²/C²
- \( Q_1 \) = charge on particle 1 = charge of proton = \( 1.6 \times 10^{-19} \) C,
- \( Q_2 \) = charge on particle 2 = charge of electron = \( 1.6 \times 10^{-19} \) C,
- \( r \) = distance between two charges = \( 5.3 \times 10^{-11} \) m.

$$F = 9.0 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{(5.3 \times 10^{-11})^2} = 8.2 \times 10^{-8} \text{ newtons.}$$

One of the predictions of Einstein's theory of relativity is that the mass of moving body is greater than its mass at rest. Using the equation:

$$M = \frac{M_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Where:
- \( M \) = mass of the moving body,
- \( M_0 \) = mass of the body at rest,
- \( v \) = velocity of the body,
- \( c \) = speed of light (2.997 \( \times \) \( 10^8 \) m/sec).

Find the mass of an electron traveling at 75% of the speed of light. If the rest mass of an electron is \( 9.109 \times 10^{-31} \) kg. If \( v = 0.75c \), then the equation becomes:

$$M = \frac{M_0}{\sqrt{1 - (0.75c)^2}}$$

Substituting:

$$M = \frac{9.109 \times 10^{-31}}{\sqrt{1 - (0.75)^2}}$$

Display shows:

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<tr>
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</tr>
<tr>
<td>EE</td>
<td>9.109</td>
<td>00</td>
</tr>
<tr>
<td>31</td>
<td>9.109</td>
<td>31</td>
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<tr>
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<td>9.109</td>
<td>-31</td>
</tr>
<tr>
<td>ENT</td>
<td>9.109</td>
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<td>.75</td>
<td>0.75</td>
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<td></td>
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<tr>
<td>X</td>
<td>0.5625</td>
<td>(.75)^2</td>
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<tr>
<td>-</td>
<td>0.4375</td>
<td>1 - (.75)^2</td>
</tr>
<tr>
<td>√</td>
<td>0.6614378</td>
<td>( \sqrt{1 - (.75)^2} )</td>
</tr>
<tr>
<td>÷</td>
<td>1.3771514</td>
<td>-30</td>
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Mass of electron travelling at 75% the speed of light,
= \( M_0 / \sqrt{1 - (0.75)^2} \)
How many gram-atoms of Iron (Fe) are present in 250 grams of iron?

Since the atomic mass of Fe = 55.847 atomic mass units (u) = 55.847 grams/gram atom,

$$\text{Gram-atoms of Fe} = \frac{\text{mass of Fe}}{\text{atomic mass of Fe}} = \frac{250 \text{ grams}}{55.847 \text{ g/gram-atom}}$$

KEY IN | DISPLAY SHOWS | COMMENTS
---|---|---
250 | 250 | Grams of Fe.
ENT | 250 | 
55.847 | 55.847 | Atomic mass of Fe.
4.476516 | 4.476516 | Gram-atoms of Fe in 250 grams.

In the above example, how many atoms of Fe are in the sample?

Since the number of atoms in a sample of any substance is the number of gram-atoms it contains multiplied by Avogadro’s number (N = 6.023 x 10^{23} atoms/gram-atom),

$$\text{Atoms of Fe} = 4.476516 \text{ gram-atoms} \times 6.023 \times 10^{23} \text{ atoms/gram-atom} = 4.476516 \times 6.023 \times 10^{23} = 2.6962 \times 10^{24} \text{ atoms}.$$
What is the molarity of a solution that contains 135 grams of calcium chloride, \( \text{CaCl}_2 \), per liter?

Using the formula mass of \( \text{CaCl}_2 \):
\[
1 \text{ Ca} = 1 \times 40.08 \text{ u} = 40.08 \text{ u} \\
2 \text{ Cl} = 2 \times 35.453 \text{ u} = 70.906 \text{ u} \\
\frac{110.986 \text{ u}}{110.986 \text{ g/mole}} = 110.986 \text{ g/mole}
\]

in the equation:
\[
\text{number of moles} = \frac{\text{mass of CaCl}_2}{\text{formula mass of CaCl}_2} = \frac{135 \text{ grams}}{110.986 \text{ g/mole}} = 1.21 \text{ mole.}
\]

So the concentration of the solution is 1.21 moles/liter.

What is the tension at the ends of a cable where the span is 700 feet and the sag is 45 feet if each cable of the suspension bridge carries a horizontal load of 620 lbs/ft?

Using the equation:
\[
T = \frac{1}{2}wa \sqrt{1 + \frac{a^2}{16d^2}}
\]

where:
- \( T \) = tension,
- \( w \) = weight (horizontal load),
- \( a \) = length of span,
- \( d \) = sag,

\[
= \frac{1}{2} \times 620 \times 700 \times \sqrt{1 + \frac{700^2}{16 \times 45^2}} \\
= 871342 \text{ lbs.}
\]
What is the equivalent resistance of a 220 ohm resistor, a 145 ohm resistor and a 175 ohm resistor connected in parallel?

Using the equation:

\[
R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}
\]

\[
= \frac{1}{\frac{1}{220} + \frac{1}{145} + \frac{1}{175}}
\]

Find the capacitance of a capacitor having eleven 1-sq-inch plates with a dielectric of mica 5 mils thick.

Using the formula:

\[
C = \frac{0.0885 \text{ kA}}{d} \left( n - 1 \right)
\]

where: \( k \) = dielectric constant = 6.5 for mica,

\( A \) = area of one plate in square centimeters,

\( n \) = the number of plates,

\( d \) = distance between plates in centimeters.

\[
C = \frac{0.0885 \times 1 \times (2.54 \text{ cm/in})^2 \times (11 - 1)}{5 \times 10^{-3} \text{ in} \times 2.54 \text{ cm/in}}
\]

\[
= 449.58 \text{ picofarads.}
\]
### Compute the mean ($\bar{x}$) of the following data: (2, 7, 3, 5, 2).

Using the formula:

$$\bar{x} = \frac{\sum x}{n}$$

**Key In** | **Display Shows** | **Comments**
---|---|---
2.54 | 2.54 cm/in. | 
11 | 11 n. | 
1 | 1 | 
5 | 5.03 0.0885 kA (n−1). | 
3 | 5.03 d. | 
2.54 | 2.54 | 
1.27 | 1.27 −02 | 
449.58 | 

**KEY IN** | **DISPLAY SHOWS** | **COMMENTS**
---|---|---
2 | 2 | $x_1$. |
7 | 7 | $x_2$. |
3 | 3 | $x_3$. |
5 | 5 | $x_4$. |
2 | 2 | $x_5$. |
5 | 5 | n. |

Repeat these steps $n-1$ times.

**Mean ($\bar{x}$)**
Compute the harmonic mean \(M_h\) of the following data: \((2, 7, 3, 5, 2)\).

Using the formula:

\[
M_h = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \frac{1}{x_3} + \frac{1}{x_4} + \frac{1}{x_5}}
\]

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</tr>
<tr>
<td>(1/x)</td>
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<td></td>
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<tr>
<td>7</td>
<td>7</td>
<td>(x_2)</td>
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<td>3</td>
<td>3</td>
<td>(x_3)</td>
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<tr>
<td>(1/x)</td>
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<td>5</td>
<td>5</td>
<td>(x_4)</td>
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<tr>
<td>+</td>
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<tr>
<td>5</td>
<td>5</td>
<td>(n)</td>
</tr>
</tbody>
</table>

Repeat these steps \(n-1\) times.

Compute the geometric mean \(M_g\) of the following data: \((2, 7, 3, 5, 2)\).

Using the formula:

\[
M_g = \sqrt[n]{x_1 \cdot x_2 \cdot x_3 \cdot x_4 \cdot x_5}
\]

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<td>(x_1)</td>
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<tr>
<td>(\times)</td>
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<td></td>
</tr>
<tr>
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<td>3</td>
<td>(x_3)</td>
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<td>(\times)</td>
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<tr>
<td>5</td>
<td>5</td>
<td>(x_4)</td>
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<td>2</td>
<td>2</td>
<td>(x_5)</td>
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<tr>
<td>(\times)</td>
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<tr>
<td>5</td>
<td>5</td>
<td>(n)</td>
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<tr>
<td>(1/x)</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>(\sqrt[n]{x})</td>
<td>3.3469546</td>
<td>Geometric mean (M_g).</td>
</tr>
</tbody>
</table>
Find the predicted ground speed and true heading for a planned flight with the following flight triangle factors known:

\[ \alpha = \text{true course} = 30^\circ \]
from North.

\[ \beta = \text{wind direction} = 50^\circ \]
from North.

TAS = true air speed = 140 mph.

V = wind velocity = 42 mph.

\[ \gamma = \text{true heading} \]

PGS = predicted ground speed = ?

### Predicted Ground Speed

Using the equation:

\[
\text{PGS} = V \cos(\beta - \alpha) + \sqrt{[V \cos(\beta - \alpha)]^2 - V^2 + \text{TAS}^2}
\]

\[
= 42 \cos(50 - 30) + \sqrt{[42 \cos (50 - 30)]^2 - 42^2 + 140^2}
\]

### True Heading

Using the equation:

\[
\gamma = \alpha - \arcsin \left( \frac{V \sin(\beta - \alpha)}{\text{TAS}} \right) = 30 - \arcsin \left( \frac{42 \sin (50 - 30)}{140} \right)
\]
Calculate the angle of sight \( \theta \) that chemical retardant should be dropped from a fire-fighting plane to reach the fire if the plane is at 3250 feet with a velocity of 85 mph? Using the formula:

\[
\theta = \arccos \left( \cos \beta \cos \gamma + \sin \beta \sin \gamma \cos \alpha \right) \times 60
\]

where:
- \( \alpha = 122.4^\circ - 77^\circ = 45.4^\circ \),
- \( \beta = 90^\circ - 37.6^\circ = 52.4^\circ \), and
- \( \gamma = 90^\circ - 38.8^\circ = 51.2^\circ \).

\[
a = \arccos \left( \cos 52.4 \cos 51.2 + \sin 52.4 \sin 51.2 \cos 45.4 \right) \times 60.
\]

What is the great circle route between San Francisco and Washington D.C.?

Using the formula:

\[
a = \arccos \left( \cos b \cos c + \sin b \sin c \cos \alpha \right) \times 60
\]

where:
- \( \alpha = 122.4^\circ - 77^\circ = 45.4^\circ \),
- \( b = 90^\circ - 37.6^\circ = 52.4^\circ \), and
- \( c = 90^\circ - 38.8^\circ = 51.2^\circ \).

\[
a = \arccos \left( \cos 52.4 \cos 51.2 + \sin 52.4 \sin 51.2 \cos 45.4 \right) \times 60.
\]
\[ \theta = \tan^{-1} \frac{v_0 t}{y} \]

Where: \( \theta \) = angle of sight,
\( v_0 \) = velocity of the plane,
\( y \) = altitude of the plane,
\( t \) = time of fall for the retardant.

Time of fall for the retardant can be calculated using the formula:

\[ t = \sqrt{\frac{2y}{g}} \]

Where: \( g \) = force of gravity = 32 ft/sec\(^2\).

**FINANCE**

What will $7,000 be worth in five years if it is compounded annually at a rate of 8.2% per year?

Using the formula: \( FV = PV(1 + i)^n \)

where: \( FV \) = future value,
\( PV \) = present value,
\( i \) = interest per period (in decimal),
\( n \) = number of periods.

\[ = 7000 (1 + .082)^5 \]

**KEY IN** | **DISPLAY SHOWS** | **COMMENTS**
--- | --- | ---
1 | 1 | Base number.
ENT | 1. | Enter.
.082 | 0.082 | i, interest per period.
+ | 1.082 | Add.
5 | 5 | n, number of periods.
\( \times \) | 1.4829825 | \((1 + i)^n\).
7000 | 7000 | PV, present value.
\( \times \) | 10380.877 | Future value (FV).

Compute the annual rate of return (after taxes) of an investment of $10,000 which, after 3\( \frac{1}{2} \) years is worth $12,550 if the tax rate is 38%.

Using the formula:

\[ r = \frac{(FV - PV)(1 - \text{tax rate})}{PV} \times n \]

Where: \( r \) = rate of return,
\( FV \) = future value,
\( PV \) = present value,
\( n \) = number of periods.

**KEY IN** | **DISPLAY SHOWS** | **COMMENTS**
--- | --- | ---
12550 | 12550 | FV.
ENT | 12550. | Enter.
10000 | 10000 | PV.
MS | 10000. | Save for use in dividing.
- | 2550. | FV - PV.
Part 1.
What is the annual payment on a loan of $86,000 taken for 10 years if the rate is 8% per year?

Using the formula:
\[
PMT = \frac{PV \times (1 + i)^{n}}{1 - (1 + i)^{-n}}
\]
where:
- \( PMT \) = payment,
- \( PV \) = present value,
- \( i \) = interest rate per period (in decimal),
- \( n \) = number of periods.

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>ENT</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>.08</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>1.08</td>
<td>1 + i</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>n</td>
</tr>
<tr>
<td>CHS</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>( x^y )</td>
<td>0.4631938</td>
<td>( (1 + i)^{-n} )</td>
</tr>
<tr>
<td>CHS</td>
<td>-0.4631938</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Part 2.
In the above example (part 1), what is the remaining balance after the sixth payment?

Using the formula:
\[
BAL_k = PMT \left[ \frac{1 - (1 + i)^{k-n}}{i} \right]
\]

Where:
- \( k \) = number of payments made.

<table>
<thead>
<tr>
<th>KEY IN</th>
<th>DISPLAY SHOWS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5368062</td>
<td>1 - (1 + i)^{-n}</td>
<td></td>
</tr>
<tr>
<td>.08</td>
<td>0.08</td>
<td>i</td>
</tr>
<tr>
<td>x-y</td>
<td>0.5368062</td>
<td></td>
</tr>
<tr>
<td>÷</td>
<td>0.1490295</td>
<td>i/1 - (1 + i)^{-n}</td>
</tr>
<tr>
<td>86000</td>
<td>86000</td>
<td>PV</td>
</tr>
<tr>
<td>×</td>
<td>12816.537</td>
<td>PMT</td>
</tr>
</tbody>
</table>

See Appendix B — Part 4 for a stack diagram of this example.
The hyperbolic and inverse hyperbolic functions can be found by using the Gudermannian function:

\[ \text{gd} \, x = 2 \arctan e^x - \frac{\pi}{2} \] (Note: \( \frac{\pi}{2} = 90^\circ \)).

and the inverse Gudermannian function:

\[ \text{gd}^{-1} \, x = \ln \tan \left[ \frac{\pi}{4} + \frac{x}{2} \right] \] (Note: \( \frac{\pi}{4} = 45^\circ \)),

in conjunction with the following formulas:

\[
\sinh x = \frac{e^x - e^{-x}}{2},
\]
\[
\sinh^{-1} x = \ln \left[ x + \sqrt{x^2 + 1} \right] = \text{gd}^{-1} (\sin^{-1} x),
\]
\[
\cosh x = \frac{e^x + e^{-x}}{2},
\]
\[
\cosh^{-1} x = \text{sech}^{-1} \frac{1}{x},
\]
\[
\tanh x = \frac{\sinh x}{\cosh x} = \sin \text{gd} x,
\]
\[
\tanh^{-1} x = \frac{1}{2} \ln \left[ 1 + x^2 / (1 - x) \right] = \text{gd}^{-1} (\sin^{-1} x),
\]
\[
\coth x = \frac{1}{\tanh x},
\]
\[
\coth^{-1} x = \tanh^{-1} \frac{1}{x},
\]
\[
\text{sech} x = \frac{1}{\cosh x},
\]
\[
\text{sech}^{-1} x = \left[ \ln \frac{1}{x} + \sqrt{1/x^2 - 1} \right] = \text{gd}^{-1} (\cos^{-1} x),
\]
\[
\text{csch} x = \frac{1}{\sinh x},
\]
\[
\text{csch}^{-1} x = \sinh^{-1} \frac{1}{x}.
\]

Examples:

Gudermannian function: \( \text{gd} \, 0.225 = 12.78301 \)
Key in: \( .225 \, \text{e}^x \, \text{arc} \, \tan \, 2 \times \, 90 \)
Display shows: 12.78301

Inverse Gudermannian function: \( \text{gd}^{-1} \, 60^\circ = -1.3169571 \)
Key in: \( 60 \, \text{ENT} \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 1.3169571

Hyperbolic sine: \( \sinh 2.5 = 6.050203 \)
Key in: \( 2.5 \, \text{e}^x \, \text{ENT} \, 1/x \, - \, 2 \)
Display shows: 6.050203

Hyperbolic cosine: \( \cosh 2.5 = 6.132288 \)
Key in: \( 2.5 \, \text{e}^x \, \text{ENT} \, 1/x \, + \, 2 \)
Display shows: 6.132288

Hyperbolic tangent: \( \tanh 2.5 = 0.9866173 \)
Key in: \( 2.5 \, \text{e}^x \, \text{arc} \, \tan \, 2 \times \, 90 \ texts{tan} \)
Display shows: 0.9866173

Hyperbolic cotangent: \( \coth 2.5 = 1.013564 \)
Key in: \( 2.5 \, \text{e}^x \, \text{arc} \, \tan \, 2 \times \, 90 \ texts{tan} \)
Display shows: 1.013564

Hyperbolic secant: \( \text{sech} 2.5 = 0.1630712 \)
Key in: \( 2.5 \, \text{e}^x \, \text{ENT} \, 1/x \, + \, 2 \)
Display shows: 0.1630712

Hyperbolic cosecant: \( \text{csch} 2.5 = 0.1652837 \)
Key in: \( 2.5 \, \text{e}^x \, \text{arc} \, \tan \, 2 \times \, 90 \ texts{tan} \)
Display shows: 0.1652837

Inverse hyperbolic sine: \( \sinh^{-1} 30 = 4.0947481 \)
Key in: \( 30 \, \text{arc} \, \tan \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 4.0947481

Inverse hyperbolic tangent: \( \tanh^{-1} 0.52 = 0.5763266 \)
Key in: \( .52 \, \text{arc} \, \sin \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 0.5763266

Inverse hyperbolic secant: \( \text{sech}^{-1} 0.52 = 1.2713823 \)
Key in: \( .52 \, \text{arc} \, \cos \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 1.2713823

Inverse hyperbolic cosine: \( \cosh^{-1} 30 = 4.0941957 \)
Key in: \( 30 \, 1/x \, \text{arc} \, \cos \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 4.0941957

Inverse hyperbolic cotangent: \( \coth^{-1} 30 = 3.334028 \)
Key in: \( 30 \, 1/x \, \text{arc} \, \sin \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 3.334028

Inverse hyperbolic cosecant: \( \text{csch}^{-1} 0.52 = 1.4086939 \)
Key in: \( .52 \, 1/x \, \text{arc} \, \tan \, 2 \div \, 45 \, \text{+ tan in} \)
Display shows: 1.4086939
Appendix B—Part 3
Some Common Mathematical Formulae with Examples

Rectangle, area and perimeter
Rectangle of width X and length Y
Area = XY
Perimeter = 2X + 2Y
Example: Rectangle of width 4 and length 8:
Area: Key in: 4 ENT 8 ×
Display shows: 32.
Perimeter: Key in: 2 ENT 4 × 2 ENT 8 × +
Display shows: 24.

Circle, area and circumference
Circle of radius r.
Area = \(\pi r^2\)
Circumference = \(2\pi r\)
Example: Circle of radius 5.
Area: Key in: \(\pi\) ENT 5 ENT \(\times\) \(\times\)
Display shows: 78.539817
Circumference: Key in: 2 ENT \(\pi\) \(\times\) 5 \(\times\)
Display shows: 31.415927

Regular polygon circumscribed in a circle, area and perimeter
Regular polygon with n sides circumscribed in a circle of radius r.
Area = \(\frac{1}{2}nr^2 \sin \frac{360}{n}\)
Perimeter = \(2nr \sin \frac{180}{n}\)
Example: Polygon with 8 sides inscribed in a circle of radius 5.
Area: Key in: 1 ENT 2 \(\div\) 8 \(\times\) 5 ENT \(\times\) \(\times\) 360 ENT 8 \(\div\) \(\sin\) \(\times\)
Display shows: 70.71064
Perimeter: Key in: 2 ENT 8 \(\times\) 5 \(\times\) 180 \(\div\) \(\sin\) \(\times\)
Display shows: 30.614688

Ellipse, area and circumference
Ellipse of major axis X and minor axis Y.
Area = \(\frac{1}{4}\pi XY\)
Circumference = \(2\pi \sqrt{1/8(X^2 + Y^2)}\)
Example: Ellipse of major axis 8 and minor axis 4.
Area: Key in: \[1 \ \text{ENT} \ 4 \ \div \ \pi \ \times \ 8 \ \times \ 4 \ \times \]
Display shows: 25.132739
Circumference: Key in: \[1 \ \text{ENT} \ 8 \ \div \ \pi \ \times \ 4 \ \times \ \text{ENT} \ \times \ 2 \ \times \ \pi \ \times \]
Display shows: 19.869172

Cone, area and volume
Cone of radius \(r\) and height \(h\)
Volume: \[\frac{1}{3} \pi r^2 h\]
Area: \[\pi r \sqrt{r^2 + h^2}\]

Example: Cone of radius 5 and height 10.
Volume: Key in: \[1 \ \text{ENT} \ 3 \ \div \ \pi \ \times \ 5 \ \times \ \text{ENT} \ \times \ 10 \ \times \]
Display shows: 261.79935
Area: Key in: \[\pi \ \text{ENT} \ 5 \ \text{MS} \ \times \ \text{MR} \ \text{ENT} \ \times \ 10 \ \text{ENT} \ \div \ \sqrt{\times} \ \text{ENT} \ \times \]
Display shows: 175.62035

Regular polygon circumscribing a circle, area and perimeter
Regular polygon with \(n\) sides circumscribing a circle of radius 5.
Area: \[nr \tan \frac{180}{n}\]
Perimeter: \[2nr \tan \frac{180}{n}\]

Example: Polygon with 8 sides circumscribing a circle of radius 5.
Area: Key in: \[8 \ \text{ENT} \ 5 \ \text{ENT} \ \times \ \times \ \text{ENT} \ \times \ 180 \ \text{ENT} \ 8 \ \div \ \sin \ \times \]
Display shows: 76.53672
Perimeter: Key in: \[2 \ \text{ENT} \ 8 \ \times \ 5 \ \times \ \text{ENT} \ 8 \ \div \ \tan \ \times \]
Display shows: 33.137096

Sphere, area and volume
Sphere of radius \(r\).
Volume: \[\frac{4}{3} \pi r^3\]
Area: \[4 \pi r^2\]
Distance between two points, \( P_1 \) and \( P_2 \)

Distance \( d \) between two points \( P_1(x_1, y_1) \) and \( P_2(x_2, y_2) \).

\[
d = \sqrt{(x_2-x_1)^2 + (y_2-y_1)^2}
\]

Example: Distance between points \( P_1(3,4) \) and \( P_2(5,8) \).

Key in: \( 5 \ \text{ENT} \ 3 \ \text{ENT} \ 4 \ \text{ENT} \ 8 \ \text{ENT} \ 4 \ \text{ENT} \ \div \ \sqrt{} \)

Display shows: 4.472135

Torus, area and volume

Torus of inner radius \( x \) and outer radius \( y \).

Volume = \( \frac{1}{2} \pi^2 \)

Area = \( \pi^2 (y^2 - x^2) \)

Example: Torus with inner radius 2 and outer radius 4.

Volume: Key in: 1 \text{ ENT} 4 \div \pi \ \text{ENT} \times \times 2

\text{ENT} 4 \text{ ENT} 4 \ \text{ENT} 2 \ \text{ENT} \times \times \times \times

Display shows: 59.217626

Area: Key in: \( \pi \ \text{ENT} \times \times 4 \ \text{ENT} \times \times 2 \ \text{ENT} \times \times \times \times \times \times \times

Display shows: 118.43525

Slope and angle of line between points

Slope = \( m = \frac{y_2-y_1}{x_2-x_1} = \tan \theta \)

Example: Slope: Key in: 8 \ \text{ENT} \ 4 \ \text{ENT} \ 5

Display shows: 2.

Angle: Key in: \( \text{arc tan} \)

Display shows: 63.434781°
### Stack Diagram for $X=R \cos \theta, Y=R \sin \theta$

**Register Contents**

<table>
<thead>
<tr>
<th>M</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
<td></td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Y</td>
<td>$\theta$</td>
<td>$\theta$</td>
<td>$\theta$</td>
<td>R</td>
<td>$\theta$</td>
<td>$\theta$</td>
<td>$\cos \theta$</td>
<td>$\theta$</td>
<td>$\cos \theta$</td>
<td>$\theta$</td>
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<tr>
<td>X</td>
<td>$\theta$</td>
<td>$\theta$</td>
<td>R</td>
<td>R</td>
<td>$\theta$</td>
<td>$\theta$</td>
<td>$\cos \theta$</td>
<td>R</td>
<td>$X=\cos \theta$</td>
<td>$\theta$</td>
</tr>
<tr>
<td>Key In</td>
<td>$\theta$</td>
<td>ENT</td>
<td>R</td>
<td>MS</td>
<td>X-Y</td>
<td>ENT</td>
<td>COS</td>
<td>MR</td>
<td>X</td>
<td>X-Y</td>
</tr>
</tbody>
</table>

### Stack Diagram for PMT = PV $\left[ \frac{i}{1-(1+i)^{-n}} \right]$  

**Register Contents**

<table>
<thead>
<tr>
<th>M</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>1</td>
<td>1</td>
<td>1+i</td>
<td>1+i</td>
<td>$-(1+i)^{-n}$</td>
<td>$1-(1+i)^{-n}$</td>
<td>i</td>
<td>$\frac{i}{1-(1+i)^{-n}}$</td>
<td>PV</td>
<td>PV $\left[ \frac{i}{1-(1+i)^{-n}} \right]$</td>
</tr>
<tr>
<td>X</td>
<td>1</td>
<td>1</td>
<td>i</td>
<td>1+i</td>
<td>n</td>
<td>$-(1+i)^{-n}$</td>
<td>$1-(1+i)^{-n}$</td>
<td>i</td>
<td>$\frac{i}{1-(1+i)^{-n}}$</td>
<td>PV</td>
</tr>
<tr>
<td>Key In</td>
<td>1</td>
<td>ENT</td>
<td>i</td>
<td>+n</td>
<td>CHS</td>
<td>$Y^X$</td>
<td>CHS</td>
<td>1</td>
<td>+i</td>
<td>X-Y</td>
</tr>
</tbody>
</table>
STACK DIAGRAM FOR \( \sinh x = \frac{e^x - e^{-x}}{2} \)

<table>
<thead>
<tr>
<th>REGISTER CONTENTS</th>
<th>M</th>
<th>T</th>
<th>Z</th>
<th>Y</th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
</table>

| KEY IN | X | e^x | ENT | \( \frac{1}{x} \) | - | 2 | ÷ |

STACK DIAGRAM OF \( R = \sqrt{x^2 + y^2} \) AND \( \Theta = \arctan \frac{y}{x} \)

<table>
<thead>
<tr>
<th>REGISTER CONTENTS</th>
<th>M</th>
<th>T</th>
<th>Z</th>
<th>Y</th>
<th>X</th>
<th>X</th>
<th>X</th>
<th>X</th>
</tr>
</thead>
</table>

| KEY IN | X | ENT | ENT | X | Y | MS | ENT | X | ± | \( \sqrt{x-y} \) | MR | X | y | ÷ | \( \arctan \) |
# Appendix C — Tables

## Table 1: Conditions for Error Indication

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>CONDITION (x = contents of register X)</th>
</tr>
</thead>
<tbody>
<tr>
<td>÷ or 1/x</td>
<td></td>
</tr>
<tr>
<td>y^x</td>
<td>y &lt; 0</td>
</tr>
<tr>
<td></td>
<td>x log y &gt; 99</td>
</tr>
<tr>
<td>e^x</td>
<td></td>
</tr>
<tr>
<td>10^x</td>
<td></td>
</tr>
<tr>
<td>log x or ln x</td>
<td>x ≤ 0</td>
</tr>
<tr>
<td>sin x, cos x,</td>
<td>x &lt; 0 or x &gt; 90</td>
</tr>
<tr>
<td>tan x</td>
<td></td>
</tr>
<tr>
<td>arc sin x or</td>
<td>x &lt; 0 or x &gt; 1</td>
</tr>
<tr>
<td>arc cos x</td>
<td></td>
</tr>
<tr>
<td>arc tan x</td>
<td>x &lt; 0</td>
</tr>
<tr>
<td>Program</td>
<td>Loading more than 100 steps</td>
</tr>
</tbody>
</table>

## Table 2: Range and Accuracy of Functions

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>± or 1/x</td>
<td>±1 x 10^-99 ≤ x</td>
</tr>
<tr>
<td>÷, 1/x</td>
<td>±9.999999 x 10^99</td>
</tr>
<tr>
<td>e^x</td>
<td>±1 x 10^-99 ≤ x</td>
</tr>
<tr>
<td>log x</td>
<td>0 &lt; x ≤ ±9.999999 x 10^99</td>
</tr>
<tr>
<td>ln x</td>
<td>0 &lt; x ≤ ±9.999999 x 10^99</td>
</tr>
<tr>
<td>10^x</td>
<td>±1 x 10^-99 ≤ x ≤ ±99</td>
</tr>
<tr>
<td>e^x</td>
<td>±1 x 10^-99 ≤ x ≤ ±99</td>
</tr>
<tr>
<td>y^x</td>
<td>y &gt; 0</td>
</tr>
<tr>
<td>sin, cos, tan</td>
<td>0° ≤ x ≤ ±90°</td>
</tr>
<tr>
<td>arc sin,</td>
<td>0 ≤ x ≤ ±1</td>
</tr>
<tr>
<td>arc cos</td>
<td></td>
</tr>
<tr>
<td>arc tan</td>
<td>0 ≤ x ≤ ±9.99999999 x 10^99</td>
</tr>
</tbody>
</table>
Other Products

Other “professional” calculators from NOVUS...

Novus 4510 Mathematician
The Electronic Slide Rule
- Trig and inverse trig functions
- Common and natural logs and anti-logs
- Fully addressable, accumulating memory

Novus 4515 Mathematician PR
The Programmable Electronic Slide Rule
- Same features as Novus 4510
- 100-step programming capability

Novus 4520 Scientist
The Scientist's Electronic Slide Rule
- Scientific notation
- Trig and inverse trig functions
- Common and natural logs and anti-logs

Novus 6010 International Computer
The Electronic Measurement Converter
- More than 65 international measurement conversions
- Fully addressable, accumulating memory
- Total calculating capability with live percent

Novus 6020 Financier
The Electronic Financial Calculator
- Dedicated to solving financial calculations
- Pre-programmed financial equations
- Fully addressable, accumulating memory

Novus 6025 Financier PR
The Programmable Electronic Financial Calculator
- Same features as Novus 6020
- 100-step programming capability

Novus 6030 Statistician
The Electronic Statistical Calculator
- Dedicated to solving statistical calculations
- Pre-programmed statistical equations
- Fully addressable, accumulating memory

Novus 6035 Statistician PR
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- Same features as Novus 6030
- 100-step programming capability

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NOVUS CUSTOMER RELATIONS DEPT.
1177 Kern Avenue
Sunnyvale, CA 94086
(408) 733-2600
Model Number 4525

NOVUS, the consumer products division of National Semiconductor Corporation, is proud to guarantee your electronic calculator to be free from defects in workmanship and materials for a period of one year from the date of your purchase. Defects caused by abuse, accidents, modifications, negligence, misuse or other causes beyond the control of NOVUS are, of course, not covered by this warranty, nor are batteries. Should the calculator prove defective within 30 days of purchase, NOVUS will repair or, at its discretion, replace it free of charge. If the defect occurs after 30 days from date of purchase, a charge of $3.50 will be made for handling and insurance. If your calculator becomes defective after the one-year period, NOVUS will make repairs for a nominal charge of $20.00. Simply mail it prepaid and insured with your check or money order to the nearest NOVUS service center. Repair prices are subject to change without notice. Please do not send or include cash. Make your check or money order payable to NOVUS. Upon receipt, your calculator will be promptly serviced and returned to you freight prepaid.
Optional Information

Was this calculator purchased for:
- [ ] Gift  [ ] Personal use

What is your occupation?
- [ ] Student or Teacher  [ ] Professional
- [ ] Executive  [ ] Financial or Commercial
- [ ] Engineering or Scientific  [ ] Statistical fields
- [ ] Other occupation

What is your age group?
- [ ] Under 18  [ ] 18-34  [ ] 35-49  [ ] 50-over

Where will you most use your Novus calculator?
- [ ] At home  [ ] At school  [ ] At work
- [ ] During travel

Where did you learn about the Novus calculators?
- [ ] Magazine  [ ] Newspaper  [ ] Television
- [ ] Radio  [ ] Mail  [ ] Store salesman
- [ ] Friend
- [ ] Other

What most attracted you to your Novus calculator?
- [ ] Appearance  [ ] Size  [ ] Reputation
- [ ] Price  [ ] Features and capabilities

Warranty Information
For Your Records

NOVUS Warranty Certificate
Please retain for your records. See insert for product service locations.

Model Number: 4525
Serial Number: 112988
Purchased from: SIMPSONS - SEARS ST. LAURENT
Date purchased: 6/29/76