

# WP43S REFERENCE MANUAL

This manual documents *WP 43S*, a free scientific software for the calculator *DM42* of *SwissMicros*. You can redistribute *WP 43S* and/or modify it under the terms of the GNU General Public License as published by the Free Software Foundation, either version 3 of the License, or (at your option) any later version.

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**This manual is very preliminary; it will change while we develop *WP 43S* in course of this project.** We reserve the right to do so at any time. The very basic principles of *WP 43S* will stay constant, however. Stay informed by watching [https://gitlab.com/Over\\_score/wp43s](https://gitlab.com/Over_score/wp43s) .

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The pictures on p. 152 and bottom of p. 153 were kindly supplied by SwissMicros. The plots in Appendix H are based on material found in Wikipedia. The other photographs, pictures, diagrams, and graphics were created by the author.

Internet addresses are specified as found and verified at 2019-06-26. Please note such addresses may change without notice at any time.

This manual is published in English since it became the *lingua franca* of our time (after Greek, Latin, and French) – using it we can reach the maximum number of people without further translations. I apologize to the people of other languages and inserted some ‘translator’s notes’ where applicable.

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WP 43S would not have been created without our love for *Classics*, *Woodstocks*, *Stings*, *Spices*, *Nuts*, *Voyagers*, and *Pioneers*. Thus we want to quote what was printed in Hewlett-Packard pocket calculator manuals until 1980, so it will not fade:

*"The success and prosperity of our company will be assured only if we offer our customers superior products that fill real needs and provide lasting value, and that are supported by a wide variety of useful services, both before and after sales."*

*Statement of Corporate Objectives  
Hewlett-Packard*

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# WELCOME!

This is the reference volume of the *WP 43S* documentation. It supplements the *WP 43S Owner's Manual* with detailed information about each and every *item* (i.e. command, *menu*, *catalog*, browser, application, constant, conversion, digit, and character) provided in your *WP 43S*. The *Index of Items* in *Section 1* takes almost half of this volume.

*Section 2* presents the structure and contents of all *menus* and *catalogs*. *Section 3* shows further access methods to operations and lists all operations requiring at least one parameter.

The appendices cover additional special topics as listed in the *Table of Contents* above.

Enjoy!

*Walter Bonin*

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## Print Conventions and Common Abbreviations

- Throughout this manual, standard text font is Arial. Emphasis is added by underlining or **bold** printing. Calculator COMMANDS and MENUS are generally called by their names, printed capitalized in running text (*menus* underlined). **Quoted text is printed blue** (as well as [translator's footnotes](#)). *Specific terms, titles, trademarks, names or abbreviations* are printed in italics, [hyperlinks](#) in blue underlined italics. The latter will beam you to its target in the original .pdf file – it cannot work in a printed copy for obvious reasons; thus such a link generally refers to a page number, to the [Table of Contents](#), or to a fully specified external address.
- Bold italic Arial letters such as *n* are used for variables; bold normal letters for constant **sample values** (e.g. labels, numbers, or characters).
- Courier is used for **file names** and describing numeric formats.
- Times New Roman regular letters are for unit symbols and for mathematical functions. Italics of this font are for *unit names* in running text.
- Times New Roman bold capitals are used for **REGISTER ADDRESSES**, lower case bold italics for *register contents*. So e.g. the value *y* lives in *register Y* and *r45* in *R45*. Overall stack contents are generally quoted in the order [*x, y, z, ...*]. We keep the term *register* for the space where an individual object is stored, although the actual size of such a *register* may vary widely following the size of the object stored therein.
- This **KEY** font (created by *Luiz Vieira* of Brasil) is taken for references to calculator keys, including **SOFTKEYS** in general. For shifted operations like **GTO** or **LBL**, the respective color is used. **Alphanumeric** and numeric calculator outputs (like  $1.234 \times 10^{-56}$  or  $7,089 \cdot 10^{-12}$ ) are printed as you see them on the calculator screen.
- We will use decimal points in most parts of this manual (but you may set your *WP 43S* to commas as well, of course). Although that point is less visible than a comma, ‘comma people’ seem to be more tolerant against points used as radix marks than vice versa (based on the number of complaints read).

All this holds unless stated otherwise locally.

The following abbreviations are used throughout this manual:

*ADM* = angular display mode (see *Section 2* of the *OM*).

*AIM* = alpha input mode (see *Section 2* of the *OM*).

*CDF* = cumulated distribution function (see *Section 2* of the *OM*).

*DP* = double precision.

*FM* = flash memory (a special kind of *RAM*, see *Sect. 3* of the *OM*).

*HP* = *Hewlett-Packard*.

*IOI* = *Index of Items* (see pp. 12ff).

*LCD* = liquid crystal display.

*PDF* = probability density function (see *Section 2* of the *OM*).

*OM* = Owner's Manual.

*PEM* = program-entry mode (see *Section 3* of the *OM*).

*PMF* = probability mass function (see *Section 2* of the *OM*).

*px* = pixels.

*RAM* = random access memory, allowing read and write operations.

*RPN* = reverse Polish notation (see *Section 1* of the *OM*).

*SP* = single precision.

*SRS* = subroutine return stack (see *App. B* on pp. 156ff).

*TVM* = *Time Value of Money* – a preprogrammed application for dealing with investments and loans, featured by all financial *HP* calculators since 1972 (see *Sect. 5* of the *OM*).

Some more abbreviations may be used and explained locally.

## SECTION 1: INDEX OF ITEMS (IOI)

All the *items* provided on your *WP 43S* (more than 850) are listed below with their reserved *names* (as they are printed in routines) and the key-strokes necessary to call them. Most *items* shall be picked from *menus* (see pp. 114ff) or *catalogs*.<sup>1</sup>

Sorting in this index, in CATALOG, and CNST works in the following order:

\_ 0...9 Aa...Zz Aα...Ωω ( ) + - × / ±  
, . ! ? : ; ' " · \* @ \_ ~ → ← ↑ ↓ ↵  
< ≤ = ≈ ≠ ≥ > % \$ € £ ¥ √ ∫ ∞  
& \ ^ | [ ] { } ☒ #

Superscripts and subscripts are handled like normal characters in sorting. The ☒ above is the printer symbol heading all print commands.

In principle, *WP 43S* operations work as the corresponding ones did on the *WP 34S* where applicable (see App. E). Referring to vintage calculators, most functions and keystroke-programming will work as they did on the *HP-42S*, bit and integer functions as on the *HP-16C*, unless specified otherwise. Also for functions inspired by other vintage calculators as mentioned in the index below, their manuals may contain helpful additional information.

Operations working with the accumulated statistical data are marked light blue. Those operating on complex parameters are marked light yellow. Operations asking you for confirmation are printed red.

All operations may be entered in *PEM* as well unless marked violet or stated otherwise – many functions contained in P.FN and TEST will make most sense in *PEM*.

---

<sup>1</sup> For commands stored in *menus*, we list the keys calling the respective *menu*, the *prefix(es)* of the respective *menu* row (if applicable), and the command as shown therein. We are confident you will find the corresponding *softkey*. *Items* stored in CNST are listed with their reserved names only, however, since they will be explained in detail in a separate chapter below.

Some 300 functions featured in your *WP 43S* are new compared to *HP's RPN pocket calculators*.<sup>2</sup> Operations carrying familiar names but deviating in their functionality from previous *HP RPN* calculators or the *WP 34S* are marked light red.

For the vast majority of operations, remarks start with a number:

- (0) represents functions without any effects on the *stack* (e.g. mode setting functions);
- (1) is for *monadic functions*,
- (2) for *dyadic functions*, and
- (3) for *triadic functions* as defined in *Section 1* of the *OM*;
- (-1) stands for functions pushing one object on the *stack* and
- (-2) for functions pushing two objects on the *stack*.

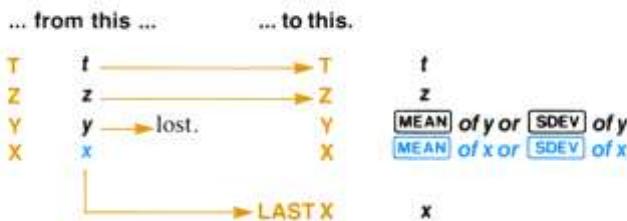
Note some functions overwrite two *stack* levels instead of pushing two values on it: e.g. →POL and →REC, as you may have expected.<sup>3</sup>

---

<sup>2</sup> We did not compare the *RPL* calculators of the last three decades or the *HP Prime*. They are exceeding the realm of shirt pocket calculators.

<sup>3</sup> On the *HP-42S*, however, also statistical functions returning two values do that – while the *Spices* (e.g. *HP-34C*) and *Voyagers* (e.g. *HP-15C*) push both results on the stack instead as you expect from *RPN* calculators. For your information, the picture below shows what the *HP-55*, *HP-19C/29C*, *HP-67/97*, *HP-41C*, and *HP-42S* do there:

The illustration below shows what happens in the stack when you execute **[MEAN]** or **[SDEV]**. The contents of the stack registers are changed...



Alas, *HP* does not give any reason for this deviation from simple logic until today. In our opinion this is not reasonable, so for the *WP 43S* we stick to the paradigm as implemented on the *Voyagers* in this matter (as we did for the *WP 34S / 31S* before).

Operation or function **parameters** will be taken from the lowest *stack register(s)* unless mentioned explicitly in second column of the *IOI* – then they have to trail the command. Some parameters of statistical distributions shall be given in *registers I, J, and K* as specified.

Three examples of the parameter notation used throughout the *IOI* are shown below; assume **R12** contains **15.67** generally here, i.e. **r12 = 15.67**.

1. **n** represents an arbitrary integer number which must be keyed in directly, while
  - n** represents such a number which may be specified indirectly via a *register* or variable as well (as shown in the tables in *Section 1* of the *OM*); and
  - n** stands for the respective number itself;

**Example:** RSD **12** rounds *x* to 12 significant digits, while  
RSD **→12** rounds *x* to 15 significant digits.

2. **r** (or **s**) represents an arbitrary *register address* or variable name which must be keyed in directly or picked from a *menu*, while
  - r** (or **s**) represents such an address or name which may be specified indirectly as well; and
  - r** (or **s**) stands for the contents of the address specified – **r** or **s** may be used as an address itself;

**Example:** STO **12** stores *x* into **R12**, while  
STO **→12** stores *x* into **R15**.

3. **label** represents an arbitrary label which must be keyed in directly or picked from a *menu*, while
  - label** represents such a label which may be specified indirectly (as shown in the addressing table in *Section 3* of the *OM*); and
  - label** stands for the respective label itself, regardless of the way it was specified.

**Example:** GTO **12** goes to local label **12**, while  
GTO **→12** goes to local label **15**.

Note that for any command XYZ requiring one trailing parameter, you can enter XYZ → ST.X and it will take its parameter from X instead.

*Automatic stack lift* is enabled after each command – except CLX, ENTER↑, Σ+, and Σ- (cf. Section 1 of the OM); numeric input immediately following one of these four operations will overwrite x instead of pushing it on the stack as usual.<sup>4</sup>

The *data types* a particular function operates on are listed in { } under “remarks” if there are restrictions – cf. App. B on pp. 156ff. Most bit and integer functions operate on *short integers* only (*data type* 10). The other functions typically work with more kinds of objects. Functions stating *data types* 8\* or 9\* instead of 8 or 9 operate on each matrix element instead of the entire matrix (as explained in Section 2 of the OM). Wherever operations return *data types* differing from their input, the output types are listed as well.<sup>5</sup>

Below, the functions checked already are highlighted green, those which didn't work (for whatever reason) are marked red. Green highlighting doesn't necessarily mean the function works correctly but its results look like in the right ballpark. What wasn't checked so far isn't highlighted at all. This applies to the respective *data types*.

---

<sup>4</sup> Some reasoning why *automatic stack lift* is disabled for these four:

- a) CLX is for clearing X to make room for a corrected value. This value shall overwrite x – an extra zero on the stack would make no sense.
- b) ENTER↑ is a *stack lift* manually initiated by the user. An additional *automatic stack lift* immediately after this command would make no sense.
- c) Σ+ and Σ- are dedicated commands for adding or subtracting data points (see the chapter about *Statistical Calculations* in Section 2 of the OM). These two commands were exclusively designed for data input since their first appearance on the HP-45 and are not really meant to be mixed with calculations.

<sup>5</sup> E.g. for °C→°F: For single (double) precision real input, output stays single (double) precision real. For integer input, however, output is single precision real.

Some functions operating on *long integers* will return either such integers or reals, depending on the input value. See the OM, Sect. 2, *Integers: Summary of Functions*. E.g.  $\sqrt[3]{x}$  will return 3 for an input of 27, i.e. for a proper cube, but return a real for an input of 28 although this is a *long integer* as well. The same function operating on *short integers* will return 3 in both cases.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$		(1) {2, 11}; {1} → {2} Convert temperatures. See pp. 136ff.
$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$		
$10^x$		(1) [1, 2, 3, 8*, 9*, 10, 11, 12] Returns $10^x$ , the inverse of $\lg(x)$ .
1COMPL	 	(0) Sets 1's complement mode for operations on <i>short integers</i> . See Sect. 2 of the OM.
$\frac{1}{2}$		(-1) {} → {2} Trivial but helpful constant for iterations.
$\frac{1}{x}$		(1) {2, 3, 8*, 9*, 11, 12}; {1} → {2} Inverts the number $x$ or all elements of the matrix $x$ .
2COMPL	 	(0) Sets 2's complement mode for operations on <i>short integers</i> . See Sect. 2 of the OM.
$2^x$		(1) [1, 2, 3, 8*, 9*, 10, 11, 12] Returns $2^x$ .
$\sqrt[3]{x}$		(1) {1, 2, 3, 8*, 9*, 10, 11, 12}; ({1} → {2}) Returns the cube root of $x$ . Roots of non-cube <i>long integers</i> will return reals.
$a$		(-1) {} → {2} <i>Gregorian year in days.</i>
$a_0$		(-1) {} → {2} <i>Bohr radius in meter.</i>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
ABS	f CAT. FCNS ABS	Works like $ x $ on p. 101. ABS is maintained for backward compatibility only.
ACOS	f CATALOG FCNS ACOS	Works like arccos below. ACOS is maintained for backward compatibility only.
ac $\rightarrow$ m <sup>2</sup>	g U f A acre $\rightarrow$ m <sup>2</sup>	(1) {2, 11}; {1} $\rightarrow$ {2}
ac <sub>us</sub> $\rightarrow$ m <sup>2</sup>	g U f A acre <sub>us</sub> $\rightarrow$ m <sup>2</sup>	Convert areas. See pp. 136ff.
ADV	f ADV	Menu. See p. 120.
AGM	g X.FN AGM	(2) {2, 3, 11, 12}; {1} $\rightarrow$ {2} Returns the <i>arithmetic-geometric mean</i> of $x$ and $y$ . Will throw an error for $x$ or $y$ being negative. See p. 233 for more.
AGRAPH	g P.FN P.FN2 g AGRAPH s	(0) Alpha graphics. Displays a graphics image. Each character in the source $s$ specifies an 8-dot-1-column pattern. The X- and Y-registers specify the pixel location of the bottom left point of this column. $1 \leq x \leq 400$ and $1 \leq y \leq 232$ are possible (but see App. K). So one row (8 px high) starting in column 1 may need up to 400 characters to specify – the more blank space is found therein the less characters may be required for describing it entirely. Cf. <i>HP-42S Owner's Manual</i> , pp. 135 – 140, and <i>HP-42S Programming Examples and Techniques</i> , pp. 214 – 223.
ALL	g DISP ALL n	(0) Sets the numeric display format to show all decimals of real or complex numbers whenever possible. ALL 00 works like ALL in HP-42S almost.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		For $x \geq 10^{16}$ (or earlier for complex numbers), however, display will switch to SCI or ENG with the maximum number of decimals necessary and displayable using the <u>large</u> font (see SCIOVR and ENGOVR). The same will happen if $x < 10^{-n}$ <u>and</u> more than 16 digits are required to show $x$ entirely.
a <sub>Moon</sub>	<b>g</b> [CNST] a <sub>Moon</sub>	(-1) {} → {2} Semi-major axis of the Moon's orbit around the earth in <i>meter</i> .
AND	<b>f</b> [BITS] AND	(2) {10} Works bitwise as in HP-16C (see Sect. 2 of the OM).
		(2) {1, 2, 11} → {1} Works like AND in HP-28S, i.e. $x$ and $y$ are interpreted before executing this operation. Zero is 'false'; any other real number is 'true'.
arccos	[TRI] arccos	(1) {3, 8*, 9*, 12}; {1, 2, 11} → {4}; Returns the tagged angle $\text{arccos}(x)$ . <sup>6</sup>
arcosh	<b>g</b> [EXP] <b>g</b> arcosh	(1) {2, 3, 8*, 9*, 11, 12}
	[TRI] <b>g</b> arcosh	Returns $\text{arcosh}(x)$ .
arcsin	[TRI] arcsin	(1) {3, 8*, 9*, 12}; {1, 2, 11} → {4}; Returns the tagged angle $\text{arcsin}(x)$ . <sup>7</sup>

<sup>6</sup> Precisely, ARCCOS returns the principal value of  $\text{arccos}(x)$ , i.e. a real part  $\in [0, \pi]$  in  $\frac{\pi}{4}\pi$ , or  $\in [0^\circ, 180^\circ]$  in  $\frac{\pi}{4}^\circ$  or  $\frac{\pi}{4}^\circ$ , or  $\in [0^g, 200^g]$  in  $\frac{\pi}{4}^g$ , or  $\in [0, 1]$  in  $\frac{\pi}{4}\pi$ . Cf. ISO/IEC 9899.

<sup>7</sup> Precisely, ARCSIN returns the principal value of  $\text{arcsin}(x)$ , i.e. a real part  $\in [-\pi/2, \pi/2]$  in  $\frac{\pi}{4}\pi$ , or  $\in [-90^\circ, 90^\circ]$  in  $\frac{\pi}{4}^\circ$  or  $\frac{\pi}{4}^\circ$ , or  $\in [-100^g, 100^g]$  in  $\frac{\pi}{4}^g$ , or  $\in [-0.5, 0.5]$  in  $\frac{\pi}{4}\pi$ . Cf. ISO/IEC 9899.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
arctan	<b>TRI arctan</b>	(1) {3, 8*, 9*, 12}; {1, 2, 11} → {4}; Returns the tagged angle $\text{arctan}(x)$ . <sup>8</sup>
arsinh	<b>g EXP g arsinh</b>	(1) {2, 3, 8*, 9*, 11, 12}
	<b>TRI g arsinh</b>	Returns $\text{arsinh}(x)$ .
artanh	<b>g EXP g artanh</b>	(1) {2, 3, 8*, 9*, 11, 12}
	<b>TRI g artanh</b>	Returns $\text{artanh}(x)$ .
ASIN	<b>f CAT. FCNS ASIN</b>	Works like arcsin above. ASIN is maintained for backward compatibility only.
ASR	<b>f BITS f ASR n</b>	(1) {10}  Works like $n$ ( $\leq 63$ ) consecutive ASR commands in HP-16C, corresponding to a division of $x$ by $2^n$ . ASR 0 executes as NOP, but loads L. See Sect. 2 of the OM.
ASSIGN	<b>f ASN item, location</b>	(0) Assigns an <i>item</i> (i.e. a function, a menu, a label, or a character) to a specified sequence of keystrokes, corresponding to a specific location on the keyboard or in a <i>menu</i> . See Section 6 of the OM.
ATAN	<b>f CATALOG FCNS ATAN</b>	Works like arctan above. ATAN is maintained for backward compatibility only.
atm→Pa	<b>g U→ F&amp;p; f atm→Pa</b>	(1) {2, 11}; {1} → {2}
au→m	<b>g U→ x: au→m</b>	Convert pressures and distances. See pp. 136ff.
A....Z	<b>f CATALOG CHARS A....Z</b>	Submenu of Latin letters. See pp. 114ff.

<sup>8</sup> Precisely, ARCTAN returns the principal value of  $\text{arctan}(x)$ , i.e. a real part  $\in [-\pi/2, \pi/2]$  in  $\text{4r}$ , for example (cf. ASIN), if flag D is set. Else the result interval for ATAN becomes  $(-\pi/2, \pi/2)$  in  $\text{4r}$ , for example. Cf. ISO/IEC 9899.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
A:	g  f A:	<b>_submenu</b> . See p. 136.
$a_{\oplus}$	g  a <sub>⊕</sub>	(-1) {} → {2} Semi-major axis of the Earth's orbit around the sun in <i>meter</i> .
BACK	g  P.FN2 g  n	(0) Jumps $n$ steps backwards ( $0 \leq n \leq 255$ ) in a program. E.g. BACK 1 goes to the previous program step. If BACK attempts to cross an END, an error is thrown. Reaching step 000 stops program execution and lights . Cf. SKIP.  <b>ATTENTION:</b> If you edit a section of your routine crossed by one or more BACK, SKIP, or CASE jumps, this may well result in a need to <b>manually maintain all those statements individually</b> .
bar→Pa	g  F&p: bar→Pa	(1) {2, 11}; {1} → {2} Converts pressures. See pp. 136ff.
BATT?	g  f BATT?	(-1) {} → {2} Measures the battery voltage in the range between 1.9V and 3.4V and returns this value.
bbl→m <sup>3</sup>	g  f V: f barrel → m <sup>3</sup>	(1) {2, 11}; {1} → {2} Converts volumes. See pp. 136ff.
BC?	f  g BC? n	(-1) {10} Tests if the specified bit in $x$ is clear.
BEEP	g  BEEP	(0) Sounds a sequence of four tones. See also TONE and QUIET.
BeginP	g  TVM f Begin	(0) Sets "Begin" mode in TVM: payments occur at the beginning of each period. Typical for savings plans and leasing. Cf. ENDP.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>BestF</b>	 <b>BestF</b> <i>n</i>	<p>(0) Instructs your WP 43S to select the 'best' curve fit model for the current statistical data by picking the one with maximum <i>correlation</i> out of the models allowed (almost like BEST in HP-42S).</p> <p>Relevant for L.R., CORR, COV, <math>s_{vv}</math>, <math>\hat{x}</math>, and <math>\hat{y}</math>. You can accelerate computation of these functions significantly by excluding fit models making no sense for your data (e.g. for physical or technical reasons). The parameter <i>n</i> carries this information. Each fit model corresponds to a number as listed:</p> <ul style="list-style-type: none"> <li>• LINF 1</li> <li>• EXPF 2</li> <li>• LOGF 4</li> <li>• POWERF 8</li> <li>• ROOTF 16</li> <li>• HYPF 32</li> <li>• PARABF 64</li> <li>• CAUCHF 128</li> <li>• GAUSSF 256</li> </ul> <p>Take the numbers of all models you can exclude and sum them up – the result is <i>n</i>.</p> <p><b>Example:</b>  Excluding the three 3-parameter models results in <math>n = 64 + 128 + 256 = 448</math>. So call <b>BESTF 448</b> to look for the best-fitting 2-parameter model..</p> <p>Note ORTHOF is <u>not</u> part of the set of models under investigation. See pp. 203ff for more.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>Binom</b>	<b>g PROB</b> <b>g Binom:</b> <b>Binom</b> etc.	(1) {2, 11}  <i>Binomial distribution</i> with the number of successes <b>g</b> in <b>X</b> , the probability of a success <b>p<sub>0</sub></b> in <b>I</b> , and the sample size <b>n</b> in <b>J</b> . See p. 203 for more.
<b>Binom<sub>e</sub></b>		
<b>Binom<sub>p</sub></b>		
<b>Binom<sup>-1</sup></b>		Binom <sup>-1</sup> returns the maximum number of successes <b>m</b> for a given probability <b>p</b> in <b>X</b> , <b>p<sub>0</sub></b> in <b>I</b> and <b>n</b> in <b>J</b> .
<b>Binom:</b>	<b>g PROB</b> <b>g Binom:</b>	<b>Submenu</b> . See p. 123.
<b>BITS</b>	<b>f BITS</b>	<b>Menu</b> . See p. 118.
<b>B<sub>n</sub></b>	<b>g X.FN</b> <b>B<sub>n</sub></b>	(1) {1, 2, 11}
<b>B<sub>n</sub>*</b>	<b>g X.FN</b> <b>B<sub>n</sub>*</b>	B <sub>n</sub> and B <sub>n</sub> * return the Bernoulli number for an integer <b>n &gt; 0</b> given in <b>X</b> , working with different definitions (see both formulas on p. 201).
<b>BS?</b>	<b>f BITS</b> <b>g BS? n</b>	(0) {10}  Tests if the specified bit in <b>x</b> is set.
<b>Btu→J</b>	<b>g U→ E: Btu→J</b>	(1) {2, 11}; {1} → {2}  Converts energies. See pp. 136ff.
<b>c</b>	<b>g CNST</b> <b>c</b>	(-1) {} → {2}
<b>c<sub>1</sub></b>	<b>g CNST</b> <b>c<sub>1</sub></b>	Speed of light in vacuum in <i>meter per second</i> ;
<b>c<sub>2</sub></b>	<b>g CNST</b> <b>c<sub>2</sub></b>	first and second radiation constants in <i>Planck's Law</i> (see p. 130).
<b>cal→J</b>	<b>g U→ E: cal→J</b>	(1) {2, 11}; {1} → {2}  Converts energies. See pp. 136ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CASE	<b>g P.FN</b> P.FN2 <b>g CASE s</b>	<p>(0) Works like SKIP below but takes the number of steps to skip from <i>s</i>.</p> <p><b>Example:</b> Assume a program section:</p> <pre> ... 100  CASE 12 101  GTO 01 102  GTO 02 103  GTO 07 104  GTO 05 105  LBL 01 ... 132  LBL 02 ... 153  LBL 05 ... 234  LBL 07 ... </pre> <p>In execution of this program, <i>r12</i> will be checked in step 100: if <math>r12 \leq 1</math> then the program will proceed to step 101 and continue with a jump to step 105, for <math>r12 = 2</math> the program will go to step 102, etc., resulting in a nice controlled dispatcher for <math>1 \leq r12 \leq 4</math>.</p> <p><b>ATTENTION:</b> CASE might surprise you for <math>r12 &gt; 4</math> in the example above. Take care of the input you provide!</p> <p>If you edit a section of your routine crossed by one or more BACK, SKIP, or CASE jumps, this may well result in a need to <b>manually maintain all those statements individually</b>.</p>
CATALOG	<b>f CATALOG</b>	<b>Catalog</b> of everything. See pp. 114ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Cauch	<b>g PROB</b> <b>f Cauch:</b> Cauch	(1) {2, 11}  Cauchy-Lorentz distribution (a.k.a. Lorentz or Breit-Wigner distribution) with the location $x_0$ specified in I and the shape $\gamma$ in J. See p. 206 for more.
Cauch <sub>e</sub>	etc.	
Cauch <sub>p</sub>		
Cauch <sup>-1</sup>		Cauch <sup>-1</sup> returns $x$ for a given probability $p$ in X, with $x_0$ in I and $\gamma$ in J.
Cauch:	<b>g PROB</b> <b>f Cauch:</b>	Submenu. See p. 123.
CauchF	<b>f STAT</b> ▼ <b>f CauchF</b>	(0) Selects the Cauchy (a.k.a. Lorentz) peak fit model. Relevant for CORR, COV, L.R., $s_{xy}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 212ff for more.
CB	<b>f BITS</b> <b>g CB</b> <i>n</i>	(1) {10}  Clears the specified bit in $x$ , i.e. sets it to 0.
CEIL	<b>g INTS</b> <b>g CEIL</b>	(1) {8*}; {1, 2, 11} → {1}  Returns the smallest integer $\geq x$ . Cf. FLOOR.
CF	<b>g FLAGS</b> CF <i>n</i>  <b>g CLR</b> CF <i>n</i>	(0) Clears the flag specified, i.e. sets it to 0.
CHARS	<b>f CATALOG</b> CHARS	Submenu of characters. See pp. 114ff.
CLALL	<b>g CLR</b> <b>g CLall</b>	(0) Clears all registers, user flags, variables, and programs in RAM. Modes will stay as they are. Cf. CLCVAR, CLFALL, CLPALL, CLREGS, CLSTK, and RESET.
CLCVAR	<b>g CLR</b> CLCVAR	(0) Clears all variables used in the <i>current program</i> , i.e. sets all such real and complex variables to 0., all integer ones to 0, all time variables to 0:00:00, all date variables to January 1 <sup>st</sup> of year 0, all character strings to zero length, and all the elements of all matrix variables used to zero.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CLFALL	<b>g</b> <b>FLAGS</b> <b>g</b> CLFall	(0) Clears all global and local user <i>flags</i> . See CF.
	<b>g</b> <b>CLR</b> <b>f</b> CLFall	
CLK	<b>g</b> <b>CLK</b>	<b>Menu</b> . See p. 114.
CLK12	<b>g</b> <b>CLK</b> ▲ <b>f</b> CLK12	(0) Sets 12h time display mode: e.g. 1:23 will become 1:23am, 23:45 will become 11:45pm. Shortens the date display in the <i>status bar</i> to two digits for the year. Cf. CLK24.
CLK24	<b>g</b> <b>CLK</b> ▲ <b>f</b> CLK24	(0) Sets international 24h time display mode. Expands the date display in the <i>status bar</i> to four digits for the year. Cf. CLK12.
CLLCD	<b>g</b> <b>CLR</b> <b>f</b> CLLCD	(0) Clears the <i>LCD</i> in the rectangular window north and west of the point <i>x</i> , <i>y</i> . I.e. all pixels $\geq x$ and $\geq y$ are cleared.
CLMENU	<b>g</b> <b>CLR</b> CLMENU	(0) Clears all <i>menu</i> key definitions for the programmable <i>menu</i> . See MENU.
	<b>g</b> <b>P.FN</b> P.FN2 ...	
CLP	<b>g</b> <b>CLR</b> CLP	(0) Clears the <i>current program</i> in <i>RAM</i> or <i>FM</i> . Freed memory is returned to the pool of free space.
CLPALL	<b>g</b> <b>CLR</b> <b>f</b> CLPall	(0) Clears all programs in <i>RAM</i> . Cf. CLP.
CLR	<b>g</b> <b>CLR</b>	<b>Menu</b> . See p. 120.
CLREGS	<b>g</b> <b>CLR</b> <b>f</b> CLREGS	(0) Clears all global and local general purpose <i>registers</i> allocated (see also LOCRI), i.e. sets all these registers to 0. The contents of the <i>stack</i> and <b>L</b> are kept.
CLSTK	<b>g</b> <b>CLR</b> <b>f</b> CLSTK	Clears all <i>stack registers</i> currently allocated (i.e. either X ... T or X ... D). All other <i>register</i> contents are kept. Cf. CLREGS.
	<b>0</b> <b>g</b> <b>FILL</b>	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CLX	<b>g CLR CLX</b>  <b>⬅</b>	(1) Clears register <b>X</b> , disabling <i>automatic stack lift</i> . The shortcut works for closed <i>x</i> only. Cf. CLREGS.
CLΣ	<b>f STAT g CLΣ</b>  <b>g CLR CLΣ</b>	(0) Clears the statistical summation <i>registers</i> and releases the memory allocated for them (see p. 159).
CNST	<b>g CNST</b>	<b>Menu.</b> See CONST below and pp. 136ff.
COMB	<b>g PROB C<sub>yx</sub></b>	(2) {1} Returns the number of possible <u>subsets</u> of <i>x</i> items taken out of a set of <i>y</i> items (i.e. choose <i>x</i> out of <i>y</i> ). No item occurs more than once in a subset, and <u>different orders</u> of the same <i>x</i> items are <u>not counted</u> separately. Cf. PERM.  (2) {2, 3, 11, 12} See pp. 201ff for the formula.
CONJ	<b>g CPX conj</b>	(1) {3, 9*, 12} Returns the complex conjugate of <i>x</i> .
CONST	<b>g P.FN</b> <b>f CONST n</b>	(-1) {} → {2} Returns the constant stored at position <i>n</i> in CONST (see pp. 128ff). Allows for indirectly addressing these constants.
CONVG?	<b>g TEST</b> <b>g CONVG? r</b>	(0) {2, 11} Checks for convergence by comparing <i>x</i> and <i>y</i> as determined by the lowest five bits of <i>r</i> .  a) The very lowest two bits set the tolerance limit: $0 = 10^{-14}, \quad 1 = 10^{-24}, \quad 2 = 10^{-32}.$

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		<p>b) The next two bits determine the comparison mode using the tolerance limit set:      0 = compare the numbers <math>x</math> and <math>y</math> relatively,      1 = compare them absolutely.</p> <p>c) The top bit tells how special numbers are handled:      0 = NaN and <math>\pm\infty</math> are considered converged,      1 = they are not considered converged.</p> <p>Now, <math>r = a + 4b + 16c</math>.</p>
CORR	f STAT ▲ r	(-1) {} → {2}  Returns the <i>coefficient of correlation</i> for the current statistical data and curve fit model. See pp. 212ff for more.
cos	TRI cos	(1) {2, 3, 8*, 9*, 11, 12}; {1, 4} → {2}  Returns the cosine of the angle in X (see Section 2 of the OM for details).
cosh	g EXP g cosh  TRI g cosh	(1) {2, 3, 8*, 9*, 11, 12}  Returns the hyperbolic cosine of $x$ .
COV	f STAT ▲  f cov	(-1) {} → {2}  Returns the population covariance for the two data sets entered via $\Sigma+$ , depending on the curve fit model selected. See $s_{XY}$ for the sample covariance and pp. 203ff for more.
CPX	g CPX	Menu. See p. 121.
CPXi	g CPX g CPXi etc.	(0) Selects either the letter $i$ or $j$ for displaying the imaginary number $i$ .
CPXj		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CPXRES	$\text{g MODE}$ $f \text{ CPXRES}$ $\text{g FLAGS SF }$	(0) Allows for complex results of real number calculations. Cf. REALRES.
CPXS	$f \text{ CAT. VARS CPXS}$	Submenu of complex variables defined at execution time. See pp. 114f.
CPX?	$\text{g TEST } \Delta \text{ CPX?}$	(0) Checks if $x$ is complex. Returns <b>true</b> if X contains data of type 3, 9, or 12 with nonzero imaginary part.
CROSS	$f \text{ MATX}$ $f \text{ cross}$  $\text{g CPX cross}$	<p>(2) {8}  Requires two real 2D or 3D vectors in X and Y and returns their cross product. Crossing of 2D vectors works as for complex numbers.</p> <p>(2) {3} → {2}; {12} → {11}  When two complex numbers are crossed, your WP 43S simply returns a real number that is equal to the signed magnitude of the resulting moment vector.</p>
ct→kg	$\text{g U\!}\rightarrow\text{ m: }$ $f \text{ carat}\rightarrow\text{kg}$	(1) {2, 11}; {1} → {2}
cwt→kg	$\text{g U\!}\rightarrow\text{ m: }$ $\text{cwt}\rightarrow\text{kg}$	Convert masses. See pp. 136ff.
CX→RE	$\text{CC}$	<p>(-1) {3} → {2}; {9} → {8}; {12} → {11}</p> <p>Cuts a closed complex object <math>x</math>, putting either</p> <ul style="list-style-type: none"> <li>• (for <math>\text{\texttt{L}}</math>) its real part in Y and its imaginary part in X, or</li> <li>• (for <math>\text{\texttt{O}}</math>) magnitude in Y and phase in X.</li> </ul>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DATE	<b>g CLK DATE</b>	(-1) {} → {6} Recalls the <i>date</i> from the real-time clock and displays it in the format selected. See D.MY, M.DY, and Y.MD. Furthermore, DATE shows the day of week (see Sect. 2 of the OM).
DATES	<b>f CATALOG</b> <b>VARS f DATES</b>	Submenu of date variables defined at execution time. See pp. 114f.
DATE→	<b>g CLK DATE→</b>	(-2) {2, 6, 11} → {1} Assumes <i>x</i> containing a <i>date</i> in the format selected (or a real number in corresponding format) and pushes its three components as integers on the stack. Reversible by →DATE.
DAY	<b>g CLK f DAY</b>	(1) {2, 6, 11} → {1} Assumes <i>x</i> containing a <i>date</i> in the format selected (or a real number in corresponding format) and extracts the day.
DBL?	<b>g TEST</b> ▲ <b>f DBL?</b>	(0) Checks if <i>x</i> contains a double precision real or complex number.
DBLR	<b>g INTS</b> <b>g DBLR</b> etc.	{10} Double word length commands for remainder, multiplication and division. <sup>9</sup>
DBL×		DBLR and DBL / accept a double size dividend in <b>Y</b> and <b>Z</b> (most significant bits in <b>Y</b> ), the divisor in <b>X</b> as usual, and return the result in <b>X</b> .
DBL/		DBL× takes <i>x</i> and <i>y</i> as factors as usual but returns the product in <b>X</b> and <b>Y</b> (most significant bits in <b>X</b> ).

<sup>9</sup> See the HP-16C Owner's Handbook, Section 4 (pp. 52ff).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>dB→fr</b>	<b>g U→ ▲ dB → field ratio</b>	(1) {2, 11}; {1} → {2}
<b>dB→pr</b>	<b>g U→ ▲ dB → power ratio</b>	Convert ratios. See pp. 136ff.
<b>DEC</b>	<b>f LOOP f DEC r</b>	(0) {1, 2, 10, 11}  Decrements <i>r</i> by 1. Does not load <b>L</b> even for target address X.
<b>DECOMP</b>	<b>f PARTS DECOMP</b>	(-1) {1, 2, 11} → {1}  Decomposes <i>x</i> (after converting it to an <i>improper fraction</i> , if applicable), returning a stack [ <i>denominator(x)</i> , <i>numerator(x)</i> , ...]. Reversible by division.  <b>Example:</b> If X contains 2.25 then DECOMP will return <i>x</i> = 4 and <i>y</i> = 9.
<b>DEG</b>	<b>g MODE DEG</b>	(0) Sets the ADM to <i>decimal degrees</i> .
<b>DEG→</b>	<b>f L→ f DEG→</b>	(1) {1, 2, 11} → {4}  Converts angles as described on p. 143.
<b>DENANY</b>	<b>g MODE g DENANY</b>	(0) Sets default fraction display format like in HP-35S – any denominator up to the value set by DENMAX may appear. This is the most precise way of displaying a decimal number as a fraction with DENMAX given.  <b>Example:</b> If DENMAX = 5 then DENANY allows denominators 1, 2, 3, 4, and 5.
<b>DENFAC</b>	<b>g MODE g DENFAC</b>	(0) Sets ‘factors of the maximum denominator’, i.e. the denominator may be an integer factor of DENMAX only.  <b>Example:</b> If DENMAX = 60 then DENFAC will allow for denominators 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60. Now you know why 60 was a holy number in ancient Babylon.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DENFIX	<b>g MODE</b> <b>g DENFIX</b>	(0) Sets fixed denominator format, i.e. the one and only denominator allowed is the value set by DENMAX.
DENMAX	<b>g MODE</b> <b>g DENMAX</b>	(1) Works like /c on HP-35S, but the maximum legal denominator is 9 999. For $x < 1$ or $x > 9\ 999$ , DENMAX will be set to 9 999. For $x = 1$ , the current DENMAX setting is recalled, replacing $x$ .
DET	<b>f CATALOG</b> <b>FCNS DET</b>	Works like  M  explained on p. 101. DET is maintained for backward compatibility only.
DIGITS	<b>f CAT. DIGITS</b>	Submenu of digits. See pp. 114f.
DISP	<b>g DISP</b>	Menu. See p. 121.
DOT	<b>g CPX dot</b>	(2) {3} → {2}; {12} → {11} Returns $Re(x) \cdot Re(y) + Im(x) \cdot Im(y)$
	<b>f MATX f dot</b>	(2) {8} → {2}; {9} → {3} Requires two matrices in $x$ and $y$ and returns their dot (scalar) product. The dot product is defined as the sum of the products of the corresponding elements in both matrices. Note both matrices must be of the same size; else DOT will throw an error. See Sect. 2 of the OM.
DROP	<b>g DROP</b>	Drops $x$ ... from the stack. See Sect. 1 of the OM for details.
DROPy	<b>g STK DROPy</b>	Drops $y$

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DSE		<p>(0) {1, 2, 10, 11}</p> <p>Given <math>cccccc.ffffii</math> in the source, DSE decrements <math>r</math> by <math>ii</math>, skipping next program step if then <math>cccccc \leq ffff</math>.</p> <p>If <math>r</math> features no fractional part then <math>fff</math> is 0. If <math>ii = 0</math>, <math>cccccc</math> will be decremented by 1.</p> <p>DSE does not load <b>L</b> even for destination address <b>X</b>.</p> <p>Note that neither <math>fff</math> nor <math>ii</math> can be negative, and DSE is only sensible with <math>cccccc &gt; 0</math>.</p>
DSL		<p>(0) {1, 2, 10, 11}</p> <p>Works like DSE but skips if <math>cccccc &lt; ffff</math>.</p>
DSTACK		<p>(0) Sets the maximum number of <i>stack registers</i> displayed. For an input of 1, only <math>x</math> will be shown directly above the <i>menu section</i>; for 2, <math>x</math> and <math>y</math> will be displayed; maximum input is 4.</p> <p>Expanded views of e.g. matrices and multi-level returns like SUM will work as described in the OM regardless of the number chosen for DSTACK. In any case, command input will be echoed directly below the <i>status bar</i>.</p> <p>This command is for old-school calculator users who may feel distracted by a multitude of <i>stack registers</i> displayed changing simultaneously.</p>
DSZ		<p>(0) {1, 2, 10, 11}</p> <p>Decrement <math>r</math> by 1 and skips the next step if <math> r  &lt; 1</math> thereafter. Does not load <b>L</b> even for target address <b>X</b>. Cf. HP-29C, HP-67, HP-16C.</p>
D.MS		<p>(0) Sets the <i>ADM</i> to <i>sexagesimal degrees</i>.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
D.MS→	f L→ f D.MS→	(1) {1, 2, 11} → {4} Converts angles as described on pp. 143f.
D.MY	g CLK ▲ D.MY	(0) Sets the format dd.mm.yyyy for date display.
D→J	g CLK f D→J	(1) {2, 6, 11} → {1} Assumes $x$ containing a date in the format selected (or a real number in corresponding format) and converts it to a Julian day number <sup>10</sup> according to J/G setting.
D→R	f L→ g D→R	(1) {1, 2, 11} → {4}
D→D.MS	f L→ g D→D.MS	Convert angles as described on p. 143.
e	g CNST e	(-1) {} → {2}
e <sub>E</sub>	g CNST e <sub>E</sub>	Elementary charge in coulomb and Euler's e.
EIGVAL	f MATX ▲ g EIGVAL	(-1) {8, 9} Evaluates the matrix $x$ and pushes a diagonal matrix containing its eigenvalues on the stack.
EIGVEC	f MATX ▲ g EIGVEC	(-1) {8, 9} Evaluates the matrix $x$ and pushes a matrix containing its eigenvectors on the stack.
END	g P.FN END	(0) Last command in a program and terminal for searching local labels as described in the OM Sect. 3. Works like RTN in all other aspects.
ENDP	g FIN TVM f End	(0) Sets "End" mode in TVM: payments occur at the end of each period. Typical for loans and investments. Cf. BEGINP.

<sup>10</sup> Translator's note: Julian day number translates to "Julianisches Datum" in German and «jour Julien» in French. See the corresponding articles in Wikipedia for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
ENG	<b>g DISP ENG n</b>	(0) Sets engineer's display format (see <i>Section 2</i> of the OM).
ENGOVR	<b>g DISP ▲ ENGOVR</b>	(0) Defines that numbers exceeding the range displayable in ALL or FIX will be shown in engineer's format. Cf. SCIOVR.
ENORM	<b>f MATX g ENORM</b>	(1) {8, 9} → {2}  Calculates the Euclidean norm of the matrix in X. The Euclidean norm is defined as the square root of the sum of squares of all matrix elements. Works like FNRM on HP-42S. For a vector, ENORM returns its length. Cf.  x  on p. 101.
ENTER↑	<b>ENTER↑</b>	(-1) Separates two entries in input. Copies x into Y, disabling <i>automatic stack lift</i> . See p. 111 and the OM ( <i>Section 1</i> ) for details.
ENTRY?	<b>g TEST g ENTRY?</b>	(0) Checks the (internal) entry flag. It is set if: <ul style="list-style-type: none"> <li>any character is entered in A/M, or</li> <li>any command is accepted for entry (be it via <b>ENTER↑</b>, a function key, or <b>R/S</b> with a partial command line).</li> </ul> Useful in routines, e.g. after PAUSE.
EQN	<b>g EQN</b>	Menu. See p. 121.
EQ.DEL	<b>g EQN f DELETE</b>	Deletes an equation.
EQ.EDI	<b>g EQN EDIT</b>	Opens the <i>Equation Editor</i> to edit an existing equation.
EQ.NEW	<b>g EQN NEW</b>	Opens the <i>Equation Editor</i> to enter a new equation.
erf	<b>g X.FN erf</b> etc.	(1) {2, 11}; {1} → {2}
erfc		Returns the error function or its complement. See pp. 233ff for more.

See Section 4 of the OM.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
ERR	<b>g P.FN</b> ERR <b>n</b>	(0) Raises the error specified. The consequences are the same as if the corresponding error really occurred, so e.g. a running routine will be stopped and the message will be thrown. See App. C on pp. 169ff for the respective error codes. Cf. MSG.
EVEN?	<b>g TEST</b> <b>f EVEN?</b>	(0) Checks if $x$ is integer and even.
$e^x$	<b>e<sup>x</sup></b>	(1) {2, 3, 8*, 9*, 11, 12}; {1, 10} → {2} Returns $e^x$ .
EXITALL	<b>g P.FN</b> P.FN2 EXITall	(0) Exits all menus.
EXP	<b>g EXP</b>	Menu. See p. 121.
ExpF	<b>f STAT</b> ▾ <b>ExpF</b>	(0) Selects the exponential curve fit model. Relevant for CORR, COV, L.R., $s_{xy}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 203ff for more.
Expon	<b>g PROB</b> <b>f Expon:</b> Expon etc.	(1) {2, 11}
Expon <sub>e</sub>		<i>Exponential distribution</i> with the rate $\lambda$ in J. See pp. 203ff for more.
Expon <sub>p</sub>		Expon <sup>-1</sup> returns the survival time $t_s$ for a given probability $p$ in X, with $\lambda$ in J.
Expon <sup>-1</sup>		
Expon:	<b>g PROB</b> <b>f Expon:</b>	Submenu. See p. 123.
EXPT	<b>f PARTS</b> EXPT	(1) {1, 2, 11} → {1} Returns the exponent $h$ of the number $x = m \cdot 10^h$ displayed. Cf. MANT.
$e^{x-1}$	<b>g EXP</b> <b>f e<sup>x-1</sup></b>	(1) {2, 3, 8*, 9*, 11, 12} For $x \approx 0$ , this returns a more accurate result for the fractional part than $e^x$ does.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
e/m <sub>e</sub>	<b>g [CNST] e/m<sub>e</sub></b>	(-1) {} → {2} Electron charge to mass ratio in <i>coulomb per kilogram</i> .
E:	<b>g [U→] E:</b>	<i>_submenu</i> . See p. 136.
F	<b>g [CNST] F</b>	(-1) {} → {2} <i>Faraday constant in coulomb per mol.</i>
FAST	<b>g [MODE] f FAST</b>	(0) Sets the processor speed to 'fast'. This is <i>startup default</i> and is kept for fresh batteries. Cf. SLOW.
FB	<b>f [BITS] g FB n</b>	(1) {10} Inverts ('flips') the specified bit in <i>x</i> .
FBR	<b>g a.FN g FBR</b>	(0) Font browser. Displays all characters implemented in the 2 fonts designed for your WP 43S.
FCNS	<b>f [CAT.] FCNS</b>	<i>submenu</i> of provided functions. See pp. 114ff.
FC?	<b>g FLAGS FC? n</b>	(0) Tests if the specified <i>flag</i> is clear.
FC?C	<b>g FLAGS f FC?C n</b>	(0) Tests if the specified <i>flag</i> is clear. Clears, flips, or sets this <i>flag</i> after testing, respectively. etc.
FC?F		
FC?S		
FF	<b>g FLAGS FF n</b>	(0) Flips the <i>flag</i> specified.
FIB	<b>g X.FN f FIB</b>	(1) {1} Returns the Fibonacci number (see pp. 201f).  (1) {2, 3, 11, 12} Returns the extended Fibonacci number.
FILL	<b>g FILL</b>	Copies <i>x</i> to all stack registers.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
FIN	<b>g FIN</b>	<b>Menu.</b> See p. 121.
FIX	<b>g DISP FIX n</b>	(0) Sets fixed point display format (see the OM, Sect. 2).
FLAGS	<b>g FLAGS</b>	<b>Menu.</b> See p. 121.
FLASH	<b>f CATALOG PROGS FLASH</b>	<b>Submenu</b> of global labels defined at execution time. See pp. 114f.
FLASH?	<b>g INFO f FLASH?</b>	(-1) {} → {1} Returns the number of free words in FM (1 word = 2 bytes).
FLOOR	<b>g INTS g FLOOR</b>	(1) {8*}; {1, 2, 11} → {1} Returns the greatest integer ≤ $x$ . Cf. CEIL.
$fm \rightarrow m$	<b>g U→ x: ▲ fathom → m</b>	(1) {2, 11}; {1} → {2} Converts distances. See pp. 136ff.
FP	<b>f PARTS FP</b>	(1) {1, 2, 8*, 10, 11} Returns the fractional part of $x$ . Cf. IP.
FP?	<b>g TEST f FP?</b>	(0) Tests $x$ for having a fractional part ≠ 0 .
$F_e(x)$	<b>g PROB F:</b>	<b>(1) {2, 11}</b> <i>Fisher's F distribution.</i> $F_e(x)$ equals $Q(F)$ on HP-21S. The degrees of freedom are specified in <b>I</b> and <b>J</b> . See pp. 203ff for more.
$F_p(x)$	<b>F<sub>p</sub>(x)</b>	
$F(x)$	<b>etc.</b>	
$F^{-1}(p)$		
$fr \rightarrow dB$	<b>g U→ ▲ field ratio→dB</b>	(1) {2, 11}; {1} → {2} Converts ratios. See pp. 136ff.
FS?	<b>g FLAGS FS? n</b>	(0) Tests if the specified <i>flag</i> is set.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
FS?C	<b>g</b> <b>FLAGS</b> <b>f</b> FS?C <i>n</i> etc.	(0) Tests if the specified <i>flag</i> is set. Clears, flips, or sets this <i>flag</i> after testing, respectively.
FS?S		
ft. $\rightarrow$ m	<b>g</b> <b>U<math>\leftrightarrow</math></b> <b>x:</b> <b>f</b> ft. $\rightarrow$ m	(1) {2, 11}; {1} $\rightarrow$ {2}
ft <sub>US</sub> $\rightarrow$ m	<b>g</b> <b>U<math>\leftrightarrow</math></b> <b>x:</b> <b>▲</b> survey foot <sub>US</sub> $\rightarrow$ m	Convert distances. See pp. 136ff.
fz <sub>UK</sub> $\rightarrow$ m <sup>3</sup>	<b>g</b> <b>U<math>\leftrightarrow</math></b> <b>f</b> <b>V:</b> <b>f</b> fz <sub>UK</sub> $\rightarrow$ m <sup>3</sup>	(1) {2, 11}; {1} $\rightarrow$ {2}
fz <sub>US</sub> $\rightarrow$ m <sup>3</sup>	<b>g</b> <b>U<math>\leftrightarrow</math></b> <b>f</b> <b>V:</b> <b>f</b> fz <sub>US</sub> $\rightarrow$ m <sup>3</sup>	Convert volumes. See pp. 136ff.
F <sub><math>\alpha</math></sub>	<b>g</b> <b>CNST</b> F <sub><math>\alpha</math></sub>	(-1) {} $\rightarrow$ {2}
F <sub><math>\delta</math></sub>	<b>g</b> <b>CNST</b> F <sub><math>\delta</math></sub>	Feigenbaum's $\alpha$ and $\delta$ .
F:	<b>g</b> <b>PROB</b> F:	Submenu. See p. 123.
f'	<b>g</b> <b>EQN</b> f'	Submenus for calculating the first or second derivative of a given equation. See the OM (Sect. 4) for more.
f''	<b>g</b> <b>EQN</b> f''	
f'(x)	<b>f</b> <b>ADV</b> f'(x) <i>labl</i>	{1, 2, 11} $\rightarrow$ {2}  f'(x) [f'(x)] returns the 1 <sup>st</sup> [2 <sup>nd</sup> ] derivative of the function f(x) at position x. This f(x) must be specified in a routine starting with LBL labl. On return, Y, Z, and T will be cleared and the position x will be in L. See Section 4 of the OM for more.
f''(x)	<b>f</b> <b>ADV</b> <b>f</b> f''(x) <i>labl</i>	<b>ATTENTION:</b> f'(x) and f''(x) fill all stack registers with x before calling the routine specified.
F&p:	<b>g</b> <b>U<math>\leftrightarrow</math></b> F&p:	Submenu. See p. 136.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
G	<b>g</b> <b>CNST</b> <b>G</b>	(-1) {} → {2} Newtonian constant of gravitation in $m^3/kg\ s^2$ ; also called $\gamma$ by other authors.
$G_0$	<b>g</b> <b>CNST</b> <b><math>G_0</math></b>	(-1) {} → {2} Conductance quantum in <i>siemens</i> .
GAP	<b>g</b> <b>DISP</b> <b>▲</b> <b>f</b> <b>GAP</b> <b>n</b>	(0) Defines the interval for inserting digit group separators in reals. For integers, the intervals are fixed to 4 digits for binary and 3 for any other base – except 4, 8, and 16 where the interval is 2. In input, gaps will always be inserted as chosen for reals. After GAP 0, <u>no</u> group separators will be displayed neither in reals nor integers at all. See Sect. 2 of the OM.
GaussF	<b>f</b> <b>STAT</b> <b>▼</b> <b>f</b> <b>GaussF</b>	(0) Selects the Gauß peak fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 212ff for more.
$G_C$	<b>g</b> <b>CNST</b> <b><math>G_C</math></b>	(-1) {} → {2} Catalan's (mathematical) constant.
GCD	<b>g</b> <b>INTS</b> <b>g</b> <b>GCD</b>	(2) {1; 10} Returns the Greatest Common Divisor of $x$ and $y$ . <sup>11</sup> This will always be positive.
$g_d$	<b>g</b> <b>X.FN</b> <b>f</b> <b><math>g_d</math></b> etc.	(1) {2, 3, 11, 12} ; {1} → {2} Returns the Gudermannian function or its inverse. See p. 234 for details.

<sup>11</sup> See also LCM. Remember school?

Translator's notes for French readers: GCD correspond à PGCD en français,  
 Translator's notes for German readers: GCD entspricht ggT auf Deutsch.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>g<sub>e</sub></b>	<b>g [CNST] g<sub>e</sub></b>	(-1) {} → {2} Landé's electron g-factor.
<b>Geom</b>	<b>g [PROB]</b> <b>g Geom: Geom</b> etc.	(1) {2, 11}
<b>Geom<sub>e</sub></b>		Geometric distribution: The CDF returns the probability for a first success after $m = x$ Bernoulli experiments. The probability $p_0$ for a success in each such experiment must be specified in <b>J</b> . See pp. 203ff for more.
<b>Geom<sub>p</sub></b>		
<b>Geom<sup>-1</sup></b>		Geom <sup>-1</sup> returns the number of failures $f$ before 1 <sup>st</sup> success for given probabilities $p$ in <b>X</b> , $p_0$ in <b>J</b> .
<b>Geom:</b>	<b>g [PROB] f Geom:</b>	Submenu. See p. 123.
<b>gl<sub>uk</sub>→m<sup>3</sup></b>	<b>g [U→] f V: gl<sub>uk</sub>→m<sup>3</sup></b>	(1) {2, 11}; {1} → {2}
<b>gl<sub>us</sub>→m<sup>3</sup></b>	<b>g [U→] f V: gl<sub>us</sub>→m<sup>3</sup></b>	Convert volumes. See pp. 136ff.
<b>GM<sub>⊕</sub></b>	<b>g [CNST] GM<sub>⊕</sub></b>	(-1) {} → {2} Newtonian constant of gravitation times the Earth's mass with its atmosphere included according to WGS84. <sup>12</sup> Displayed in $m^3/s^2$ .
<b>GRAD</b>	<b>g [MODE] GRAD</b>	(0) Sets the ADM to grad/gon. <sup>13</sup>
<b>GRAD→</b>	<b>f [L→] f GRAD→</b>	(1) {1, 2, 11} → {4} Converts angles as described on pp. 143f.
<b>GTO</b>	<b>f [GTO] labl</b>	(0) In PEM: inserts an unconditional branch to <b>labl</b> . Else positions the program pointer to <b>labl</b> .

<sup>12</sup> See [http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350\\_2.html](http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html) .

<sup>13</sup> This angular unit is also known as *gradian* in the English language.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
GTO.	<b>f GTO</b> . <i>n</i>	to step <i>n</i> (specify up to four digits until becoming unambiguous in used program memory).
	<b>f GTO</b> . <i>label</i>	to the global label specified.
	<b>f GTO</b> . ▲	(0) Puts the program pointer ...
	<b>f GTO</b> . ▼	directly after <u>previous</u> END, going to the top of <i>current program</i> (see Section 3 of the OM).
	<b>f GTO</b> . ..	directly after <u>next</u> END, going to the top of <i>next program</i> .
$g_{\oplus}$	<b>g CNST</b> $g_{\oplus}$	$(-1) \{ \} \rightarrow \{2\}$ Standard earth acceleration in $m/s^2$ .
	<b>g CNST</b> $h$	$(-1) \{ \} \rightarrow \{2\}$ <i>Planck constant in joule-second.</i>
$H_n$	<b>g X.FN</b> Orthog $H_n$	$(2) \{2, 11\}; \{1\} \rightarrow \{2\}$
$H_{np}$	... Orthog <b>f</b> $H_{np}$	<i>Hermite polynomials for probability (<math>H_n</math>) and physics (<math>H_{np}</math>). See p. 218 for details.</i>
$hp_E \rightarrow W$	<b>g U→</b> P: $hp_E \rightarrow W$ etc.	$(1) \{2, 11\}; \{1\} \rightarrow \{2\}$ Convert powers. See pp. 136ff.
$hp_M \rightarrow W$		
$hp_UK \rightarrow W$		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Hyper	<b>g PROB</b> <b>g Hyper:</b> Hyper etc.	(1) {2, 11}  Hypergeometric distribution with the number of successes $g$ in X, the probability of a success $p_0$ in I, the sample size $n$ in J, and the batch size $n_0$ in K. See pp. 203ff for the formula.
Hyper <sub>e</sub>		
Hyper <sub>p</sub>		
Hyper <sup>-1</sup>		Hyper <sup>-1</sup> returns the maximum number of successes $m$ for a given probability $p$ in X, $p_0$ in I, $n$ in J, and $n_0$ in K.
Hyper:	<b>g PROB</b> <b>g Hyper:</b>	Submenu. See p. 123.
HypF	<b>f STAT</b> ▾ <b>f HypF</b>	(0) Selects the hyperbolic fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 212ff for more.
$\hbar$	<b>g CNST</b> $\hbar$	(-1) {} → {2}  $= \frac{h}{2\pi}$ , so-called Dirac constant in joule-second.
IDIV	<b>g INTS</b> <b>f IDIV</b>	(2) {1, 10}; {2, 11} → {1}  Integer division, working like <b>/</b> <b>IP</b> .
IDIVR	<b>f CATALOG</b> FCNS IDIVR	{1, 10}; {2, 11} → {1}  Like IDIV but also returns the remainder in Y.
iHg→Pa	<b>g U→</b> F&p: <b>f in.Hg</b> → Pa	(1) {2, 11}; {1} → {2}  Converts pressures. See pp. 136ff.
Im	<b>g CPX</b> <b>f Im</b>  <b>f PARTS</b> <b>g Im</b>	(1) {3} → {2}; {9} → {8}; {12} → {11}  Returns the imaginary part of x. Cf. RE.
IMPFRC	<b>g d/c</b>	(1) {2, 11}  Allows only <i>improper fractions</i> in display (e.g. $\frac{5}{3}$ instead of $1\frac{2}{3}$ ). Displays any reals (with $ x  < 10^6$ ) according to the settings by DEN... as <i>improper fractions</i> . Cf. PROFRC.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
INC	<b>f</b> LOOP <b>f</b> INC <i>r</i>	(0) {1, 2, 10, 11} Increments <i>r</i> by 1. Does not load L even for target address X.
INDEX	<b>f</b> MATX <b>f</b> INDEX <i>name</i>	(1) Indexes a named matrix. You can also index a matrix by editing it (see M.EDIT or M.EDIN). After exiting the <i>Matrix Editor</i> , the matrix is no longer indexed.  See also <i>Matrix Utility Functions</i> in the <i>HP-42S Owner's Manual</i> , pp. 223ff.
INFO	<b>g</b> INFO	Menu. See p. 122.
INPUT	<b>g</b> P.FN INPUT <i>r</i>	Works in programs only: Recalls the content of the source specified into X, displays the name of the source along with <i>r</i> , and halts program execution, allowing you to enter or calculate a value; pressing R/S then stores <i>x</i> into said destination and continues program execution – pressing EXIT instead cancels INPUT, so R/S thereafter will continue with the source content as it was.  If you use an input variable name undefined at execution time, INPUT automatically creates the variable with an initial value of zero.
INTS	<b>g</b> INTS	Menu. See p. 122.
INT?	<b>g</b> TEST <b>f</b> INT?	(0) Tests <i>x</i> for being an integer, i.e. having a fractional part equal to zero. Cf. FP?.
INVRT	<b>f</b> CATALOG FCNS INVRT	Works like $[M]^{-1}$ on p. 101. INVRT is maintained for backward compatibility only.
in. $\rightarrow$ m	<b>g</b> U $\rightarrow$ x: <b>g</b> in. $\rightarrow$ m	(1) {2, 11}; {1} $\rightarrow$ {2} Converts distances. See pp. 136ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
IP	f PARTS IP	(1) {1, 2, 8*, 10, 11} Returns the integer part of $x$ . Cf. FP.
ISE	f LOOP ISE r	(0) {1, 2, 10, 11} Given ccccccc.ffffii in the source, ISE increments $r$ by ii, skipping next program step if ccccccc $\geq$ ffff then. If $r$ has no fractional part then ffff = 0 and ii = 0. If ii = 0, ccccccc will be incremented by 1. ISE does not load L even for target address X. Note that neither ffff nor ii can be negative, but ccccccc can.
ISG	f LOOP ISG r	(0) {1, 2, 10, 11} Works like ISE but skips if ccccccc > ffff.
ISZ	f LOOP ISZ r	(0) {1, 2, 10, 11} Increments $r$ by 1, skipping next program step if then $ r  < 1$ . ISZ does not load L even for target address X. Cf. HP-29C, HP-67, and HP-16C.
I <sub>xyz</sub>	g X.FN f I <sub>xyz</sub>	(3) {1, 2, 11} Returns the <i>regularized Beta function</i> .  See p. 234 for more.
IΓ <sub>p</sub>	g X.FN f IΓ <sub>p</sub>	(2) {1, 2, 11}
IΓ <sub>q</sub>	etc.	Returns the <i>regularized Gamma function</i> (one of two kinds).
I+	f MATX ▲ I+	(1) Increments or decrements the row index of the indexed matrix. See INDEX and also J+, J-, RCLEL, STOEL, RCLIJ, and STOIJ.
I-	f MATX ▲ I-	
I/O	g I/O	Menu. See p. 122.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
J <sub>y</sub> (x)	 	(2) {2, 11}; {1} → {2} J <sub>y</sub> (x) returns the <i>Bessel function of first kind</i> and order $y$ . See p. 235 for details.
J+	▲ J+	(1) <b>Increments</b> or decrements the column index of the indexed matrix. If M.GROW is set and the pointers I and J are at the last element of the matrix, executing J+ creates a new row at the end of the matrix. See INDEX and also I+, I-, RCSEL, STOEL, RCLIJ, and STOIJ.
J-	▲ J-	
J/G	▲	(0) {2, 6} Sets the date the Gregorian calendar was introduced in the region you are interested in. See <i>Dates</i> in Section 2 of the OM.
J→Btu	E: J→Btu	(1) {2, 11}; {1} → {2}
J→cal	etc.	Convert energies. See pp. 136ff.
J→D		(1) {1} → {6} Takes $x$ as a <i>Julian day number</i> <sup>14</sup> and converts it to a common <i>date</i> according to J/G (s. above) and the date format selected.
J→Wh	E: J→Wh	(1) {2, 11}; {1} → {2} Converts energies. See pp. 136ff.
k	k	(-1) {} → {2} Boltzmann constant in <i>joule per kelvin</i> .
KEY		See KEYG and KEYX below.

<sup>14</sup> Translator's note: *Julian day number* translates to "Julianisches Datum" in German and «jour Julien» in French. See the corresponding articles in Wikipedia for more information about these numbers.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
KEYG	<b>g P.FN P.FN2</b> <b>KEYG key#, labl</b>	Defines the label to be branched to (KEYG) or called (KEYX) when a particular softkey is pressed. KEYG and KEYX work in PEM only and will be translated to a program step  <b>KEY key# GTO labl</b> or  <b>KEY key# XEQ labl ,</b>
KEYX	<b>g P.FN P.FN2</b> <b>KEYX key#, labl</b>	respectively. Key numbers go from 1 to 18 with 1 corresponding to <b>F1</b> , 9 to <b>f F3</b> , and 14 to <b>g F2</b> , for example.
KEY?	<b>g TEST</b> <b>g KEY? r</b>	(0) Tests if a key was pressed while a routine was running or paused. If <u>no</u> key was pressed in that interval, the next program step after KEY? will be executed; else it will be skipped and the code of said key will be stored in <i>r</i> . Key codes reflect the rows and columns on the keyboard (see the OM, Sect. 3; cf. GETKEY on HP-42S).
kg→ct	<b>g U→ m: f kg → carat</b>	(1) {2, 11}; {1} → {2} Convert masses. See pp. 136ff.
kg→cwt	<b>g U→ m: kg → cwt</b>	
kg→lb.	etc.	
kg→oz		
kg→scw	<b>g U→ m: f kg → sh.cwt</b>	
kg→sto	<b>g U→ m: f kg → stone</b>	
kg→s.t	<b>g U→ m: ▲ kg → short ton</b>	
kg→ton	<b>g U→ m: ▲ kg → ton</b>	
kg→trz	<b>g U→ m: f kg → tr.oz</b>	
K <sub>J</sub>	<b>g CNST K<sub>J</sub></b>	(-1) {} → {2} Josephson constant in <i>hertz per volt</i> .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
KTYP?	<b>g INFO</b> <b>KTYP? <i>r</i></b>	<p>(-1) { } → {1}</p> <p>Assumes a key code in the address specified (see KEY?), checks it, and returns the key type:</p> <ul style="list-style-type: none"> <li>• 0 ... 9 if it corresponds to a digit 0 ... 9,</li> <li>• 10 if it corresponds to ., E, or +/−,</li> <li>• 11 if it corresponds to f or g,</li> <li>• 13 if it corresponds to a softkey, and</li> <li>• 12 if it corresponds to any other key.</li> </ul> <p>May help in user interaction with routines (see the OM, Section 3)..</p>
LASTx	<b>RCL L</b>	(-1) See Section 1 of the OM. Actually, this command will be recorded as RCL L in routines.
lbf→N	<b>g U- F&amp;p: lbf→N</b>	(1) {2, 11}; {1} → {2}
lb.→kg	<b>g U- m: lb.→kg</b>	Convert forces and masses. See pp. 136ff.
LBL	<b>g LBL <i>label</i></b>	(0) Identifies programs and routines for execution and branching. Read more about labels and specifying them in Sect. 3 of the OM.
LBL?	<b>g TEST</b> <b>g LBL? <i>label</i></b>	(0) Tests for existence of the label specified, anywhere in program memory. See LBL for more.
LCM	<b>g INTS</b> <b>f LCM</b>	<p>(2) {1; 10}</p> <p>Returns the Least Common Multiple of <math>x</math> and <math>y</math>.<sup>15</sup> This will always be positive.</p>

<sup>15</sup> See also GCD. Remember school?

Translator's notes for French readers: LCM correspond à PPCM en français,  
 Translator's notes for German readers: LCM entspricht kgV auf Deutsch..

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LEAP?	<b>g TEST</b> <b>f LEAP?</b>	(0) {2, 6, 11} Assumes $x$ containing a date in the format selected (or a real number in corresponding format), extracts the year, and tests for a leap year.
LgNrm	<b>g PROB</b>	(1) {2, 11}
LgNrm <sub>e</sub>	<b>f LgNrm:</b> LgNrm etc.	<i>Log-normal distribution</i> with $\mu = \ln \bar{x}_g$ specified in <b>I</b> and $\sigma = \ln \varepsilon$ in <b>J</b> . See $\bar{x}_g$ and $\varepsilon$ below and pp. 203ff for more.
LgNrm <sub>p</sub>		
LgNrm <sup>-1</sup>		$\text{LgNrm}^{-1}$ returns $x$ for a given probability $p$ in <b>X</b> , with $\mu$ in <b>I</b> and $\sigma$ in <b>J</b> .
LgNrm:	<b>g PROB</b> <b>f LgNrm:</b>	Submenu. See p. 123.
LinF	<b>f STAT</b> ▾ LinF	(0) Selects the linear fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 203ff for more.
LJ	<b>f BITS</b> ▲ <b>g LJ</b>	(-1) {10} Left justifies a bit pattern within its word size as in HP-16C: The stack will lift, placing the left-justified word in <b>Y</b> and the count (of bit-shifts necessary to left justify the word) in <b>X</b> .  <b>Example</b> for word size 8: 1 0110 <sub>2</sub> LJ returns $x = 3$ and $y = 1011\ 0000_2$ .
L <sub>m</sub>	<b>g X.FN Orthog L<sub>m</sub></b>	(2) {2, 11}; {1} → {2} Laguerre polynomials. See pp. 218f for more.
L <sub>mx</sub>	<b>g X.FN Orthog L<sub>mx</sub></b>	(3) {2, 11}; {1} → {2} Laguerre's generalized polynomials. See pp. 218f for more.
LN	<b>In</b>	(1) {2, 3, 8*, 9*, 11, 12}; {1, 10} → {2} Returns the natural logarithm of $x$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LN( $1+x$ )	[g] EXP [f] ln 1+x	(1) {2, 3, 8*, 9*, 11, 12} For $x \approx 0$ , this returns a more accurate result for the fractional part than ln( $x$ ) does.
LN $\beta$	[g] X.FN [g] ln $\beta$	(2) {2, 3, 11, 12}; {1} → {2} Returns the natural logarithm of Euler's Beta function (see p. 90).
LN $\Gamma$	[g] X.FN [g] ln $\Gamma$	(1) {2, 3, 11, 12}; {1} → {2} Returns the natural logarithm of $\Gamma(x)$ (see p. 91). Allows also for calculating really great factorials.
LOAD	[g] I/O LOAD	Restores the entire backup from FM and returns <b>Backup restored</b> . Thus, LOAD = LOADP + LOADDR + LOADSS + LOADΣ. <sup>16</sup>
LOADP	[g] I/O LOADP	(0) Loads the complete program memory from backup and appends it to the programs already in RAM. This will only work if there is enough space – else an error will be thrown. <sup>16</sup>
LOADDR	[g] I/O LOADDR	(0) Recovers the numbered general purpose registers from backup. Lettered registers will not be recalled. <sup>16</sup>
LOADSS	[g] I/O LOADSS	(0) Recovers the system state from backup. <sup>16</sup>
LOADΣ	[g] I/O LOADΣ	(0) Recovers the statistical summation registers from backup. Throws an error if there are none. <sup>16</sup>
LocR	[g] P.FN [g] LocR n	(0) Allocates $n$ local registers ( $\leq 100$ ) and 16 local flags for the current routine. See the OM, Sect. 3.

<sup>16</sup> See SAVE on p. 73 and App. A on pp. 143f for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LocR?	<b>g INFO</b> <b>f LocR?</b>	(-1) {} → {1} Returns the number of <i>local registers</i> currently allocated.
LOG <sub>10</sub>	<b>g lg</b>	(1) {1, 2, 3, 8*, 9*, 10, 11, 12} {{1} → {2}} Returns the logarithm of <i>x</i> for base 10.
LOG <sub>2</sub>	<b>g EXP</b> lb x	(1) {1, 2, 3, 8*, 9*, 10, 11, 12} {{1} → {2}} Returns the logarithm of <i>x</i> for base 2.
LogF	<b>f STAT</b> ▼ LogF	(0) Selects the logarithmic curve fit model. Relevant for CORR, COV, L.R., s <sub>XY</sub> , $\hat{x}$ , and $\hat{y}$ . See pp. 203ff for more.
Logis	<b>g PROB</b> <b>f Logis:</b> Logis etc.	(1) {2, 11} <i>Logistic distribution</i> with $\mu$ given in <b>I</b> and $s$ in <b>J</b> . See pp. 203ff for details.
Logis <sub>e</sub>		
Logis <sub>p</sub>		
Logis <sup>-1</sup>		
Logis:	<b>g PROB</b> <b>f Logis:</b>	Submenu. See p. 123.
LOG <sub>xy</sub>	<b>g EXP</b> log <sub>xy</sub>	(2) {1, 2, 3, 8*, 9*, 10, 11, 12}; {{1} → {2}} Returns the logarithm of <i>y</i> for the base <i>x</i> .
LOOP	<b>f LOOP</b>	Menu. See p. 122.
l <sub>PL</sub>	<b>g CNST</b> l <sub>PL</sub>	(-1) {} → {2} <i>Planck length</i> in <i>meter</i> .
ly→m	<b>g U→</b> x: ly→m	(1) {2, 11}; {1} → {2} Converts distances. See pp. 136ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LZOFF	<b>f BITS</b> ▼ <b>f LZOFF</b>	(0) Toggle leading zeros in <i>short integers</i> like <i>flag 3</i> does in HP-16C. Works in bases 2, 4, 8, and 16 only.
LZON	<b>f BITS</b> ▼ <b>LZON</b>	
L.INTS	<b>f CATALOG</b> <b>VARS L.INTS</b>	Submenu of <i>long integer</i> variables defined at execution time. See pp. 114ff.
L.R.	<b>f STAT</b> ▲ <b>L.R.</b>	(-2) {} → {2} Pushes the parameters $a_2$ (in Z), $a_1$ (in Y), and $a_0$ (in X) of the fit curve through the data points accumulated in the statistical summation <i>registers</i> on the <i>stack</i> , according to the curve fit model selected (see LINF, ORTHOF, EXPF, POWERF, LOGF, HYPF, ROOTF, PARABF, CAUCHF, GAUSSF). For a straight line, $a_0$ is its y-intercept and $a_1$ is its slope. See pp. 203ff for more.
$m^2 \rightarrow ac$	<b>g U→ f A: <math>m^2 \rightarrow acre</math></b>	(1) {2, 11}; {1} → {2} Convert areas. See pp. 136ff.
$m^2 \rightarrow ac_{us}$	<b>g U→ f A: <math>m^2 \rightarrow acre_{us}</math></b>	
$m^3 \rightarrow bbl$	<b>g U→ f V: f <math>m^3 \rightarrow barrel</math></b>	(1) {2, 11}; {1} → {2} Convert volumes. See pp. 136ff.
$m^3 \rightarrow fz_{uk}$	<b>g U→ f V: f <math>m^3 \rightarrow floz_{uk}</math></b> etc.	
$m^3 \rightarrow fz_{us}$	<b>g U→ f V: f <math>m^3 \rightarrow gl_{uk}</math></b> etc.	
$m^3 \rightarrow gl_{us}$	<b>g U→ f V: f <math>m^3 \rightarrow gl_{us}</math></b> etc.	
MANT	<b>f PARTS MANT</b>	(1) {2, 11}; {1} → {2} Returns the mantissa $m$ of the number $x = m \cdot 10^h$ displayed. Cf. EXPT.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
MASKL	f BITS MASKL n	(-1) {} → {10} Work like MASKL and MASKR on HP-16C, but with the mask length (or its address) following the command instead of taken from X. Thus, the mask is pushed on the stack.
MASKR	f BITS MASKR n	<b>Example:</b> For WSIZE 8, MASKL 3 returns a mask word 1110 0000 <sub>2</sub> . Use it e.g. for extracting the three most significant bits of an arbitrary byte via AND.
MATRS	f CATALOG VARS MATRS	Submenu of matrix variables defined at execution time. See pp. 114f.
MATR?	g TEST ▲ MATR?	(0) Checks if x is a real or complex matrix.
MATX	f MATX	Menu. See p. 122.
Mat_X	f MATX SIM EQ Mat X	(-1) Returns the solution vector of a system of linear equations (see Section 2 of the OM).
max	g X.FN g max	(2) {1, 2, 4, 5, 6, 10, 11} Returns the maximum of x and y.
m_e	g CNST m_e	(-1) {} → {2} Electron mass in kilogram.
MEM?	g INFO MEM?	(-1) {} → {1} Returns the number of free words in program memory (1 word = 2 bytes), also taking into account the local registers allocated.
MENU	g P.FN P.FN2 MENU	Displays the programmable menu. See the HP-42S OM, Part 2, Section 10, p. 146.
MENUS	f CAT. MENUS	Submenu of menus defined at execution time. See pp. 114ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
min	[g] X.FN [g] min	(2) {1, 2, 4, 5, 6, 10, 11} Returns the minimum of $x$ and $y$ .
MIRROR	[f] BITS [f] MIRROR	(1) {10} Reflects the bit pattern in $x$ (e.g. $0001\ 0111_2$ would become $1110\ 1000_2$ for word size 8).
mi. $\rightarrow$ m	[g] U- x: [f] mi. $\rightarrow$ m	(1) {2, 11}; {1} $\rightarrow$ {2} Converts distances. See pp. 136ff.
M <sub>Moon</sub>	[g] CNST M <sub>Moon</sub>	(-1) {} $\rightarrow$ {2}
m <sub>n</sub>	etc.	Masses of the Moon and the neutron in <i>kilogram</i> ;
m <sub>n</sub> /m <sub>p</sub>		neutron to proton mass ratio.
MOD	[g] INTS [f] MOD	(2) {1, 2, 3, 10, 11, 12} Returns $y \bmod x$ (see <i>Section 2</i> of the OM for examples). Cf. RMD.
MODE	[g] MODE	Menu. See p. 122.
MONTH	[g] CLK [f] MONTH	(1) {2, 6, 11} $\rightarrow$ {1} Assumes $x$ containing a <i>date</i> in the format selected (or a real number in corresponding format) and extracts the month.
m <sub>p</sub>	[g] CNST m <sub>p</sub>	(-1) {} $\rightarrow$ {2}
m <sub>PL</sub>	etc.	Proton mass and <i>Planck</i> mass in <i>kilogram</i> ;
m <sub>p</sub> /m <sub>e</sub>		proton to electron mass ratio.
MSG	[g] P.FN P.FN2 [f] MSG	(0) {1, 2, 11} Throws the ( <i>temporary</i> ) <i>error message</i> specified by the integer part of $x$ . Cf. ERR. See App. C on pp. 169ff for the respective error codes.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$m_u$	<b>g</b> [CNST] $m_u$	(-1) {} → {2}
$m_u c^2$	<b>g</b> [CNST] $m_u c^2$	Atomic mass constant in <i>kilogram</i> and its energy equivalent in <i>joule</i> .
MULT×	<b>g</b> [DISP] ▲ MULT×	(0) Select the symbol for multiplication display.
MULT-	<b>g</b> [DISP] ▲ MULT-	
MULπ	<b>g</b> [MODE] MULπ	(0) Sets the ADM to <i>multiples of π</i> .
MULπ→	<b>f</b> [L→] <b>f</b> MULπ→	(1) {1, 2, 11} → {4} Converts angles as described on pp. 143f.
MVAR	<b>g</b> [P.FN] P.FN2 <b>f</b> MVAR <i>name</i>	(0) Defines a <i>menu variable</i> . Such variables are required for VARMNU. Works in <i>PEM</i> only.
MyMenu	<b>f</b> [CAT.] MENUS MyMenu	User menu. See the OM, Section 6.
Myα	<b>f</b> [CAT.] CHARS Myα	User menu in AIM.
$m_\mu$	<b>g</b> [CNST] $m_\mu$	(-1) {} → {2} Muon mass in <i>kilogram</i> .
M.DELR	<b>f</b> DELR with M.EDIT displayed	(0) {8, 9} Deletes the current row of elements (where the cursor is in). Will not work if the matrix has only one row.
M.DIM	<b>f</b> [MATX] <b>f</b> DIM <i>name</i>	(0) {1, 2} Creates a new named matrix or re-dimensions an existing matrix to IP(y) rows and IP(x) columns. See DIM in the <i>HP-42S Owner's Manual</i> , p. 217.
M.DIM?	<b>g</b> [INFO] <b>g</b> DIM?  <b>f</b> [MATX] ▲ <b>f</b> DIM?	{8, 9} → {1} Returns the dimensions of the matrix <i>x</i> (rows to Y, columns to X). Note the matrix is saved in L. Previous y goes into Z, previous z into T, etc.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
M.DY		(0) Selects the format mm/dd/yyyy for <i>date</i> display.
M.EDI		(2) {8, 9} Opens <i>x</i> using the <i>Matrix Editor</i> (like MATRIX EDIT in HP-42S). See <i>Section 2</i> of the OM.
M.EDIN		(2) Opens a named matrix using the <i>Matrix Editor</i> (like MATRIX EDITN in HP-42S). See <i>Section 2</i> of the OM.
M.EDIT		<i>Submenu</i> for matrix editing, called by M.EDI or M.EDIN. See p. 122.
M.GET		(0) {1, 2} → {8, 9} Gets a sub-matrix with IP(y) rows and IP(x) columns out of the indexed matrix into <i>X</i> (like GETM in HP-42S). Cf. M.PUT.
M.GOTO	 with M.EDIT displayed	(0) Asks for target row and column and moves to this matrix element.
M.GROW	 with M.EDIT displayed	(0) Allows the indexed matrix to grow automatically (see J+ above and <i>Section 2</i> of the OM; see also GROW in the <i>HP-42S Owner's Manual</i> , p. 213.). Cf. M.WRAP.
M.INSR	 with M.EDIT displayed	(0) {8, 9} Inserts a new row of elements containing zero, left of the current cursor position in the matrix.
M.LU		(1) Takes a <i>descriptor</i> of a square matrix in <i>X</i> . Transforms ( <i>X</i> ) into its LU decomposition in-situ. The value in <i>X</i> is replaced by a <i>descriptor</i> that defines the pivots that were required to calculate the decomposition. The most significant digit is the pivot for the first diagonal entry, the next most significant for the second and so forth.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
M.NEW	f MATX NEW	(2) {1, 2} → {8} Creates a new matrix (like NEW in HP-42S). Its number of rows shall be supplied in Y and its number of columns in X. M.NEW returns a clear matrix in X – all its elements are set to zero.
M.OLD	OLD with M.EDIT displayed	(0) Recalls the old element content (like OLD in HP-42S). See Section 2 of the OM.
M.PUT	f MATX g PUTM	(0) {8, 9} Puts the matrix x as is into the indexed matrix (like PUTM in HP-42S). Cf. M.GET.
M.R>R	f MATX ▲ f R>R	(0) {8, 9} Swaps row x and row y of the indexed matrix (like R>>R in HP-42S).
M.SIMQ		Submenu of MATX, called by SIM_EQ.
M.SQR?	g TEST ▲ f M.SQR?	(0) Returns true if x is a square matrix.
M.WRAP	f WRAP with M.EDIT displayed	(0) Controls the index pointers (see Section 2 of the OM). Cf. M.GROW.
m:	g U→ m:	Submenu. See p. 136.
m→au	g U→ x: m→au	(1) {2, 11}; {1} → {2} Convert distances or heights. See pp. 136ff.
m→fm.	g U→ x: ▲ m → fathom	
m→ft.	g U→ x: f m → ft.	
m→ft <sub>us</sub>	g U→ x: ▲ m → survey foot <sub>us</sub>	
m→in.	g U→ x: g m → in.	
m→ly	g U→ x: m → ly	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
m→mi.	[g] [U→] [x:] [f] m→mi.	
m→nmi.	[g] [U→] [x:] [f] m→nmi.	
m→pc	[g] [U→] [x:] m→pc	
m→pt.	[g] [U→] [x:] [g] m → point	
m→yd.	[g] [U→] [x:] [g] m→yd.	
m <sub>⊕</sub>	[g] [CNST] m <sub>⊕</sub> etc.	(-1) {} → {2}
m <sub>⊕</sub>		Masses of the Sun and Earth in <i>kilogram</i> .
N <sub>A</sub>	[g] [CNST] N <sub>A</sub>	(-1) {} → {2} Avogadro's number in <i>particles per mol</i> .
NaN	[g] [CNST] NaN	(-1) Not a Number.
NAND	[f] [BITS] [f] NAND	(2) Works in analogy to AND. See p. 18.
NaN?	[g] [TEST] ▲ [f] NaN?	(0) Returns true if x is Not a Number.
NBin	[g] [PROB]	(1) {2, 11}
NBin <sub>e</sub>	[g] [NBIN: NBIN] etc.	
NBin <sub>p</sub>		
NBin <sup>-1</sup>		
NBin:	[g] [PROB] [g] NBIN:	Submenu. See p. 123.
NEIGHB	[g] [INFO] [f] NEIGHB	(2) {1} Returns ... • x + 1 for x < y ; • x for x = y ; • x - 1 for x > y .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		(2) {2, 3, 11, 12} Returns the nearest machine-representable number to $x$ in the direction towards $y$ in the mode set. For <ul style="list-style-type: none"> <li>... <math>x &lt; y</math>, it is the machine successor of <math>x</math>;</li> <li>... <math>x = y</math>, it is <math>y</math>;</li> <li>... <math>x &gt; y</math>, it is the machine predecessor of <math>x</math>.</li> </ul> NEIGHB may be useful investigating numeric stability (see NEIGHBOR in the <i>HP-71 Math Pac</i> ).
NEXTP	<b>g X.FN</b> <b>g NEXTP</b>	(1) {1, 2, 11} → {1} Returns the next prime number greater than $x$ .
nmi.→m	<b>g U+ x: f nmi.→m</b>	(1) {2, 11}; {1} → {2} Converts distances. See pp. 136ff.
NOP	<b>g P.FN</b> P.FN2 <b>f NOP</b>	(0) 'Empty' program step (for historical reasons only).
NOR	<b>f BITS</b> <b>f NOR</b>	(2) Works in analogy to AND. See p. 18.
Norml	<b>g PROB</b>	(1) {2, 11}
Normle	<b>Norml:</b> Norml etc.	<i>Normal distribution</i> with an arbitrary mean $\mu$ given in I and a standard deviation $\sigma$ in J. See Sect. 2 of the OM for an application example and pp. 203ff for more.
Normlp		Norml <sup>-1</sup> returns $x$ for a given probability $p$ in X, with $\mu$ in I and $\sigma$ in J.
Norml <sup>-1</sup>		
Norml:	<b>g PROB</b> Norml:	Submenu. See p. 123.
NOT	<b>f BITS</b> NOT	(1) {10} Inverts $x$ bit-wise as on HP-16C.  (1) {1, 2, 11} → {1} Returns 1 for $x = 0$ , and 0 for $x \neq 0$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$n\Sigma$	<b>g SUMS n</b>	(-1) { } → {1} Recalls the number of accumulated data points.
$N \rightarrow lbf$	<b>g U- F&amp;p: N→lbf</b>	(1) {2, 11}; {1} → {2} Converts forces. See pp. 136ff.
ODD?	<b>g TEST f ODD?</b>	(0) Checks if $x$ is integer and odd.
OFF	<b>g OFF</b>	(0) In PEM, inserts a step to turn your WP 43S off under program control. Else turns your WP 43S off.
OR	<b>f BITS OR</b>	(2) Works in analogy to AND. See p. 18.
OrthoF	<b>f STAT ▾ f OrthoF</b>	(0) Selects the linear orthogonal fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 212ff for more.
ORTHOG	<b>g X.FN Orthog</b>	Submenu. See p. 126.
$oz \rightarrow kg$	<b>g U- m: oz→kg</b>	(1) {2, 11}; {1} → {2} Converts masses. See pp. 136ff.
$P_0$	<b>g CNST P<sub>0</sub></b>	(-1) { } → {2} Standard atmospheric pressure in <i>pascal</i> .
ParabF	<b>f STAT ▾ f ParabF</b>	(0) Selects the parabolic fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 212ff for more.
PAUSE	<b>g P.FN PAUSE n</b>	(0) With a routine running, refreshes the display and pauses program execution for $n$ ticks (see TICKS), with $0 \leq n \leq 99$ . The pause will terminate early when you press a key.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Pa→atm	<b>g</b> <b>U→</b> <b>F&amp;p:</b> <b>f</b> Pa→atm	(1) {2, 11}; {1} → {2} Convert pressures. See pp. 136ff.
Pa→bar	<b>g</b> <b>U→</b> <b>F&amp;p:</b> Pa→bar	
Pa→iHg	<b>g</b> <b>U→</b> <b>F&amp;p:</b> <b>f</b> Pa → in.Hg	
Pa→psi	<b>g</b> <b>U→</b> <b>F&amp;p:</b> Pa→psi	
Pa→tor	<b>g</b> <b>U→</b> <b>F&amp;p:</b> <b>f</b> Pa → torr	
PARTS	<b>f</b> PARTS	Menu. See p. 123.
pc→m	<b>g</b> <b>U→</b> <b>x:</b> pc→m	(1) {2, 11}; {1} → {2} Converts distances. See pp. 136ff.
PERM	<b>g</b> PROB <b>P<sub>yx</sub></b>	(2) {1} Returns the number of possible <u>arrangements</u> (a.k.a. <i>permutations</i> ) of <i>x items</i> taken out of a set of <i>y items</i> . No item occurs more than once in an arrangement, and <u>different orders</u> of the same <i>x items</i> are counted separately. Cf. COMB.  (2) {2, 3, 11, 12} See pp. 201ff for the formula.
PGMINT	<b>f</b> ADV <b>f</b> PGMINT <b>labl</b>	Specifies the address of the expression to be integrated or solved, respectively.
PGMSLV	<b>f</b> ADV <b>f</b> PGMSLV <b>labl</b>	See Section 4 of the OM.
PIXEL	<b>g</b> P.FN P.FN2 <b>g</b> PIXEL	(0) Turns on a single pixel (dot) on the screen. The location of the pixel is given by the numbers in the X- and Y-registers. See AGRAPH on p. 17 for more.
PLOT	<b>f</b> STAT <b>g</b> PLOT	(0) See p. xxiii for more.
P <sub>n</sub>	<b>g</b> X.FN Orthog P <sub>n</sub>	(1) {2, 11}; {1} → {2} Legendre polynomials. See pp. 218f for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
POINT	<b>[g P.FN] P.FN2</b> <b>[g POINT]</b>	(1) {1, 2, 11} Turns on a square point ( $3 \times 3$ px ■) on the screen. The location of its center is given by integer parts of the numbers in the X- and Y-registers. See AGRAPH on p. 17 for more.
Poiss	<b>[g PROB]</b>	(1) {2, 11}; {1} → {2}
Poiss <sub>e</sub>	<b>[g Poiss: Poiss</b> etc.	Poisson distribution with the number of successes <b>g</b> in X and the Poisson parameter <b>λ</b> in I. See pp. 203ff for details.
Poiss <sup>-1</sup>	<b>[g PROB]</b> <b>[g Poiss: Poiss<sup>-1</sup>]</b>	(1) {2, 11} Returns the maximum number of successes <b>m</b> for a given probability <b>p</b> in X and <b>λ</b> in I.
Poiss:	<b>[g PROB] [g Poiss:]</b>	Submenu. See p. 123.
POLAR	<b>[g MODE] POLAR</b>  <b>[g CPX] [g POLAR]</b>	(0) Sets polar format for displaying complex numbers.
PopLR	<b>[g P.FN]</b> <b>[g PopLR]</b>	(0) Pops the local registers allocated to the <i>current routine</i> (see <i>Section 3</i> of the OM) <u>without returning to the calling routine</u> . See LOCR and RTN.
PowerF	<b>[f STAT]</b> <b>[▼ PowerF]</b>	(0) Selects the power curve fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ (see pp. 203ff for more).
pr→dB	<b>[g U→] ▲</b> <b>power ratio → dB</b>	(1) {2, 11}; {1} → {2} Converts ratios. See pp. 136ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
PRCL	<b>g P.FN f PRCL</b>	(0) Copies the <i>current program</i> (from <i>FM</i> or <i>RAM</i> ) and appends it to <i>RAM</i> , where it can then be edited (see the OM). PRCL allows for duplicating programs in <i>RAM</i> . Will only work with enough space at destination.  Recall a library routine from <i>FM</i> , edit it, and PSTO – this way you can modify this part of the <i>FM</i> library (see PSTO).
PRIME?	<b>g TEST f PRIME?</b>	(0) {1, 2, 11}  Checks if the absolute value of $IP(x)$ is a prime. The method is believed to work for integers up to $9 \times 10^{18}$ .
PROB	<b>g PROB</b>	<i>Menu</i> . See p. 123.
PROFRC	<b>f a b/c</b>	(1) {2, 11}  Allows only <i>proper fractions</i> in display. Displays any reals (with $ x  < 10^6$ ) according to the settings by DEN... as <i>proper fractions</i> , e.g. 1.25 or $\frac{5}{4}$ as $1\frac{1}{4}$ . Cf. IMPFRC.
PROGS	<b>f CAT. PROGS</b>	<i>Submenu</i> of global labels defined at execution time. See pp. 114f.
psi→Pa	<b>g U→ F&amp;p: psi→Pa</b>	(1) {2, 11}; {1} → {2}  Converts pressures. See pp. 136ff.
PSTO	<b>g P.FN f PSTO</b>	(0) Copies the <i>current program</i> (see the OM) from <i>RAM</i> and appends it to the <i>FM</i> library. Cf. PRCL.  This program must include at least one LBL statement with a global label (preferably at its beginning). If a program with the same label already exists in the library it will be deleted first. Global labels may be browsed in <b>CATALOG PROGS</b> and called by XEQ.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
pt. $\rightarrow$ m	<b>g U-</b> <b>x:</b> <b>g point</b> $\rightarrow$ m	(1) {2, 11}; {1} $\rightarrow$ {2} Converts heights. See pp. 136ff.
PUTK	<b>g P.FN</b> <b>f PUTK r</b>	(0) Assumes a key code in the address specified. Stops program execution, takes said code and puts it in the keyboard buffer resulting in immediate execution of the corresponding call. <b>R/S</b> is required to resume program execution then. May help in user interaction with routines (see the OM, Section 3).
P.FN	<b>g P.FN</b>	<b>Menu</b> . See p. 124.
P.FN2	<b>g P.FN</b> P.FN2	<b>Submenu</b> . See p. 124.
P:	<b>g U-</b> P:	<b>Submenu</b> . See p. 136.
QUIET	<b>g I/O</b> <b>f QUIET</b>  <b>g MODE</b> <b>f ...</b>	(0) Toggles the flag to disable or enable the beeper.
R	<b>g CNST</b> R	(-1) {} $\rightarrow$ {2} Molar gas constant in <i>joule per mol and kelvin</i> .
RAD	<b>g MODE</b> RAD	(0) Sets the ADM to <i>radians</i> .
RAD $\rightarrow$	<b>f L-</b> <b>f RAD<math>\rightarrow</math></b>	(1) {1, 2, 11} $\rightarrow$ {4} Converts angles as described on pp. 143f.
RAM	<b>f CATALOG</b> PROGS RAM	<b>Submenu</b> of global labels defined at execution time. See pp. 114f.
RAN#	<b>g PROB</b> <b>▲ RAN#</b>	(-1) {} $\rightarrow$ {2} Returns a random number between 0 and 1 like RAN does in HP-42S. See also SEED.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RBR	[f] RBR	Calls the <i>register browser</i> . See Sect. 5 of the OM. You may call RBR also in PEM but it is not programmable.
RCL	[RCL] r	(-1) Recalls the content of a <i>register</i> or variable.
RCLCFG	[RCL] [f] Config r	(0) Recalls a <i>configuration</i> stored by STOCFG (see Section 2 of the OM). Watch that you really address a <i>configuration</i> !
RCLEL	[f] MATX [g] RCLEL	(-1) {} → {2, 3}
	[RCL] [g] ...EL	Recalls a copy of the current element $a_{ij}$ of the indexed matrix. Cf. STOEL.
RCLIJ	[f] MATX ▲ RCLIJ	(-2) {} → {1}
	[RCL] [g] ...IJ	Recalls the current values of the matrix index pointers into X (= column number) and Y (= row number). If the pointers both equal zero, then there is currently no indexed matrix. Cf. STOIJ.
RCLS	[RCL] [f] Stack r	Recalls 4 or 8 values from a set of <i>registers</i> starting at address r, and pushes them on the <i>stack</i> . This is the converse command of STOS.
RCL+	[RCL] + r	(1) Recalls a content of a <i>register</i> or variable, executes the operation specified, and puts the result on the <i>stack</i> like a <i>monadic</i> function. <sup>17</sup>
RCL-	[RCL] - r	
RCL×	[RCL] × r	
RCL/	[RCL] / r	
RCL↑	[RCL] [f] Max r	(1) {1, 2, 4, 5, 6, 10, 11}
	[RCL] ▲ r	Replaces x with the maximum of r and x. <sup>17</sup>

<sup>17</sup> Only legal operations according to the matrices in Section 2 of the OM will work. See also the examples given there.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RCL <sub>v</sub>	[RCL] f Min r [RCL] ▼ r	(0) {1, 2, 4, 5, 6, 10, 11} Replaces $x$ with the minimum of $r$ and $x$ . <sup>17</sup>
RDP	g DISP f RDP n	(1) {2, 3, 5, 8*, 9*, 11, 12} Rounds $x$ to $n$ decimal places ( $0 \leq n \leq 99$ , think of FIX format), taking the RM setting into account. See RM and compare RSD.
RDX, RDX.	g DISP ▲ RDX, etc.	(0) Select a comma or a point as decimal radix mark.
Re	g CPX Re f PARTS g Re	(1) {3} → {2}; {9} → {8}; {12} → {11} Returns the real part of $x$ . Cf. IM.
r <sub>e</sub>	g CNST r <sub>e</sub>	(-1) {} → {2} Classical electron radius in <i>meter</i> .
REALRES	g MODE f REALRE g FLAGS CF	(0) Allows only real results, no complex ones. The letter S cannot be shown in the <i>menu</i> view for space reasons there. Cf. CPXRES.
REALS	f CAT. VARS REALS	Submenu of real variables defined at execution time. See pp. 114f.
REAL?	g TEST ▲ REAL?	(0) Checks if $x$ is a real number or matrix.
RECT	g MODE RECT g CPX g RECT	(0) Sets rectangular (Cartesian) format for displaying complex numbers.
RECV	g I/O f RECV	(0) Prepares your WP 43S for receiving data via serial I/O. See SEND and Section 3 in the OM for more.

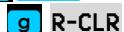
Item	Keystrokes	Remarks (see pp. 12ff for general information)
RESET	<b>g CLR g RESET</b>	Executes CLALL and resets all modes to <i>startup default</i> , i.e. 24h, 2COMPL, ALL 0, CPXi, DEG, DENANY, DENMAX 0, DSTACK 4, GAP 3, J/G <b>1752-01-01</b> , LinF, LocR 0, LZOFF, MULT $\times$ , PROFRC, RDX., REALRES, RECT, RM 0, SCIOVR, SSIZE4, TDISP -1, WSIZE <b>64</b> , and Y.MD. See these individual commands for more.
RE $\rightarrow$ CX	<b>CC</b>	<p>(2) {2} <math>\rightarrow</math> {3}; {11} <math>\rightarrow</math> {12}</p> <p>Composes a complex number out of two reals or integers <math>x</math> and <math>y</math>, setting <b>C</b> and taking either</p> <ul style="list-style-type: none"> <li>• (for <b>L</b>) the real part from <b>Y</b> and the imaginary part from <b>X</b>, or</li> <li>• (for <b>O</b>) the magnitude from <b>Y</b> and the phase from <b>X</b>.</li> </ul> <p>(2) {8} <math>\rightarrow</math> {9}</p> <p>Works in analogy for two real matrices <math>x</math> and <math>y</math>.</p>
Re $\leftrightarrow$ Im	<b>g CPX Re<math>\leftrightarrow</math>Im</b>	<p>(1) {3, 9*, 12}</p> <p>Swaps real and imaginary parts of complex objects.</p>
RJ	<b>f BITS ▲ f RJ</b>	<p>(-1) {10}</p> <p>Right justifies a bit pattern within its word size, in analogy to LJ (see there).</p> <p><b>Example:</b> 10 1100<sub>2</sub> RJ results in <math>y = 1011_2</math> and <math>x = 2</math>.</p>
R <sub>K</sub>	<b>g CNST R<sub>K</sub></b>	(-1) {} $\rightarrow$ {2} <i>Von Klitzing constant in ohm.</i>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RL	 <b>n</b> etc.	(1) {10} Work like <b>n</b> consecutive RLs / RLCs on HP-16C, similar to RLn / RLCn there. For RL, $0 \leq n \leq 63$ . For RLC, $0 \leq n \leq 64$ . RL 0 / RLC 0 execute as NOP, but load L. See the OM, Sect. 2, for more.
RLC		
RM	 RM <b>n</b>	(0) Sets floating point rounding mode. This rounding mode is used only for RSD or when converting from the extended precision internal format (39 digits) to packed reals. It will <u>not</u> alter the display nor change the behavior of ROUND. The following 7 modes are supported: 0: round half even: $\frac{1}{2} = 0.5$ rounds to next even number (default). <sup>18</sup> 1: round half up: 0.5 rounds up ('business-man's rounding'). <sup>19</sup> 2: round half down: 0.5 rounds down. 3: round up: rounds away from 0. 4: round down: rounds towards 0 (truncates). 5: ceiling: rounds towards $+\infty$ . 6: floor: rounds towards $-\infty$ .
RMD	RMD	(2) {1, 2, 3, 10, 11, 12} Returns the remainder of a division. Equals RMD on HP-16C but works for reals as well. See Section 2 of the OM for examples. Cf. MOD.
R <sub>Moon</sub>	R <sub>Moon</sub>	(-1) {} → {2} Mean radius of the Moon in <i>meter</i> .

<sup>18</sup> This is the way of rounding used in science.

<sup>19</sup> Translator's notes for French and German readers: Cela correspond à l'arrondi commercial. / Das entspricht kaufmännischer Rundung.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RM?		(-1) { } → {1} Returns the floating point rounding mode set. See RM for more.
RNORM		(1) {8, 9} Calculates the row norm of the matrix $x$ , i.e. the maximum value (over all rows) of the sums of the absolute values of all elements in a row (like RNRM on HP-42S). For a vector, the row norm is the largest absolute value of any of its elements.
RootF		(0) Selects the root fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 212ff for more.
ROUND		(1) {2, 3, 4, 5, 6, 8*, 9*, 11, 12}
		Rounds $x$ using the current display format like RND on HP-42S.
ROUNDI		(1) {8}; {2, 11} → {1};
		Rounds $x$ to next integer. $\frac{1}{2}$ rounds to 1.
RR	 etc.	(1) {10} Work like $n$ consecutive RRs / RRCs on HP-16C, similar to RRn / RRCn there. For RR, $0 \leq n \leq 63$ . For RRC, $0 \leq n \leq 64$ . RR 0 / RRC 0 execute as NOP, but load L. See the OM, Sect. 2, for more.
RSD		(1) {2, 3, 5, 8*, 9*, 11, 12} Rounds $x$ to $n$ significant digits ( $1 \leq n \leq 34$ ), taking the RM setting into account. See RM, cf. RDP.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RSUM	 	(1) {8, 9} Calculates the row sum of the matrix $x$ , returning an $m \times 1$ matrix filled with the row sums of the $m \times n$ input matrix.
RTN		(0) In <i>PEM</i> : RTN is the logically last command in a routine (see <i>Section 3</i> of the OM).  In a routine executing: RTN pops local data (cf. PopLR) and returns to the caller, i.e. moves the program pointer one step behind the XEQ instruction that called said routine. If there is none (i.e. this routine is top level), program execution halts, the program pointer is set to step 0000, and $\overline{1}$ is lit.  If <b>RTN</b> is pressed in <i>run mode</i> with no routine executing, it resets the program pointer to the start of <i>current program</i> (see <i>Section 3</i> of the OM). If the program is in <i>FM</i> , the pointer is set to step 0000 in <i>RAM</i> , and $\overline{1}$ is lit.
RTN+1	 	(0) Works like RTN, but moves the program pointer <u>two</u> steps behind the XEQ instruction that called said routine.
R-CLR	 	(0) {2, 11}  Interprets $x$ in the form $sss.nn$ . Clears $nn$ registers starting with address $sss$ .  <b>Example:</b> For $x = 34.567$ , R-CLR will clear R34 through R89.  <b>ATTENTION:</b> For $nn = 0$ , clearing will cover the maximum available: <ul style="list-style-type: none"><li>• For <math>sss \in [0; 99]</math>, it will stop at R99.</li><li>• For <math>sss \in [100; 111]</math>, it will stop at K.</li><li>• For <math>sss \geq 112</math>, it will stop at the highest allocated local register.</li></ul>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
R-COPY	 	(0) {2, 11} Interprets $x$ in the form $sss.nn$ . Takes $nn$ registers starting with address $sss$ and copies their contents to $ddd$ etc. <b>Example:</b> For $x = 7.0304567$ , $r07$ , $r08$ , $r09$ will be copied into $R45$ , $R46$ , $R47$ , respectively. For $x < 0$ , R-COPY will take $nn$ registers from FM instead, starting with register number $ sss $ . Destination will be in RAM always. <b>ATTENTION:</b> For $nn = 0$ , copying will cover the maximum available as explained with R-CLR. Then $x$ must be negative.
R-SORT	 	(0) {2, 11} Interprets $x$ in the form $sss.nn$ . Sorts the contents of $nn$ registers starting with address $sss$ . <b>Example:</b> Assume $x = 49.036\ 9$ , $r49 = 1.2$ , $r50 = -3.4$ , and $r51 = 0$ ; then R-SORT will return $r49 = -3.4$ , $r50 = 0$ , and $r51 = 1.2$ . <b>ATTENTION:</b> For $nn = 0$ , sorting will cover the maximum available as explained with R-CLR.
R-SWAP	 	(0) {2, 11} Works like R-COPY but <u>swaps</u> the contents of source and destination registers.
R→D		(1) {1, 2, 11} → {4} Converts angles as described on pp. 143f.
R↑		Rotates the stack contents one level up or down, respectively. See Section 1 of the OM for details.
R↓		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$R_{\infty}$	<b>g CNST</b> $R_{\infty}$ etc.	(-1) {} → {2}  Rydberg constant (see p. 133); mean radii of the Sun and Earth in <i>meter</i> .
$R_{\odot}$		
$R_{\oplus}$		
$s$	<b>f STAT</b> $s$	(-2) {} → {2}  Takes the statistical sums accumulated, calculates the <i>sample standard deviations</i> $s_y$ and $s_x$ and pushes them on the stack. See Sect. 2 of the OM for the output format and pp. 203ff for the formula.
$Sa$	<b>g CNST</b> $Sa$	(-1) {} → {2}  Semi-major axis in <i>meter</i> of the Earth model WGS84. <sup>20</sup>
SAVE	<b>f SAVE</b>	(0) Saves user program space, <i>registers</i> and system state to <i>FM</i> , and returns <b>Saved</b> . Recall your backup using the different flavors of LOAD.
SB	<b>f BITS</b> <b>g SB</b> $n$	(1) {10}  Sets the specified bit in $x$ .
Sb	<b>g CNST</b> $Sb$	(-1) {} → {2}  Semi-minor axis in <i>meter</i> of WGS84. <sup>20</sup>
SCI	<b>g DISP</b> $SCI$ $n$	(0) Sets scientific display format (see Section 2 of the OM).
$scw \rightarrow kg$	<b>g U→</b> $m:$ <b>f</b> short cwt → kg	(1) {2, 11}; {1} → {2}  Converts masses. See pp. 136ff.

<sup>20</sup> This model is used to define the Earth's surface for surveying and GPS. See [http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350\\_2.html](http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html)

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SCI0VR	 	(0) Defines that numbers exceeding the range displayable in ALL or FIX will be shown in scientific format. Cf. ENGOVR, see RESET.
SDIGS?	 	(-1) {} → {1} Returns the number of significant digits set by SETSIG.
SDL	  etc.	(1) {2, 11}
		Shifts digits left (right) by <i>n</i> decimal positions, equivalent to multiplying (dividing) <i>x</i> by $10^n$ . Cf. SL and SR for binary integers.
Se <sup>2</sup>	 	(-1) {} → {2} First eccentricity squared of the Earth model WGS84 (see footnote 20 on previous page).
SEED	 	(0) {2, 11} Stores a seed for random number generation. If <i>x</i> = 0, the seed is taken from the real-time clock.
SEND	 	(0) Sends all RAM data to the device connected via serial I/O. See RECV and Section 3 in the OM for more.
SETCHN	 	(0) Sets regional preferences (see Section 2 of the OM).
SETDAT	 	(0) Sets the date for the real-time clock (the emulator takes this information from the PC clock).
SETEUR	...	
SETIND	...	(0) Set some regional preferences (see Section 2 of the OM). These commands are accessed like SETCHN above.
SETJPN	...	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SETSIG	<b>g MODE</b> ▲ <b>f SETSIG</b>	(0) {1} Sets the number of significant digits (0 ... 34) for rounding after each operation. SETSIG 0 sets maximum precision.
SETTIM	<b>g CLK</b> ▲ <b>SETTIM</b>	(0) Sets the time for the real-time clock (the emulator takes this information from the PC clock).
SETUK SETUSA	<b>g DISP</b> ▲ <b>g UK</b> etc.	(0) Set some regional preferences (see Section 2 of the OM).
Se'²	<b>g CNST</b> <b>Se'²</b>	(-1) {} → {2} Second eccentricity squared of the Earth model WGS84 (see footnote 20 on p. 71).
SF	<b>g FLAGS</b> <b>SF n</b>	(0) Sets the flag specified.
Sf⁻¹	<b>g CNST</b> <b>Sf⁻¹</b>	(-1) {} → {2} Flattening parameter of the Earth model WGS84 (see footnote 20 on p. 71).
SHOW	<b>g SHOW</b>	(0) {2, 11, 12} Shows all digits stored in a number until next keystroke.
SIGN	<b>f PARTS</b> <b>sign</b>	(1) {8}; {1, 2, 10, 11} → {1} Returns 1 for $x > 0$ , -1 for $x < 0$ , and 0 for $x = 0$ or non-numeric data. Corresponds to the mathematical function signum( $x$ ).
	<b>g CPX</b> <b>f sign</b>	(1) {3, 12} Returns the unit vector of the complex number $x$ (cf. UNITV). Maintained for backward compatibility only.
SIGNMT	<b>f BITS</b> ▼ <b>SIGNMT</b> <b>g MODE</b> ▲ ...	(0) Sets sign-and-mantissa mode for operations on <i>short integers</i> . See Section 2 of the OM.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SIM_EQ	f [MATX] SIM EQ n	(0) Solves a system of $n$ linear equations $(MATA) \cdot MAT\vec{X} = MAT\vec{B}$ . If these matrices are not defined before, they will be created automatically at execution time. See Sect. 2 of the OM for more.
sin	[TRI] sin	(1) {2, 3, 8*, 9*, 11, 12}; {1, 4} → {2} Returns the sine of the angle in X.
sinc	g [X.FN] ▲ sinc	(1) {2, 3, 8*, 9*, 11, 12} Returns $\sin(x)/x$ for $x \neq 0$ and 1 for $x = 0$ . Note input has to be supplied in radians.
sinh	g [EXP] g sinh	(1) {2, 3, 8*, 9*, 11, 12}
	[TRI] g sinh	Returns the hyperbolic sine of x.
SKIP	g [P.FN] P.FN2 g SKIP n	(0) Skips $n$ program steps forwards ( $0 \leq n \leq 255$ ). So e.g. SKIP 2 skips over the next two steps, going e.g. from step 123 to step 126. If SKIP attempts to cross an END, an error is thrown. <b>ATTENTION:</b> If you edit a section of your routine crossed by one or more BACK, SKIP, or CASE jumps, this may well result in a need to <b>manually maintain all those statements individually</b> .
SL	f [BITS] ▲ SL n	(1) {10} Works like $n$ ( $\leq 63$ ) consecutive SLs on HP-16C. SL 0 executes as NOP, but loads L. See Sect. 2 of the OM for more.
SLOW	g [MODE] f SLOW	(0) Sets the processor speed to 'slow', about $\frac{1}{2}$ of 'fast'. This is also automatically set for low battery voltage (see the OM, Sect. 2). Cf. FAST.

Item	Keystrokes	Remarks (see pp. 12ff for general information)												
SLVQ	<b>f ADV SLVQ</b>	<p><b>[1, 2, 3] → {2 or 3}</b></p> <p>Solves the quadratic equation <math>ax^2 + bx + c = 0</math> with its parameters on the input stack [<b>c, b, a, ...</b>], and tests the result.</p> <ul style="list-style-type: none"> <li>• If <math>r := b^2 - 4ac \geq 0</math>, SLVQ returns <math>-\frac{b \pm \sqrt{r}}{2a}</math> in <b>Y</b> and <b>X</b>. In a routine, the step after SLVQ will be executed.</li> <li>• Else, SLVQ returns the first complex root in <b>X</b> and the second in <b>Y</b> (the complex conjugate of the first). In a routine, the step after SLVQ will be skipped.</li> </ul> <p>In either case, SLVQ returns <b>r</b> in <b>Z</b>. Higher stack registers are kept unchanged. <b>L</b> will contain equation parameter <b>c</b>.</p>												
<b>s<sub>m</sub></b>	<b>f STAT s<sub>m</sub></b>	<p><b>(-2) {} → {2}</b></p> <p>Takes the statistical data accumulated and pushes the <i>standard errors</i> (i.e. <i>std. deviations</i> of the means <math>\bar{y}</math> and <math>\bar{x}</math>) on the stack. Output format will be like the one of <b>s</b> (see the OM, Sect. 2).</p>												
SMODE?	<b>g INFO SMODE?</b>	<p><b>(-1) {} → {1}</b></p> <p>Returns the <i>integer sign mode</i> set for <i>short integers</i>, i.e.</p> <table> <tr> <td><b>true</b></td> <td><b>2</b></td> <td>for 2's complement,</td> </tr> <tr> <td><b>true</b></td> <td><b>1</b></td> <td>for 1's complement,</td> </tr> <tr> <td><b>false</b></td> <td><b>0</b></td> <td>for unsigned, or</td> </tr> <tr> <td><b>true</b></td> <td><b>-1</b></td> <td>for sign &amp; mantissa mode.</td> </tr> </table>	<b>true</b>	<b>2</b>	for 2's complement,	<b>true</b>	<b>1</b>	for 1's complement,	<b>false</b>	<b>0</b>	for unsigned, or	<b>true</b>	<b>-1</b>	for sign & mantissa mode.
<b>true</b>	<b>2</b>	for 2's complement,												
<b>true</b>	<b>1</b>	for 1's complement,												
<b>false</b>	<b>0</b>	for unsigned, or												
<b>true</b>	<b>-1</b>	for sign & mantissa mode.												
<b>s<sub>mw</sub></b>	<b>f STAT f s<sub>mw</sub></b>	<p><b>(-1) {} → {2}</b></p> <p>Returns the <i>standard error</i> for weighted data, i.e. the <i>standard deviation</i> of the mean <math>\bar{x}_w</math>.</p>												

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SOLVE	f ADV SOLVE var	{2, 3}  Solves the equation $f(var) = 0$ , with $f$ calculated by the equation specified (in PEM by PGMSLV). Two initial estimates of the root must be supplied in X and Y when calling SOLVE. It returns $var_{root}$ in X, the second last var-value tested in Y, then $f(var_{root})$ in Z, and 0 in T. Additionally, SOLVE acts as test in programs, so the next program step will be skipped if SOLVE fails to find a root. See Section 4 of the OM for more.  <b>ATTENTION:</b> SOLVE fills all stack registers with $x$ before calling the routine specified.
Solver	g EQN Solver	Submenu for solving a given equation. See the OM, Sect. 4, for more.
SPEC?	g TEST ▲ f SPEC?	(0) True if $x$ is 'special' ( $\pm\infty$ or NaN).
SR	f BITS ▲ SR n	(1) {10}  Works like $n$ ( $\leq 63$ ) consecutive SRs on HP-16C. SR 0 executes as NOP, but loads L. See Section 2 of the OM for more.
SSIZE4	g STK f SSIZE4 etc. or	Set the stack size to 4 or 8 registers, respectively (see Section 1 of the OM). Note register contents will remain unchanged in this operation (as well as if stack size is modified by any other operation – e.g. by RCLCFG).
SSIZE8	g MODE g ... etc.	
SSIZE?	g INFO SSIZE?	(-1) {} → {1}  Returns the number of stack registers currently allocated, 4 or 8.
STAT	f STAT	Menu. See p. 124.
STATUS	g FLAGS STATUS	Flag browser. See Section 5 of the OM.
STK	g STK	Menu. See p. 124.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
STO	[STO] <i>r</i>	(0) Stores <i>x</i> into destination.
STOCFG	[STO] [f] Config <i>r</i>	(0) Stores the current <i>configuration</i> for later use as described in <i>Section 2</i> of the OM. RCLCFG recalls such data.
STOEL	[f] MATX [g] STOEL [STO] [g] ...EL	(1) {1, 2, 3} Stores a copy of <i>x</i> into the indexed matrix at the current element, $a_{ij}$ . Cf. RCLEL.
STOIJ	[f] MATX [▲] STOIJ [STO] [g] ...IJ	(1) {1} Sets the index pointers to IP( <i>x</i> ) (= column number) and IP( <i>y</i> ) (= row number). Cf. RCLIJ.
STOP	[R/S]	(0) Stops program execution. May be inserted in programs to wait for input, for example.
STOS	[STO] [f] Stack <i>r</i>	(0) Stores the entire <i>stack</i> in a set of 4 or 8 registers, starting at the destination address specified. See RCLS.
STO+	[STO] [+] <i>r</i>	(0) Executes the specified operation on <i>r</i> and stores the result (e.g. $r - x$ ) at the address specified. <sup>21</sup>
STO-	[STO] [-] <i>r</i>	
STOx	[STO] [x] <i>r</i>	
STO/	[STO] [/] <i>r</i>	
STO†	[STO] [f] Max <i>r</i> [STO] [▲] <i>r</i>	(0) {1, 2, 4, 5, 6, 10, 11} Stores the maximum of <i>r</i> and <i>x</i> in the address specified. <sup>21</sup>

<sup>21</sup> Only legal operations according to the matrices in *Section 2* of the OM will work. See also the examples given there.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
STO <del>f</del>	<b>STO</b> <b>f</b> Min <b>r</b>  <b>STO</b> <b>▼</b> <b>r</b>	(0) {1, 2, 4, 5, 6, 10, 11}  Stores the minimum of <b>r</b> and <b>x</b> in the address specified. <sup>21</sup>
sto→kg	<b>g</b> <b>U→</b> <b>m:</b> <b>f</b> stone → kg	(1) {2, 11}; {1} → {2}  Converts masses. See pp. 136ff.
STRI?	<b>g</b> <b>TEST</b> <b>g</b> STRI?	(0) True if <b>x</b> is an alphanumeric string (like STR? in HP-42S).
STRING	<b>f</b> <b>CAT.</b> <b>VARS</b> STRING	<b>Submenu</b> of alpha string variables defined at execution time. See pp. 114f.
SUM	<b>f</b> <b>STAT</b> <b>f</b> SUM	(-2) {} → {2}  Recalls the linear sums $\Sigma y$ and $\Sigma x$ . Useful in basic 2D vector algebra. Output is labeled in analogy to s.
s <sub>w</sub>	<b>f</b> <b>STAT</b> <b>f</b> s <sub>w</sub>	(-1) {} → {2}  Calculates the <i>standard deviation</i> for weighted data (where the weight <b>y</b> of each data point <b>x</b> was entered via <b>[Σ+]</b> ). See pp. 203ff for the formula.
s <sub>xy</sub>	<b>f</b> <b>STAT</b> <b>▲</b> s <sub>xy</sub>	(-1) {} → {2}  Calculates the <i>sample covariance</i> for the two data sets entered via <b>[Σ+]</b> , depending on the curve fit model selected. See pp. 203ff for the formula and COV for the <i>population covariance</i> .
s.INTS	<b>f</b> <b>CATALOG</b> VARS s.INTS	<b>Submenu</b> of short integer variables defined at execution time. See pp. 114f.
s.t→kg	<b>g</b> <b>U→</b> <b>m:</b> <b>▲</b> short ton → t	(1) {2, 11}; {1} → {2}
s→year	<b>g</b> <b>U→</b> <b>f</b> s→year	Convert masses and times. See pp. 136ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
T <sub>0</sub>	[g] [CNST] T <sub>0</sub>	(-1) {} → {2} = 0°C, standard temperature in <i>kelvin</i> .
tan	[TRI] tan	(1) {2, 3, 8*, 9*, 11, 12}; {1, 4} → {2} Returns the tangent of the angle in X. Returns "Not a Number" for $x = \pm 90^\circ$ or equivalents if flag D is set.
tanh	[g] [EXP] [g] tanh	(1) {2, 3, 8*, 9*, 11, 12}
	[TRI] [g] tanh	Returns the hyperbolic tangent of x.
TDISP	[g] [CLK] [▲] TDISP n	(0) Sets time display format. TDISP 0 and 1 allow for displaying just <i>hours</i> and <i>minutes</i> , TDISP 2 for <i>seconds</i> , too, and $n \geq 3$ also for $n - 2$ digits showing decimal fractions of <i>seconds</i> . TDISP -1 allows for displaying all digits.
TEST	[g] TEST	Menu. See p. 124.
TICKS	[g] P.FN TICKS	(-1) {} → {1} Returns the number of ticks from the real-time clock at execution time. 1 tick = 0.1 s. Counting starts when the calculator is turned on.
TIME	[g] CLK TIME	(-1) {} → {5} Recalls the time from the real-time clock at execution (see Sect. 2 of the OM for the output format).
TIMER	[f] TIMER	Starts the timer application based on the real-time clock and following the timer of HP-55. See Sect. 5 of the OM for a detailed description.
TIMES	[f] CATALOG VARS [f] TIMES	Submenu of <i>time</i> variables defined at execution time. See pp. 114f.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$T_n$	<b>g X.FN Orthog T<sub>n</sub></b>	(2) {2, 11}; {1} → {2} <i>Chebyshev polynomials of first kind.</i> See pp. 218f for details.
TONE	<b>g I/O f TONE n</b>	(0) Sounds a tone according to $n$ (= 1 ... 9).
ton→kg	<b>g U→ m: ▲ ton→kg</b>	(1) {2, 11}; {1} → {2} Converts masses. See pp. 136ff.
TOP?	<b>g TEST g TOP?</b>	(0) Returns ... <ul style="list-style-type: none"> <li>• <b>false</b> if called with the program pointer being in a subroutine;</li> <li>• <b>true</b> if called in the top routine (i.e. if the program-running <i>flag</i> is set and the SRS pointer is clear).</li> </ul>
tor→Pa	<b>g U→ F&amp;p: f torr → Pa</b>	(1) {2, 11}; {1} → {2} Converts pressures. See pp. 136ff.
$T_p$	<b>g CNST T<sub>p</sub></b>	(-1) {} → {2} <i>Planck temperature in kelvin.</i>
$t_{PL}$	<b>g CNST t<sub>PL</sub></b>	(-1) {} → {2} <i>Planck time in seconds.</i>
$t_e(x)$	<b>g PROB t:</b>	(1) {2, 11}
$t_p(x)$	<b>t<sub>e</sub>(x)</b> etc.	<i>Student's t distribution.</i> The degrees of freedom are stored in J. $t_e(x)$ equals Q(t) on HP-21S. See Section 2 of the OM for an application example and pp. 203ff for more mathematical details.
$t(x)$		
$t^{-1}(p)$		
TRANS	<b>f CATALOG FCNS TRANS</b>	Works like $[M]^T$ on p. 101. TRANS is maintained for backward compatibility only.
TRI	<b>TRI</b>	<b>Menu.</b> See p. 124.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
trz→kg	<b>g U→ m: f tr.oz → kg</b>	(1) {2, 11}; {1} → {2} Converts masses. See pp. 136ff.
TVM	<b>g FIN TVM</b>	Application. See Section 5 of the OM.
t:	<b>g PROB t:</b>	Submenu. See p. 123.
t↔	<b>g STK t↔ r</b>	Swaps $t$ and $r$ , in analogy to $x\leftrightarrow$
ULP?	<b>g INFO f ULP?</b>	(1) {1, 2, 11} Returns 1 times the smallest power of ten which can be added to $x$ or subtracted from $x$ to actually change the value of $x$ in your WP 43S in the mode set. Thus 1 is returned for integers.
U <sub>n</sub>	<b>g X.FN Orthog U<sub>n</sub></b>	(2) {2, 11}; {1} → {2} <i>Chebyshev polynomials of second kind.</i> See pp. 218f for details.
UNITV	<b>f MATX f UNITY</b>	(1) {8, 9} Returns the unit vector for the matrix $x$ (like UVEC in HP-42S). Each element of the matrix is adjusted so its overall Euclidean norm becomes 1 (see ENORM); for a vector, its magnitude will become 1.
	<b>g CPX UNITY</b>	(1) {3, 12} Returns a complex number with magnitude $ r  = 1$ in direction of $x$ .
UNSIGN	<b>f BITS ▼ UNSIGN</b> <b>g MODE ▲ ...</b>	(0) Sets unsigned mode for mode for operations on <i>short integers</i> . Cf. UNSGN on HP-16C. See Section 2 of the OM.
U→	<b>g U→</b>	Menu. See p. 124.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
VARMNU	<b>g P.FN P.FN2</b> <b>f VARMNU <i>label</i></b>	Creates a variable <i>menu</i> using MVAR instructions following the global label specified. Cf. the HP-42S Owner's Manual.
VARS	<b>f CAT. VARS</b>	<b>Submenu</b> of variables defined at execution time. See pp. 114f.
VERS?	<b>g INFO g VERS?</b>	(0) Shows your firmware version and build number (see Section 2 of the OM).
VIEW	<b>f VIEW <i>r</i></b>	(0) Shows <i>r</i> until the next key is pressed.  <b>Example:</b> If <i>r</i> is e.g. a variable called <b>Test12</b> containing -123.45, <b>VIEW</b> <b>Test12</b> <b>ENTER↑</b> will display  <b>Test12 = -123.45</b>
$v_m$	<b>g CNST <math>v_m</math></b>	(-1) { } → {2}  Molar volume of an ideal gas at standard conditions in <i>cubic meter per mol</i> .
V:	<b>g U→ f V:</b>	<b>Submenu</b> . See p. 136.
$v_4$	<b>g ↗</b>	(2) {8} → {4}  Returns the angle between two 2D or 3D vectors: $\vartheta = \arccos\left(\frac{\vec{v}_1 \cdot \vec{v}_2}{ \vec{v}_1  \vec{v}_2 }\right)$

Item	Keystrokes	Remarks (see pp. 12ff for general information)
WDAY	<b>g CLK WDAY</b>	(1) {2, 6, 11} → {1} Assumes $x$ containing a <i>date</i> in the format selected (or a real number in corresponding format) and returns the name of the respective day and a corresponding integer (Monday = 1). <sup>22</sup>
Weibl	<b>g PROB</b> <b>f Weibl: Weibl</b> etc.	(1) {2, 11}
Weibl <sub>e</sub>		Weibull distribution with its shape parameter $b$ in I and its characteristic lifetime $T$ in J. See pp. 203ff for details.
Weibl <sub>p</sub>		Weibl <sup>-1</sup> returns the survival time $t_s$ for a given probability $p$ in X, with $b$ in I and $T$ in J.
Weibl <sup>-1</sup>		
Weibl:	<b>g PROB f Weibl:</b>	Submenu. See p. 123.
WHO?	<b>g INFO g WHO?</b>	(0) Displays credits to the brave men who made this project work.
Wh→J	<b>g U→ E: Wh→J</b>	(1) {2, 11}; {1} → {2} Converts energies. See pp. 136ff.
W <sub>m</sub>	<b>g X.FN</b> ▲ <b>W<sub>m</sub></b> etc.	(1) {2, 3, 11, 12}; {1} → {2}
W <sub>p</sub>		W <sub>p</sub> returns the principal branch of Lambert's W for given $x \geq -1/e$ . W <sub>m</sub> returns its negative branch (works for $x \in \mathbb{R}$ only). W <sup>-1</sup> returns $x$ for a given W <sub>p</sub> ( $\geq -1$ ). See pp. 233ff for more.
W <sup>-1</sup>		

<sup>22</sup> Translator's note: These day numbers correspond to Chinese weekdays 1 to 6 directly. For Portuguese weekdays ('segunda-feira' etc.), add 1 to days 1 to 5.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
WSIZE	 	<p>(0) Works almost like on HP-16C, but with the parameter <math>1 \leq n \leq 64</math> trailing the command instead of taken from X.</p> <p>Reducing word size truncates the values in the stack as allocated and in L. All other memory content stays as is (see App. B on pp. 156ff).</p> <p>Increasing the word size will add empty bits to each stack register. WSIZE 0 sets the word size to maximum, i.e. 64 bits.</p>
WSIZE?	 	<p>(-1) {} → {1}</p> <p>Recalls the word size set.</p>
W→hp <sub>E</sub>	 etc.	
W→hp <sub>M</sub>		
W→hp <sub>UK</sub>		
x <sup>2</sup>	  	<p>(1) {1, 2, 3, 8*, 9* 10, 11, 12}</p> <p>Return the square of x.</p>
x <sup>3</sup>		<p>(1) {1, 2, 3, 8*, 9* 10, 11, 12}</p> <p>Return the cube of x.</p>
XEQ		<p>(0) Executes the function or routine with the label specified. – In PEM, inserts a call to the subroutine with the label specified.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
xIN	<b>XEQ</b> type	with <b>type</b> = NILADIC, MONADIC, DYADIC, TRIADIC, or ... _COMPLEX defines how many <i>stack</i> levels are used for parameter input to the function under consideration. Furthermore it does some initialization work (e.g. SSIZE8).  xIN is the recommended way to start an <i>XROM routine</i> . Thereafter, SSIZE4 is legal. <b>Note</b> xIN cannot nest and <i>XROM routines</i> using xIN cannot call user code.
XNOR	<b>f</b> BITS <b>f</b> XNOR	(2) Work in analogy to AND. See p. 18.
XOR	<b>f</b> BITS XOR	
xOUT	<b>XEQ</b> way	Cleans and reverts the settings of xIN, taking care of a proper return including the correct setting of <i>I</i> and the <i>stack</i> . Typically, <b>way</b> = xOUT_NORMAL. Generally, xOUT shall be the last command of an <i>XROM routine</i> .
$\bar{x}$	<b>f</b> STAT $\bar{x}$	(-2) {} → {2}  Calculates the <i>arithmetic means</i> of the <i>y</i> - and <i>x</i> -data accumulated and pushes them on the <i>stack</i> . See also s, $s_m$ , and $\sigma$ .
$\bar{x}_g$	<b>f</b> STAT <b>g</b> $\bar{x}_g$	(-2) {} → {2}  Calculates the <i>geometric means</i> of the <i>y</i> - and <i>x</i> -data accumulated and pushes them on the <i>stack</i> . See pp. 212ff for the formula. Output format will be similar to the one of $\bar{x}$ . See also $\varepsilon$ , $\varepsilon_m$ , and $\varepsilon_p$ .
$\bar{x}_h$	<b>f</b> STAT <b>h</b> $\bar{x}_h$	(-2) {} → {2}  Calculates the <i>harmonic means</i> of the <i>y</i> - and <i>x</i> -data accumulated and pushes them on the <i>stack</i> .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\bar{x}_{\text{RMS}}$		(-2) {} → {2} Calculates the <i>quadratic means</i> of the $y$ - and $x$ -data accumulated and pushes them on the stack.
$\bar{x}_w$		(-1) {} → {2} Returns the <i>arithmetic mean</i> for weighted data (where the weight $y$ of each data point $x$ was entered via $\Sigma+$ ). See pp. 212ff for the formula. See also $s_w$ and $s_{mw}$ .
$\hat{x}$		(1) {2, 11}; {1} → {2} Returns a forecast $x$ for a given $y$ (in X) according to the curve fit model chosen. See L.R. for more.
X.FN		Menu. See p. 126.
$x!$		(1) {1, 10} Returns the <i>factorial</i> $n!$ . Note this is only defined for positive integers. $20!$ is the biggest factorial $< 2^{64}$ .
		(1) {2, 3, 11, 12} Returns $\Gamma(x + 1)$ .
$x:$		Submenu. See p. 136.
$x \rightarrow \text{DATE}$		(1) {2} → {6} Interprets the real number $x$ as a date coded in the date format selected (Y.MD, D.MY, or M.DY) and converts it to a proper date.
$x \rightarrow \alpha$		(1) {1, 2, 10, 11} → {7} Interprets $x$ as a character code and converts the integer part of $x$ to the respective character $x$ , similar to XTOA in the HP-42S.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$x \leftrightarrow r$	<b>g</b> <b>STK</b> $x \leftrightarrow r$	Swaps $x$ and $r$ , analogous to $x \leftarrow y$ . Will be listed like $x \leftrightarrow J$ , $x \leftrightarrow .12$ , $x \leftrightarrow \rightarrow 12$ , etc.
$x \leftrightarrow y$	$x \leftrightarrow y$	Swaps the stack contents $x$ and $y$ .
$x = ?$	<b>g</b> <b>TEST</b> $x = ? r$	(0) Compare $x$ with $r$ . See $x < ?$ for more.
$x \neq ?$	<b>g</b> <b>TEST</b> $x \neq ? r$	
$x = +0?$	<b>g</b> <b>TEST</b> etc.	(0) {1, 2, 3, 10, 11, 12}  These tests are for comparing <i>short integers</i> in modes 1COMPL and SIGNMT, and for <i>long integers</i> , real or complex numbers if flag <b>D</b> is set. Then e.g. $0 / (-7)$ will display $-0$ .
$x = -0?$	<b>g</b> <b>TEST</b> etc.	
$x \approx ?$	<b>g</b> <b>TEST</b> etc.	(0) {2, 3, 4, 5, 8*, 9*, 11, 12}  Will be true if the <u>rounded</u> values of $x$ and $r$ are equal (see ROUND). See $x < ?$ for more.
$x < ?$	<b>g</b> <b>TEST</b> $x < ? r$ etc.	(0) {1, 2, 4, 5, 6, 10, 11}  Compare $x$ with $r$ .  <b>Example:</b> <b>TEST</b> $x < ? K$ compares $x$ with $K$ , and will be listed as $x < ? K$ in a routine. It will return <b>true</b> if $x < k$ at execution time. See examples in Sect. 1 of the OM for more.
$x \leq ?$		
$x \geq ?$		
$x > ?$		
$\sqrt[x]{y}$	<b>g</b> <b>EXP</b> $\sqrt[x]{y}$	(2) {1, 2, 3, 10, 11, 12}; $((1) \rightarrow \{2\})$  Returns the $x^{\text{th}}$ root of $y$ . Roots of negative integers or reals may return complex numbers if CPXRES is set.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$yd \rightarrow m$	 	(1) {2, 11}; {1} → {2} Converts distances. See pp. 136ff.
YEAR		(1) {2, 6, 11} → {1} Assumes $x$ containing a <i>date</i> in the format selected (or a real number in corresponding format) and extracts the year.
year→s		(1) {2, 11}; {1} → {2} Converts times. See pp. 136ff.
$y^x$	$y^x$	(2) {1, 2, 3, 10, 11, 12} Returns the $x^{\text{th}}$ power of $y$ . It allows for raising any positive real number to an arbitrary real power, as well as any negative real number to an arbitrary integer power, all returning real results. Exceeding these boundaries may produce complex results (or errors if CPXRES is not set).
$\hat{y}$		(1) {2, 11}; {1} → {2} Returns a forecast $y$ (in $X$ ) for a given $x$ according to the curve fit model chosen. See L.R. for more.
Y.MD		(0) Sets the format yyyy-mm-dd for <i>date</i> display.
$y \leftrightarrow r$		Swaps $y$ and $r$ , in analogy to $x \leftrightarrow$ .
$Z_0$		(-1) {} → {2} Characteristic impedance of vacuum in <i>ohm</i> .
$z \leftrightarrow r$		Swaps $z$ and $r$ , in analogy to $x \leftrightarrow$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\alpha$	<b>g [CNST] <math>\alpha</math></b>	$(-1) \{ \} \rightarrow \{2\}$ Fine-structure constant.
$\alpha\text{INTL}$	<b>f [CAT.] CHARs <math>\alpha\text{INTL}</math></b>	<b>Submenu.</b> See pp. 114ff.
	<b>g [+]</b>	<b>Menu</b> in AIM (see p. 126).
$\alpha\text{LENG?}$	<b>g [INFO] g <math>\alpha\text{LENG? } r</math></b>	$(-1) \{ \} \rightarrow \{1\}$
	<b>g [a.FN] f <math>\alpha\text{LENG? } r</math></b>	Returns the number of characters found in $r$ , similar to ALENG in HP-42S. <sup>23</sup>
$\alpha\text{MATH}$	<b>f [CAT.] CHARs <math>\alpha\text{MATH}</math></b>	<b>Submenu.</b> See pp. 114ff.
	<b>g [-]</b>	<b>Menu</b> in AIM. See p. 127.
$\alpha\text{OFF}$	<b>g [P.FN] f <math>\alpha\text{OFF}</math></b> etc.	(0) Turn AIM off and on, like AOFF and AON in HP-42S.
$\alpha\text{ON}$	<b>g [INFO] g <math>\alpha\text{POS? } r</math></b>	$(-1) \{ \} \rightarrow \{1\}$ Looks in $r$ for the <b>target</b> given in X. If a match is found, $\alpha\text{POS}$ returns the position number where the <b>target</b> was found (counting the left-most character as position 0). If a match is not found, $\alpha\text{POS}$ returns -1. <sup>23</sup>
	<b>g [a.FN] <math>\alpha\text{POS? } r</math></b>	The <b>target</b> may be an individual character code or an <i>alpha string</i> . $\alpha\text{POS}$ saves a copy of the target in L. It works similar to POSA in HP-42S.
$\alpha\text{RL}$	<b>g [a.FN] <math>\alpha\text{RL } r</math></b>	(0) Rotates $r$ by $x$ characters like AROT in HP-42S, but with $x \geq 0$ . $\alpha\text{RL } 0$ executes as NOP, but loads L. <sup>23</sup>
$\alpha\text{RR}$	<b>g [a.FN] <math>\alpha\text{RR } r</math></b>	(0) Works like $\alpha\text{RL}$ but rotates to the right.

<sup>23</sup> This command will throw an error if there is no string in  $r$  at execution time.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\alpha SL$	<b>g</b> <b>a.FN</b> $\alpha SL$ <b>r</b>	(0) Shifts the $x$ leftmost characters out of $r$ , like ASHF in HP-42S. This allows for deleting the first $x$ characters in the string. $\alpha SL 0$ executes as NOP, but loads $L$ . <sup>23</sup>
$\alpha SR$	<b>g</b> <b>a.FN</b> $\alpha SR$ <b>r</b>	(0) Shifts the $x$ rightmost characters out of $r$ , like ASHF in HP-42S. This allows for deleting the last $x$ characters in the string. $\alpha SR 0$ executes as NOP, but loads $L$ . <sup>23</sup>
$\alpha.FN$	<b>g</b> <b>a.FN</b>	<b>Menu.</b> See p. 127.
$A...Ω$	<b>f</b> <b>CAT.</b> <b>CHARS</b> $A...Ω$	<b>Submenu</b> of Greek letters, see pp. 114ff.
$\alpha \bullet$	<b>f</b> <b>CAT.</b> <b>CHARS</b> $\alpha \bullet$	<b>Submenu.</b> See pp. 114ff.
	<b>g</b> <b>.</b>	<b>Menu</b> in AIM. See p. 127.
$\alpha \rightarrow x$	<b>g</b> <b>a.FN</b> $\alpha \rightarrow x$ <b>r</b>	(-1) { } → {1} Pushes the character code of the leftmost character in $r$ on the stack and removes this character from the string, similar to ATOX in HP-42S. <sup>23</sup>
$\beta(x,y)$	<b>g</b> <b>X.FN</b> <b>▲</b> $\beta(x,y)$	(2) {2, 3, 11, 12}; {1} → {2} Returns Euler's Beta $B(x,y) = \frac{\Gamma(x) \Gamma(y)}{\Gamma(x+y)}$ with $Re(x) > 0$ and $Re(y) > 0$ . Called $\beta$ here to avoid ambiguity. See $\Gamma(x)$ below.
$\gamma$	<b>g</b> <b>CNST</b> <b>γ</b>	(-1) { } → {2} Newtonian constant of gravitation (also called G by other authors) in $m^3 / kg\ s^2$ ;
$\gamma_{EM}$	<b>g</b> <b>CNST</b> <b>γ<sub>EM</sub></b>	<i>Euler-Mascheroni</i> constant (for mathematics);
$\gamma_p$	<b>g</b> <b>CNST</b> <b>γ<sub>p</sub></b>	proton gyromagnetic ratio (see p. 134).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Gamma_{xy}$	<b>g X.FN</b> □ $\Gamma_{xy}$	(2) {2, 11}; {1} → {2}
$\gamma_{xy}$	<b>g X.FN</b> □ <b>f</b> $\gamma_{xy}$	Return the <i>lower</i> or <i>upper incomplete Gamma function</i> , respectively. See pp. 233ff for more.
$\Gamma(x)$	<b>g PROB</b> □ $\Gamma(x)$	(1) {2, 3, 11, 12}; {1} → {2} Returns $\Gamma(x)$ . Note <b>x!</b> calls $\Gamma(x + 1)$ . See also $\text{LN}\Gamma$ .
$\delta x$	<b>f CAT.</b> PROGS <b>δx</b>	Predefined global label for $f'(x)$ and $f''(x)$ – see Section 4 of the OM.
$\Delta\%$	<b>f Δ%</b>	(1) {2, 11}; {1} → {2} Returns $100 \frac{x-y}{y}$ leaving $y$ unchanged, like %CH in HP-42S. Use it also for calculating markups or margins as explained in the OM, Sect. 2.
$\varepsilon$	<b>f STAT</b> <b>g</b> $\varepsilon$	(-2) {} → {2} Calculates the <i>scattering factors</i> $\varepsilon_y$ and $\varepsilon_x$ for <i>log-normally</i> distributed sample data and pushes them on the stack. This $\varepsilon_x$ works for the <i>geometric mean</i> $\bar{x}_g$ in analogy to the <i>standard deviation</i> $s$ for the <i>arithmetic mean</i> $\bar{x}$ but <u>multiplicative</u> instead of additive. See pp. 203ff for more information.
$\varepsilon_0$	<b>g CNST</b> $\varepsilon_0$	(-1) {} → {2} Electric constant or vacuum permittivity in <i>ampere-second per volt-meter</i> .
$\varepsilon_m$	<b>f STAT</b> <b>g</b> $\varepsilon_m$	(-2) {} → {2} Works like $\varepsilon$ above but returns the <i>scattering factors</i> of the two <i>geometric means</i> (in analogy to the standard error for <i>arithmetic means</i> ).
$\varepsilon_p$	<b>f STAT</b> <b>g</b> $\varepsilon_p$	(-2) {} → {2} Works like $\varepsilon$ but returns the <i>scattering factors</i> of the two populations.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\zeta(x)$	 	(1) {2, 3} Returns Riemann's Zeta. See p. 236 for more.
$\lambda_c$	 $\lambda_c$ etc.	
$\lambda_{cn}$		Compton wavelength of the electron, neutron, and proton in <i>meter</i> .
$\lambda_{cp}$		
$\mu_0$	 $\mu_0$ etc.	 Magnetic constant or vacuum permeability in <i>volt-second per ampere-meter</i> ;
$\mu_B$		Bohr magneton in <i>joule per tesla</i> ;
$\mu_e$		electron magnetic moment in <i>joule per tesla</i> ;
$\mu_e/\mu_B$		ratio of electron magnetic moment to Bohr magneton;
$\mu_n$		neutron and proton magnetic moments,
$\mu_p$		nuclear magneton, and
$\mu_u$		Muon magnetic moment in <i>joule per tesla</i> .
$\mu_\mu$		
$\pi$		 Recalls $\pi$ .
$\Pi_n$	 $\Pi_n$ <u>label</u>	Computes a product using the routine specified. See Section 4 of the OM for more. <b>ATTENTION:</b> $\Pi$ fills all <i>stack registers</i> with $x$ before calling the routine specified.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\sigma_s$		$(-2) \{ \} \rightarrow \{2\}$ Works like $s$ but returns the <i>standard deviations</i> of the two <i>populations</i> instead. See pp. 203ff.
$\sigma_B$		$(-1) \{ \} \rightarrow \{2\}$ <i>Stefan-Boltzmann constant</i> (see p. 135).
$\Sigma^{1/x}$	 etc.	$(-1) \{ \} \rightarrow \{2\}$ Recall the corresponding statistical sums, necessary for means and regressions beyond pure linear. Calling these sums by name significantly improves program readability. Note they are stored in dedicated <i>registers</i> of your WP 43S (see App. B on pp. 156ff.).
$\Sigma^{1/x^2}$		
$\Sigma^{1/y}$		
$\Sigma^{1/y^2}$		
$\Sigma \ln^2 x$	 etc.	<b>ATTENTION:</b> Depending on input data, some of the logarithmic sums may become non-numeric or some of the inverted may become infinite. If this happens no error will be thrown, however, regardless of the status of <i>flag D</i> .
$\Sigma \ln^2 y$		
$\Sigma \ln x$		
$\Sigma \ln xy$		For space reasons, two sums are abbreviated: $\Sigma \ln xy$ denotes $\sum \ln(x)\ln(y)$ .
$\Sigma \ln y/x$		$\Sigma \ln y/x$ denotes $\sum \frac{\ln(y)}{x}$ .
$\Sigma_n$		Computes a sum using the routine specified. See Section 4 of the OM for more. <b>ATTENTION:</b> $\Sigma$ fills all <i>stack registers</i> with $x$ before calling the routine specified.
$\sigma_w$		$(-1) \{ \} \rightarrow \{2\}$ Works like $s_w$ but returns the <i>standard deviation</i> of the <i>population</i> instead. See pp. 203ff.

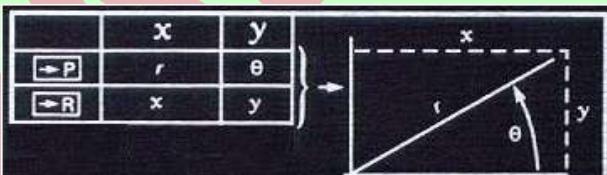
Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Sigma x$	[g] [SUMS] $\Sigma x$	
$\Sigma x^2$	etc.	
$\Sigma x^2y$	[g] [SUMS] [g] $\Sigma x^2y$	
$\Sigma x^2/y$	[g] [SUMS] $\Delta$ $\Sigma x^2/y$	
$\Sigma x^3$	[g] [SUMS] $\Delta$ [f] $\Sigma x^3$	
$\Sigma x^4$	etc.	
$\Sigma xlny$	[g] [SUMS] [g] $\Sigma xlny$	
$\Sigma xy$	[g] [SUMS] $\Sigma xy$	
$\Sigma x/y$	[g] [SUMS] $\Delta$ $\Sigma x/y$	
$\Sigma y$	[g] [SUMS] $\Sigma y$	
$\Sigma y^2$	etc.	
$\Sigma ylnx$	[g] [SUMS] [g] $\Sigma ylnx$	
$\Sigma +$	[f] [STAT] $\Sigma +$	<p style="background-color: red; color: white; padding: 2px;">[8] → {2}</p> <p>If X contains an <math>n \times 2</math> matrix then <math>\Sigma +</math> adds <math>n</math> 2D data points to the statistical sums. The <i>temporary information</i> displayed will show the last data point added.<sup>24</sup></p> <p style="background-color: green; color: white; padding: 2px;">[1, 2, 11]</p> <p>Adds one 2D data point to the statistical sums.<sup>24</sup></p>
$\Sigma -$	[f] [STAT] [f] $\Sigma -$	<p style="background-color: green; color: white; padding: 2px;">[1, 2, 11]</p> <p>Subtracts one 2D data point from the statistical sums.<sup>24</sup></p>

<sup>24</sup>  $\Sigma +$  and  $\Sigma -$  return *temporary information* as shown in Section 2 of the OM and disable *automatic stack lift*. Both commands may also be used for 2D vector adding and subtracting (see SUM and the corresponding example in Section 2 of the OM).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Phi$	<b>g</b> [CNST] $\Phi$	(-1) {} → {2} Golden ratio and magnetic flux quantum, the latter in <i>volt-second</i> .
$\Phi_0$	<b>g</b> [CNST] $\Phi_0$	
$\chi^2(x)$	<b>g</b> [PROB] $\chi^2:$ $\chi^2(x)$ etc.	(1) {2, 11} <i>Chi-square distribution</i> (with its degrees of freedom given in I). $\chi^2_u(x)$ equals $Q(\chi^2)$ on HP-21S. See Section 2 of the OM for an application example and pp. 203ff for more.
$\chi^2_e(x)$		
$\chi^2_p(x)$		
$(\chi^2)^{-1}$		
$\chi^2:$	<b>g</b> [PROB] $\chi^2:$	Submenu. See p. 123.
$\omega$	<b>g</b> [CNST] $\omega$	(-1) {} → {2} Angular velocity of the Earth in <i>radian per second</i> according to WGS84 (see footnote 20 on p. 71).
$(-1)^x$	<b>g</b> [X.FN] $\blacktriangleleft$ <b>f</b> $(-1)^x$	(1) {1, 2, 3, 8*, 9*, 10, 11, 12} If $x$ is non-integer, returns $\cos(\pi x)$ .
+	<b>+</b>	(2) Returns $y + x$ for compatible objects. See the tables in the OM, Sect. 2, for details.
$+/-$	<b>+/-</b> (for closed input)	(1) ‘Unary minus’, returns $x \times (-1)$ . See the tables in the OM, Sect. 2, for details.
-	<b>-</b>	(2) Returns $y - x$ for compatible numeric objects. See the tables in the OM, Sect. 2, for details.
$-\infty$	<b>g</b> [CNST] $-\infty$	(-1) {} → {2} Minus infinity. May the Lord of Mathematics forgive us calling this a constant, but it is counted as a numeric value in your WP 43S.

Item	Keystrokes	Remarks (see pp. 12ff for general information)									
$\times$	$\times$	(2) Returns $y \times x$ for compatible numeric objects. See the tables in Section 2 of the OM for details.									
$\times\text{MOD}$	$\text{g INTS}$ $f \times\text{MOD}$	(3) {1, 2, 10, 11} Returns $(z \times y) \bmod x$ for $x > 1$ , $y > 0$ , $z > 0$ .									
$/$	$/$	(2) Returns $y \times x^{-1}$ for compatible numeric objects. See the tables in the OM, Sect. 2, for details. Returns $y \text{ div } x$ if both $y$ and $x$ are of <i>data type</i> 1 or 10. Cf. IDIV.									
$\pm\infty?$	$\text{g INFO}$ $\text{g } \pm\infty?$	(0) {2, 11} $\rightarrow$ {1} Tests $x$ for infinity. Returns <table style="margin-left: 20px;"> <tr> <td>true</td> <td>1</td> <td>for <math>x = +\infty</math>,</td> </tr> <tr> <td>true</td> <td>-1</td> <td>for <math>x = -\infty</math>, and</td> </tr> <tr> <td>false</td> <td>0</td> <td>else.</td> </tr> </table>	true	1	for $x = +\infty$ ,	true	-1	for $x = -\infty$ , and	false	0	else.
true	1	for $x = +\infty$ ,									
true	-1	for $x = -\infty$ , and									
false	0	else.									
$\rightarrow$		Reserved symbol for indirect addressing.									
$\rightarrow\text{DATE}$	$\text{g CLK } \rightarrow\text{DATE}$	(3) {1, 2} $\rightarrow$ {6} Assumes the three components of a date (year, month, and day) supplied on the stack in proper order for the date format selected and converts them to a single date in $x$ . Thus inverts DATE $\rightarrow$ .									
$\rightarrow\text{DEG}$	$f \text{ L } \rightarrow\text{DEG}$	(1) {1, 2, 4, 11} $\rightarrow$ {4} Converts angles as described on pp. 143f.									
$\rightarrow\text{DP}$	$\text{g } \rightarrow\text{DP}$ $\text{g X.FN}$ $\Delta f \rightarrow\text{DP}$	(1) {1, 2, 11} $\rightarrow$ {11}; {3, 12} $\rightarrow$ {12} Converts $x$ into a DP number. Numbers shown as fractions will be displayed as decimal numbers (cf. IMPFRC and PROFRC). Compare $\rightarrow\text{SP}$ .									

Item	Keystrokes	Remarks (see pp. 12ff for general information)
→D.MS	f [L→] →D.MS	(1) {1, 2, 4, 11} → {4}
→GRAD	f [L→] →GRAD	Convert angles as described on pp. 143f.
→HR	f [CATALOG] FCNS →HR	(1) {5} → {2} Operates on <i>times</i> like →REAL below. →HR is maintained for backward compatibility only..
→H.MS	f [h.ms] (for closed input)	(1) {1, 2, 5, 11} → {5} Converts $x$ to a sexagesimal <i>time</i> – cf. p. 110.
→INT	f [#] base (for closed input)	(1) {1, 2, 10, 11} → {10} Converts the integer part of $x$ to a <i>short integer</i> of the base specified. Conversion to decimal may be abbreviated by [#]D, to hexadecimal by [#]H. Cf. p. 110.
→MULπ	f [L→] →MULπ	(1) {1, 2, 4, 11} → {4} Converts angles as described on pp. 143f.
→POL	g [→P]	{2, 11}; {1} → {2} Assumes X and Y containing 2D <i>Cartesian</i> coordinates of a point or components of a vector ( $x, y$ ). Converts them to the respective polar coordinates or components ( $r, \theta$ ). See the picture and cf. →REC. For switching the display format of complex numbers, choose POLAR.
→RAD	f [L→] →RAD	(1) {1, 2, 4, 11} → {4} Converts angles as described on pp. 143f

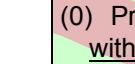
Item	Keystrokes	Remarks (see pp. 12ff for general information)
→REAL	<b>f .d</b> (for closed input)	(1) {1, 2, 4, 5, 6, 10, 11} → {2} Converts $x$ to an SP real number. Any object (e.g. a <i>time</i> ) tagged sexagesimal will be converted in a decimal number. For {6}, the date format chosen is taken into account. Numbers shown as fractions will be displayed as decimal numbers (cf. IMPFRC and PROFRC). For returning the real part of a complex number, choose RE. For cutting a complex number into its parts, use <b>[CC]</b> .
→REC	<b>f R↔</b>	{2, 11}; {1, 4} → {2} Assumes X and Y containing 2D polar coordinates of a point or components of a vector $(r, \theta)$ . Converts them to the respective Cartesian coordinates or components $(x, y)$ . See →POL.  For switching the display format of complex numbers, choose RECT.
→SP	<b>f SP↔</b>	(1) {1, 2, 11} → {2}; {3, 12} → {3}
	<b>g X.FN</b> <b>▲ f →SP</b>	Converts $x$ to an SP real number. Numbers shown as fractions will be displayed as decimal numbers (cf. IMPFRC and PROFRC). Compare →DP.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\text{X}$	<b>g STK</b> $\text{X} \_\_$	<p>Shuffles the contents of the <i>stack registers X, Y, Z, and T</i> at execution time.</p> <p><b>Examples:</b></p> <ul style="list-style-type: none"> <li><math>\text{xxxyz}</math> works like <math>\text{ENTER}^\uparrow</math> (but does <u>not</u> disable <i>automatic stack lift!</i>),</li> <li><math>\text{yxzxt}</math> works like <math>x \leftarrow y</math>,</li> <li><math>\text{yztx}</math> works like <math>R \downarrow</math> in a 4-level stack,</li> <li><math>\text{txxyz}</math> works like <math>R \uparrow</math> in a 4-level stack, but also <math>\text{yytt}</math> or <math>\text{zzzx}</math> is possible.</li> </ul> <p><b>ATTENTION:</b> This is a very powerful command although it does not look it. Note it will affect the <u>bottom four stack registers only</u>; there is no connection to A ... D, <u>regardless of stack size</u>. Playing with <math>\text{X}</math>, you may lose some stack contents and make a mess of the stack easily.</p>
$\%$	<b>g FIN</b> $\%$	<p>(1) {2, 11}; {1} <math>\rightarrow</math> {2}</p> <p>Returns <math>\frac{xy}{100}</math>, leaving <math>y</math> unchanged.</p>
$\%MRR$	<b>g FIN</b> $\%MRR$	<p>(3) {2, 11}; {1} <math>\rightarrow</math> {2}</p> <p>Returns the mean rate of return in percent per period, i.e. <math>100 \cdot \left( \sqrt[z]{x/y} - 1 \right)</math> with <math>x = \text{FV}</math> = future value after <math>z</math> periods, <math>y = \text{PV}</math> = present value. For <math>z = 1</math>, <math>\Delta\%</math> returns the same result easier.</p>
$\%T$	<b>g FIN</b> $\%T$	<p>(1) {2, 11}; {1} <math>\rightarrow</math> {2}</p> <p>Returns <math>\frac{100 x}{y}</math>, interpreted as % of <u>total</u>. Leaves <math>y</math> unchanged.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
%Σ	[g] [FIN] [%Σ]	(1) {2, 11}; {1} → {2} Returns $\frac{100 \sum x}{\sum x}$ .
%+MG	[g] [FIN] [%+MG]	(2) {2, 11}; {1} → {2} Calculates a sales price by adding a margin of $x \%$ to the cost $y$ , as %MU-Price in HP-17B. Formula: $p_{sale} = \frac{y}{1 - \frac{x}{100}}$ You may use %+MG for calculating net amounts as well; just enter a negative percentage in $x$ .
✓x	[✓x]	(1) {1, 2, 3, 8*, 9*, 10, 11, 12}; ({1} → {2}, {2} → {3}) Returns the square root of $x$ . Square roots of non-square <i>long integers</i> will return reals. Roots of negative <i>long integers</i> or reals will return complex numbers if CPXRES is set.
∫	[f] [ADV] [∫fdx] [∫] [var] (listed in programs as ∫fd trailed by the integration variable)	{2} Integrates the function given in the routine specified by PGMINT over the variable specified. Lower and upper integration limits must be supplied by the corresponding variables ↓Lim and ↑Lim, accuracy by ACC. ∫ returns the (approximated) integral in X and an upper limit of its uncertainty in Y. <b>ATTENTION:</b> ∫ fills all <i>stack registers</i> with $x$ before calling the routine specified in PGMINT.
	[g] [EQN] [∫f] [∫]	See Section 4 of the OM for more. Integrates the current equation.
∫f	[g] [EQN] [∫f]	
∫fdx	[f] [ADV] [∫fdx]	Submenus. See pp. 120f.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\infty$	<b>g [CNST] <math>\infty</math></b>	(-1) {} → {2} Infinity. May the Lord of Mathematics forgive us calling this a constant, but it is counted as a numeric value in your WP 43S.
${}^{\text{MOD}}$	<b>g [INTS]</b> <b>g <math>{}^{\text{MOD}}</math></b>	(3) {1, 2, 10, 11} Returns $(z^y) \bmod x$ for $x > 1$ , $y > 0$ , $z > 0$ .
$ M $	<b>f [MATX]  M </b>	(1) {8} → {2}; {9} → {3} Requires a square matrix in <b>X</b> and returns its determinant. The original matrix is stored in <b>L</b> .
$ x $	<b>f  x </b> or <b>f [PARTS] f  x </b>	(1) {1, 2, 4, 10, 11} Returns the absolute (unsigned) value of $x$ .
		(1) {8*} Returns a real matrix with the absolute values of all input matrix elements. Cf. ENORM.
	<b>f  x </b> or <b>g [CPX] f  x </b>	(1) {3} → {2}; {12} → {11} Returns the magnitude $\sqrt{\text{Re}(x)^2 + \text{Im}(x)^2}$ in <b>X</b> .
		(1) {9*} → {8} Returns a real matrix with the magnitudes of all input matrix elements. Cf. ENORM.
$  $	<b>g [X.FN]</b> <b>▲ f   </b>	(2) {2, 3, 11, 12}; {1} → {2} Returns $\left(\frac{1}{x} + \frac{1}{y}\right)^{-1}$ , being useful in electrical engineering especially. Returns 0. for $x$ or $y$ being zero.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$[M]^T$		(1) {8, 9} Returns the transpose of the matrix $x$ (like TRANS in HP-42S). The transpose is another matrix with rows changed by columns. If $A$ is an $n \times m$ matrix and $a_{ij}$ is an element of it then $A^T$ will be an $m \times n$ matrix $B$ with $b_{ij} = a_{ji}$ . The transpose is done in-situ and does not require any additional memory.
$[M]^{-1}$		(0) {8, 9} Takes the square matrix in X and inverts it in-situ (like INVRT on HP-42S).
$\text{4}$	 or  or 	(1) {3} → {2}; {12} → {11} Returns the phase or argument $\arg(x) = \arctan\left(\frac{\text{Im}(x)}{\text{Re}(x)}\right)$ . Cf. $ x $ . (1) {9*} → {8} Returns a matrix with the phases of all input matrix elements. Cf. $ x $ . (0) {1, 2, 4, 11} Equals NOP.
$\text{4}\rightarrow$		Menu of angular conversions. See p. 128.
ADV		(0) Prints the current contents of the print buffer and a linefeed. <b>ATTENTION:</b> The printer will actually print only when a linefeed is sent to it.
CHAR		(0) Sends a single character (with the code specified) to the printer. Character codes $n > 127$ can only be specified indirectly. MODE setting will be honored. See ADV.
DLAY		(0) Sets a delay of $n$ ticks (see TICKS) to be used with each linefeed on the printer.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LCD		(0) Sends the contents of the entire <i>LCD</i> to the printer.
MODE		(0) Sets print mode. Legal print modes are: 0: Use the printer font and character set wherever possible (default). All characters feature the same width (5 columns + 2 columns spacing). 1: Use the variable pitch display font, resulting in some jitter on the printout but packing more characters in a row. 2: Use the small display font, which allows for packing even more info in a row. 3: Send the output to the serial channel. Works for plain ASCII only – no characters will be translated. Line setup is the same as for serial communication: 9600 baud, 8 bits, no parity.
PROG		(0) Prints the listing of the <i>current program</i> (see Sect. 3 of the OM), 1 row per step. See ADV.
r	 	(0) Prints the <i>register</i> specified, right adjusted, <u>without</u> labeling the output. Note  is on the keyboard. If you want a heading label, compose the string in X first or use REGS. See ADV.
REGS		(1) Interprets <i>x</i> in the form <i>sss.nn</i> . Prints the contents of <i>nn</i> registers starting with number <b>sss</b> . Each <i>register</i> takes one row starting with a label. See also ADV.  <b>ATTENTION for nn = 0 :</b> <ul style="list-style-type: none"><li>• For <i>sss</i> ∈ [0; 99], printing will stop at R99.</li><li>• For <i>sss</i> ∈ [100; 111], printing stops at K.</li><li>• For <i>ss</i> ≥ 112, printing will stop at the highest allocated local <i>register</i>.</li></ul>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
�STK	 	(0) Prints the <i>stack</i> contents. Each <i>register</i> prints in a separate row starting with a label indicating said <i>register</i> . See �ADV.
�TAB	 	(0) Positions the print head to print column <i>n</i> (0 to 165, where <i>n</i> > 127 can only be specified indirectly). Useful in formatting (in �MODE 1 or 2 in particular). Allows also for printer plots. If <i>n</i> is less than current print head position, a linefeed will be entered to reach the new position. See �ADV.
�USER	 	(0) Prints all variable names and global program labels. The variable names are printed first, so if you are not interested in the program labels, press R/S to stop the listing.
�WIDTH	 	(-1) Returns the number of print columns that <i>x</i> would take in the print mode set. See �ADV and �MODE.  Second use: in �MODE 1 or 2, �WIDTH returns the width of <i>x</i> in px (including the last column being always blank) in the specified font.
��	 	(0) Prints the summation <i>registers</i> . Each <i>register</i> prints in one row starting with its label. See �ADV.
��#	 	(0) Sends a single <i>byte</i> , without translation, to the printer (e.g. a control code). <i>n</i> > 127 can only be specified indirectly. �MODE setting will not be honored. See �ADV.
#	 	For inserting an integer $0 \leq n \leq 255$ in a single program step. Maintained for backward compatibility to WP 34S only.
#B	 	(1) {10}  Counts the bits set in <i>x</i> (like on HP-16C).

## Predefined Variables Provided

There is a name overlap between some constants and predefined variables. Thus, the latter set is kept separate from the other *items*:

Variable	Keystrokes	Remarks (see pp. 12ff for general information)
A		Reserved variable for <i>register A</i>
ACC	f ADV ∫fdx ACC	Reserved real variable for the accuracy of integration (see Sect. 4 of the OM).
B		
C		
D		
FV	g FIN TVM FV	Reserved variable for the future value of your investment or loan in <i>TVM</i> . <sup>25</sup>
I		Reserved variable for <i>register I</i> .
i%/a	g FIN TVM i%/a	Reserved variable for the annual interest rate of your investment or loan in <i>TVM</i> . <sup>25</sup>
J		
K		
L		
Mat_A	f MATX SIM EQ Mat A	Reserved variables for solving systems of linear equations ( <i>SLE</i> , see <i>Section 2</i> of the OM).
Mat_B	f MATX SIM EQ Mat B	

<sup>25</sup> See *Section 5* of the OM.

Variable	Keystrokes	Remarks (see pp. 12ff for general information)
NPER	<b>g FIN TVM n<sub>PER</sub></b>	Reserved variable for the <u>total</u> number of <ul style="list-style-type: none"> <li>• payment periods for your loan or</li> <li>• compounding periods for your investment.</li> </ul>
PER/a	<b>g FIN TVM f per/a</b>	Reserved variable for the <u>annual</u> number of <ul style="list-style-type: none"> <li>• payments for your loan or</li> <li>• compounding periods of your investment.</li> </ul>
PMT	<b>g FIN TVM PMT</b>	Reserved variable for the payment per period for your investment or loan in <i>TVM</i> . <sup>25</sup>
PV	<b>g FIN TVM PV</b>	Reserved variable for the present value of your investment or loan in <i>TVM</i> . <sup>25</sup>
REGS		Reserved variable for the $100 \times 1$ matrix of registers – if required.
ST.A ST.B ST.C ST.D ST.T ST.X ST.Y ST.Z		Reserved variables for <i>stack registers A ... Z</i>
↑Lim ↓Lim	<b>f ADV ∫fdx ↑Lim</b> etc.	Reserved real variables for the upper and lower limit of integration (see the OM, Sect. 4).

## Nonprogrammable Commands and Keys

The commands marked **violet** in the *IOI* cannot be programmed. The same applies to all operations of the *Matrix Editor* and *Equation Editor*, as well as answers to questions your WP 43S asks.

Furthermore, all *catalog* and *menu* calls themselves as well as the operations called by **EXIT**, **P/R**, **USER**, **α**, **G**, **≡Δ**, **▲**, **≡▽**, and **▼** are neither programmable nor will they show any input echo in the top numeric row as the other commands do (cf. the OM, Sect. 2). See also *Section 2: Menus and Catalogs* (on pp. 114ff) for more about this topic.

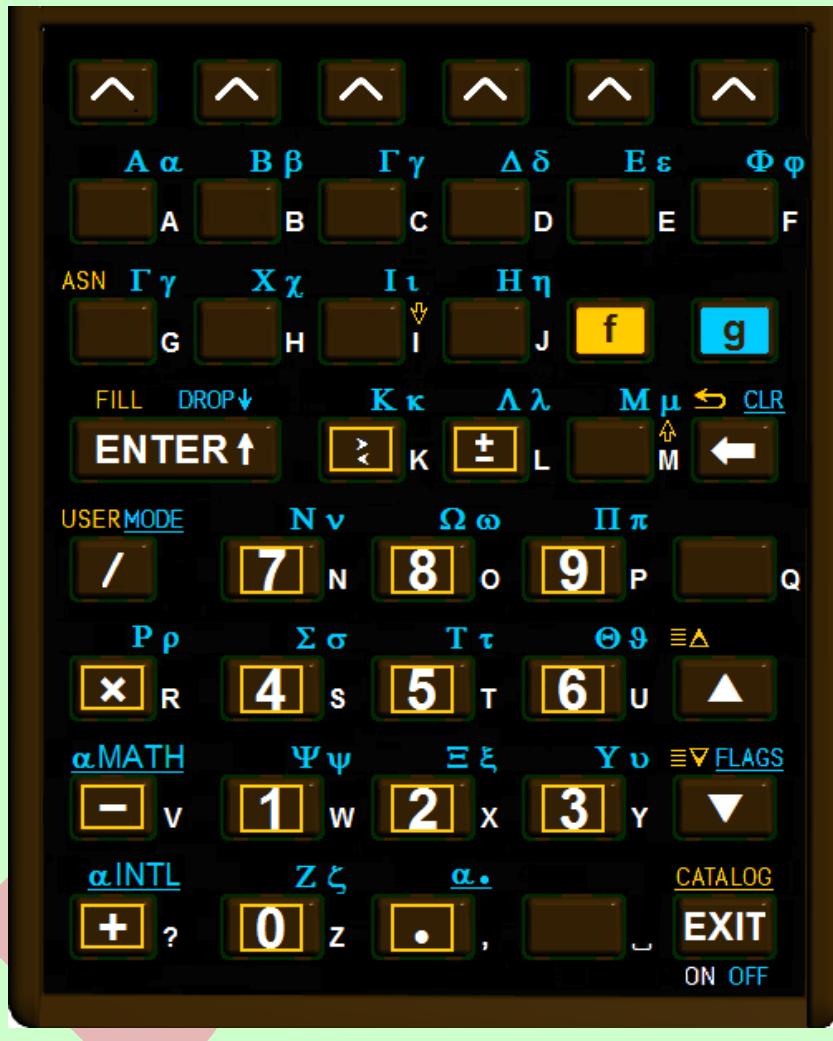
The *browsers* RBR and STATUS as well as the *application* TIMER use some keys for particular control purposes (e.g. **STO**, **RCL**, **.**, and numeric keys – see the OM, Section 5).

## Command Parameter Input and Closing It

The following table shows what will happen when particular keys are pressed while command parameter input is not finished yet (see pp. 110ff for input in X instead). Note that characters include digits and punctuation marks as well. The table lists the respective keys beginning top left on the keyboard:

Keystrokes	Situation	Remarks
<b>A</b> ... <b>Z</b>	addressing	Register or flag input. See the <i>virtual keyboard</i> in Section 1 of the OM for the letters applicable.
<b>A</b> ... <b>Z</b>	entering a label or a variable name	Appends the corresponding Latin or Greek letter or digit to the label or variable name pending. Use <b>▼</b> and <b>▲</b> to switch cases for letters. See the <i>virtual keyboard</i> on p. 109 (and cf. Section 2 of the OM).
<b>g</b> <b>A</b> ... <b>g</b> <b>O</b>		
<b>f</b> <b>O</b> ... <b>f</b> <b>9</b>		

Keystrokes	Situation	Remarks
<b>ENTER↑</b>	arbitrary parameter input pending	If there is no input yet, assumes the default, if applicable. Closes pending input, interprets it as a <i>register</i> or <i>flag</i> address or a variable name or a label or alike, and executes the command.  Cf. <i>Section 1</i> of the OM.
<b>←</b>	arbitrary parameter input pending	Deletes the rightmost character keyed in. If there is nothing left, cancels the pending command, returning to the status of your WP 43S as it was before that input was started.
<b>0 ... 9</b>	addressing	Numeric parameter input. See <i>Section 1</i> of the OM for the valid number ranges.
<b>.</b>	addressing	Header for <i>local registers</i> or <i>flags</i> .
<b>EXIT</b>	arbitrary parameter input pending	If there is an open <i>menu</i> , closes it.  Else cancels pending command input, returning to the status of your WP 43S as it was before that command was called.



## Alphanumeric Input in X and Closing It

The following table shows what will happen when particular keys are pressed with alphanumeric or numeric input in X being open still (turn to pp. 107f for command parameter input instead). The table lists the respective keystrokes top left to bottom right on the keyboard:

Keystrokes	in mode(s)	Remarks
<b>f # base</b>	¬ (A, α)	Closes input of a <i>short integer</i>
<b>f d.ms</b>		<i>sexagesimal angle</i>
<b>f .d</b>		<i>date</i>
<b>f h.ms</b>		<i>sexagesimal time</i> in X. <sup>26</sup>
<b>A ... Z</b>	A, α	Appends the corresponding Latin or Greek letter to the <i>alpha string</i> x. Use ▾ and ▾ to switch cases. See the picture on previous page and cf. <i>Section 2</i> of the OM.
<b>a A ... g o</b>		
<b>CC</b>	¬ (A, α)	Closes input of the first part of a complex number in X and waits for input of its second part (see the <i>Key Response Table</i> and <i>Section 2</i> of the OM).
<b>f R↓ (▼)</b>	A, α	Prefix for the next character becoming a subscript, if applicable.

<sup>26</sup> See *Section 2* of the OM. At closure, input will be checked – illegal digits (e.g. 8 in octal input or C in decimal) or bases or numbers (e.g. 72 minutes in a time) or characters found, or out-of-range conditions detected will cause an error thrown (see also the description of **ENTER f** on next page and the error messages in App. C).

Keystrokes	in mode(s)	Remarks
<b>ENTER↑</b>	arbitrary input pending	<p>If there was no input before, sets input to zero.</p> <p>Else closes input (in X) and checks the following conditions top-down:</p> <ul style="list-style-type: none"> <li>• If this input is alphanumeric (i.e. if it contains at least one non-numeric character except <b>.</b>), takes it as an <i>alpha string</i>.</li> <li>• Else (i.e. if this input is purely numeric) if it contains one <b>CC</b>, takes it as a complex number.</li> <li>• Else if it contains two <b>.</b>, takes it as a <i>fraction</i>.</li> <li>• Else if it contains one <b>E</b> or one <b>.</b>, takes it as a real number.</li> <li>• Else (i.e. if it contains neither a <b>CC</b> nor a <b>.</b> nor an <b>E</b>), tests it for <b>#</b>: <ul style="list-style-type: none"> <li>◦ If it contains one <b>#</b> and a valid base trailing it then takes it as a <i>short integer</i>;</li> <li>◦ else looks up if previous entry was a <i>short integer</i>: if true then takes the new input as another <i>short integer</i> of the same base; else takes the new input as a <i>long integer</i>.</li> </ul> </li> </ul> <p>Then checks the new input (according to the condition met) as outlined in footnote 26 and interprets it. Finally, unless an error had to be thrown, copies <i>x</i> into Y.</p>
<b>f [x]</b>	A, $\alpha$	Appends <b>x</b> to the <i>alpha string</i> <i>x</i> .
<b>+/-</b>	$\neg(A, \alpha)$	Changes the sign of the mantissa or exponent in numeric input as explained in Section 1 of the OM.
<b>f +/-</b>	A, $\alpha$	Appends <b>±</b> to the <i>alpha string</i> <i>x</i> .
<b>E</b>	$\neg(A, \alpha)$	Closes input of the mantissa and waits for input of the exponent (see Section 1 of the OM).
<b>f E ( ^ )</b>	A, $\alpha$	Prefix for the next character becoming a superscript, if applicable.

Keystrokes	in mode(s)	Remarks
	arbitrary input pending	Deletes the last (rightmost) character keyed in. If there is nothing left, cancels the pending input, returning to the status of your WP 43S as it was before that input was started.
	A, $\alpha$	Appends  to the <i>alpha string</i> $x$ .
	A, $\alpha$	Appends  to the <i>alpha string</i> $x$ .
	$\neg(A, \alpha)$	<p>Standard numeric input, appending the corresponding digit to <math>x</math>. Note you can enter ...</p> <ul style="list-style-type: none"> <li>• up to 16 digits plus a sign in the mantissa and up to three digits plus a sign in the exponent for a real number or any part of a complex number,</li> <li>• an arbitrary number of digits plus a sign for a <i>long integer</i>,</li> <li>• up to 64 bits for a <i>short integer</i>, or</li> <li>• up to 16 digits for the nominator and up to 4 digits for the denominator of a fraction.</li> </ul>
	A, $\alpha$	Appends the respective digit to the <i>alpha string</i> $x$ .
	A, $\alpha$	Turns to upper case for the following letter(s).
	A, $\alpha$	Turns to lower case for the following letter(s).
	A, $\alpha$	Appends  to the <i>alpha string</i> $x$ .
 A ... F	$\neg(A, \alpha)$	Numeric input for bases >10, appending the corresponding digit to $x$ . See Section 2 of the OM for more. Digits will be checked when input is closed (see the description of  above).
	A, $\alpha$	Appends  to the <i>alpha string</i> $x$ .
	A, $\alpha$	Appends  to the <i>alpha string</i> $x$ .

Keystrokes	in mode(s)	Remarks
.	¬ (A, α)	Inserts a radix mark as selected.
		Separates <i>degrees</i> from <i>minutes</i> , <i>seconds</i> , and <i>hundredths of seconds</i> in angular input, so input format is dddd.dd.mmmsshh <b>d.ms</b> for sexagesimal angles (cf. p. 110 and Section 2 of the OM).
		Separates <i>hours</i> from <i>minutes</i> , <i>seconds</i> , and fractions of <i>seconds</i> in <i>time</i> input, so input format is hhhh.mmssffff <b>h.ms</b> for sexagesimal <i>times</i> (cf. p. 110 and Section 2 of the OM).
Second .	¬ (A, α)	A second <b>.</b> in input indicates a fraction. See Section 2 of the OM for examples. The second <b>.</b> just separates the nominator and the denominator in input. Note you cannot enter <b>E</b> after you entered <b>.</b> twice – but you may delete the second dot while editing the input row.
,	A, α	Appends <b>,</b> to the <i>alpha string</i> <i>x</i> .
f .	A, α	Appends <b>.</b> to the <i>alpha string</i> <i>x</i> .
R/S	program waiting for arbitrary input	Closes input and starts its checks and interpretation like <b>ENTER↑</b> above.
	A, α	Appends a blank space to the <i>alpha string</i> <i>x</i> .
EXIT	arbitrary input pending	If there is an open <i>menu</i> , closes it. Else closes pending numeric or alphanumeric input and releases it for interpretation.

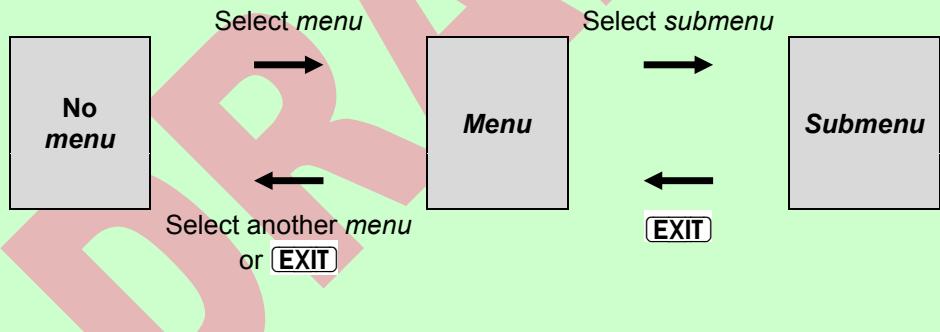
There are many more characters you can enter via the three alpha *menus* or **CATALOG CHARS**. See pp. 115 and 126ff for these menus and FBR for browsing the entire character sets provided.

## SECTION 2: MENUS AND CATALOGS

Due to the large set of operations your *WP 43S* features, most of them are stored in *menus* as they were discussed in the *OM, Section 1*. Besides operations, numeric constants, or characters (as in the alpha *menus*), there may be also other *items* contained in *menus* (e.g. *submenus*, digits).

*Catalogs* are a special kind of *menus* with their contents sorted alphabetically. Your *WP 43S* provides two *catalogs*, CATALOG and CNST. Also some *submenus* of CATALOG are treated as *catalogs* (i.e. A...Z, DIGITS, FCNS, MENUS, aINTL, and the *submenus* of VARS, see next chapter). Within *catalogs*, some special operations ease your path accessing the *items* stored there (as shown on pp. 118f).

You may switch *menus* (except *catalogs*) easily by just calling another *menu* accessible in current mode directly from the *menu* you are using – no need to **EXIT** first:



### One to Find and Rule Them All – the CATALOG

**CATALOG** calls a very particular *menu*: CATALOG contains all the *items* defined on your *WP 43S* and visible for the user. Many of them are sorted alphabetically in different branches: these *items* we call *cataloged*. Individual *cataloged items* may be accessed quickly in a way demonstrated on pp. 118f.

Note the contents of the various branches of CATALOG are presented below in reverse order compared to the display of your *WP 43S*, taking care of your top-down reading habits:

							Remarks
<b>CATALOG:</b>	FCNS	DIGITS	CHARS	PROGS	VARS	MENUS	top branches
FCNS:	$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	$10^x$	1COMPL	$1/x$	$2^x$	functions provided
	2COMPL	$\sqrt[3]{\text{x}}$	ABS	$\text{ac} \rightarrow \text{m}^2$	$\text{ac}_{\text{us}} \rightarrow \text{m}^2$	AGM	
	ALL	AND	arccos	arcosh	arcsin	arctan	
	...						
	...	#B					
DIGITS:	0	1	2	3	4	5	digits defined
	6	7	8	9	A	B	
	C	D	E	F	i		
CHARS:	A...Z	A...Ω	αINTL	αMATH	Myα	α·	character branches
A...Z:	A	B	C	D	E	...	plain Latin letters
αINTL:	Ā	Á	Ă	À	...		additional (international) Latin letters, see p. 126
αMATH:	<	≤	=	...			mathematical operators and symbols, see p. 127
A...Ω:	A	B	Γ	Δ	...		Greek letters, see p. 127
α·:	!	:	;	...			punctuation marks, see p. 128
PROGS:	RAM					FLASH	global labels currently defined
RAM:	...						empty at startup but will be filled with your creations
FLASH:	...						
VARS:	I.INTS	s.INTS	REALS	CPXS	STRING	MATRS	branches for various types of variables
	DATES	TIMES	ANGLES				

							Remarks
ANGLES:	...						all variables currently defined, placed following their <i>data types</i> – all these <i>submenus</i> are empty at startup but will be filled and grow with your creations
CPXS:	...						
DATES:	...						
L.INTS:	...						
MATRS:	...						
REALS:	...						
STRING:	...						
s.INTS	...						
TIMES:	...						
MENUS:	ANGLES	A...Z	A:	Binom:	BITS	Cauch:	(sub-) menus currently defined (shown here at startup, but this list will grow due to your creations) – see above and below for fix menu contents
	CHARS	CLK	CLR	CNST	CPX	CPXS	
	DATES	DIGITS	DISP	EQN	EXP	Expon:	
	...						
	...	→					
A:	...						(sub-) menus provided unless mentioned above already, see pp. 120ff for predefined contents – here your creations will be inserted as new entries
Binom:	...						
BITS:	...						
...							
...							

Three branches of **CATALOG** are expandable (**MENUS** and the *submenus* of **PROGS** and **VARS**) since you may create *items* of these kinds (cf. the OM, Sect. 6); the other are fixed size (**FCNS**, **DIGITS**, and **CHARS**) since all functions, digits, and characters are predefined.

Calling **CATALOG** will display its top level branches (one row of labels, being pointers to the *submenus* containing all the functions,



digits, characters, programs, variables, and *menus* defined at execution time):

Choosing one of these branches will show its first view of *items* (primary, **f**- and **g**-shifted, as applicable). Pressing the leftmost *softkey*, for instance, will call the *submenu* FCNS showing up as pictured below:

							0.004	
	ALL	AND	arccos	arcosh	arcsin	arctan		
	2COMPL	$\sqrt[3]{x}$	ABS	$ac \rightarrow m^2$	$ac_{us} \rightarrow m^2$	AGM		
	$^{\circ}C \rightarrow ^{\circ}F$	$^{\circ}F \rightarrow ^{\circ}C$	$10^x$	1COMPL	$1/x$	$2^x$		

Within CATALOG branches, browsing by **▲** will advance by only six *items* per keystroke (and **▼** will go back by six).<sup>27</sup> Select an *item* by pressing the corresponding top row key (headed by a *prefix* if applicable); e.g. call a function by pressing the corresponding *softkey*. **EXIT** will just leave CATALOG without doing anything.

All the functions available on your *WP 43S* are stored in CATALOG'FCNS. Most of them are also found (and easier to access) in other predefined *menus*. Each and every command featured on your *WP 43S*, the keystrokes calling it, and the necessary particular explanations are also listed for your reference in the *IOI* on pp. 12ff.

Remember all labels printed underlined on the keyboard point to *menus*. All *menus* available are found in CATALOG'MENUS; predefined *menu* names are listed in the *IOI* as well; their particular contents are printed in next chapter. Individual *items* may appear in more than one *menu* and also on the keyboard.

See Section 6 of the *OM* to learn how to customize your *WP 43S* by creating and filling your own *menus* (assignable to your favorite keyboard locations) and accessing the functions you stored therein. You may as well assign your favorite individual functions to almost any location on the keyboard. Actually, you can design your very own *WP 43S* user interface.

<sup>27</sup> Navigating in 'CATALOG, AIM is set as explained in the *OM*. So you may as well use the alphabetic searching method known from *WP 34S catalogs*, but the matching *item* will be displayed together with its up to 17 successors if applicable. See next chapter.

## Accessing Cataloged Items Rapidly

You can browse a *catalog* like any other *menu* just using  $\blacktriangle$  and  $\blacktriangledown$  as explained in previous chapter. In **CNST** and major parts of **CATALOG** (**FCNS**, **MENUS**, **PROGS** RAM or **FLASH**, **CHARS** & **INTL**, and the *submenus* of **VARS**), however, you may reach your target significantly faster taking advantage of the alphabetical access method demonstrated here.

Assume we are looking for the function FS?S, for **example**:

1 User input																			
Echo	<b>CATALOG FCNS</b> <i>Your WP 43S displays the first view in this catalog</i> <sup>28</sup>																		
	<table border="1"><tr><td>ALL</td><td>AND</td><td>arccos</td><td>arcosh</td><td>arcsin</td><td>arctan</td></tr><tr><td>2COMPL</td><td><math>\sqrt[3]{x}</math></td><td>ABS</td><td><math>ac \rightarrow m^2</math></td><td><math>ac_{us} \rightarrow m^2</math></td><td>AGM</td></tr><tr><td><math>^{\circ}C \rightarrow ^{\circ}F</math></td><td><math>^{\circ}F \rightarrow ^{\circ}C</math></td><td><math>10^x</math></td><td>1COMPL</td><td><math>1/x</math></td><td><math>2^x</math></td></tr></table>	ALL	AND	arccos	arcosh	arcsin	arctan	2COMPL	$\sqrt[3]{x}$	ABS	$ac \rightarrow m^2$	$ac_{us} \rightarrow m^2$	AGM	$^{\circ}C \rightarrow ^{\circ}F$	$^{\circ}F \rightarrow ^{\circ}C$	$10^x$	1COMPL	$1/x$	$2^x$
ALL	AND	arccos	arcosh	arcsin	arctan														
2COMPL	$\sqrt[3]{x}$	ABS	$ac \rightarrow m^2$	$ac_{us} \rightarrow m^2$	AGM														
$^{\circ}C \rightarrow ^{\circ}F$	$^{\circ}F \rightarrow ^{\circ}C$	$10^x$	1COMPL	$1/x$	$2^x$														
2 User input	First character of the <i>item</i> desired (e.g. <b>F</b> )																		
Echo	<i>Your WP 43S displays a view starting with the first item starting with this character</i> <sup>29</sup>																		

<sup>28</sup> ... unless you visited the same *catalog* before – then it will open showing the last view you looked at. The remaining procedure will stay unchanged though.

<sup>29</sup> This search is case independent (i.e. specifying **A** will find **a** as well). Note, however, that **A** and **a** remain different letters nevertheless. Remember you can also enter Greek letters in such a search using prefix **g**, e.g. **g** + **A** for  $\alpha$  – though watch the sorting order printed at the beginning of the *IOI*. Note the *items* in the *catalog* you search may be displayed at positions in the *menu section* deviating from the ones you see in simple browsing using just  $\blacktriangledown$  or  $\blacktriangle$ .

You may put in more than one character (see overleaf) – though after 3 seconds or after pressing  $\blacktriangledown$  or  $\blacktriangle$ , whatever comes first, the search string will be reset. Then you may continue browsing using  $\blacktriangledown$  or  $\blacktriangle$  or start a new search by entering a new first character.

If a character or sequence specified is not found then the first *item* following alphabetically will be shown – see the sorting order in the *IOI*. If there is no such *item*, then the last *item* in this *catalog* will be displayed.

				e.g.
FP	FP?	F <sub>p</sub> (x)	FS?	FS?C
FF	FIB	FILL	FIX	FLASH?
FAST	FB	FC?	FC?C	FC?F

### 3 User input

Second character of the *item* desired  
(e.g. **S**)

Echo

Your WP 43S displays a view starting with the first *item* starting with this sequence

$g_d$	$g_d^{-1}$	Geom	Geom <sub>e</sub>	Geom <sub>p</sub>	Geom <sup>-1</sup>
$F(x)$	$F^{-1}(p)$	$f'(x)$	$f''(x)$	GAP	GCD
FS?	FS?C	FS?F	FS?S	$F_p(x)$	$F_p(x)$

## 4 User input

Press the corresponding softkey

e.g. for **FS?S**

## Echo

Your *WP 43S*  
executes or inserts the command, recalls the  
constant, or inserts the letter selected.

## Result

(in this example after specifying the *flag* number):

true

1

At the bottom line, this means that ...

- any function provided can be called by **f CATALOG FCNS** + 4 keystrokes maximum if you know its first two characters (i.e. ≤ 7 keystrokes for any function out of more than 750);
  - any constant provided can be recalled by **g CNST** + 3 keystrokes maximum if you know its first character;
  - any letter provided can be inserted by **f CATALOG CHARS & INTL** (or in AIM by **g (+)**) + 3 keystrokes maximum.

## Further Menus and Their Contents

In the table below, all the *menus* provided for you beyond CATALOG are listed in alphabetical sorting order. For each *menu view*, the row of unshifted *softkeys* is listed first, then the **f**-shifted, then the **g**-shifted, following reading habits. Note, however, that on the screen of your *WP 43S* the order of these three rows is reverted with the unshifted row of each *menu view* displayed at the bottom (see the pictures above).

Different *views* within one *menu* are separated by a dashed line, *submenus* by a double line.

Menu							Remarks
<b>ADV:</b>	SOLVE	SLVQ	$f'(x)$	$\Pi_n$	$\Sigma_n$	$\int f dx$	advanced operations, see Sect. 4 of the OM
			$f''(x)$				
$\int f dx$ :			ACC	$\downarrow$ Lim	$\uparrow$ Lim	$\int$	
<b>BITS:</b>	AND	OR	XOR	NOT	MASKL	MASKR	contains all the Boole's and bit operations (first two views) and settings (third view) of <i>HP-16C</i> and <i>WP 34S</i>
	NAND	NOR	XNOR		MIRROR	ASR	
	SB	BS?	#B	FB	BC?	CB	
	SL	RL	RLC	RRC	RR	SR	
	LJ					RJ	
	1COMPL	2COMPL	UNSIGN	SIGNMT	LZON	WSIZE	
					LZOFF		
<b>CLK:</b>	DATE	$\rightarrow$ DATE	DATE $\rightarrow$	WDAY	TIME	$x \rightarrow$ DATE	date and time functions (first view) and settings (2 <sup>nd</sup> view)
	J $\rightarrow$ D	D $\rightarrow$ J		DAY	MONTH	YEAR	
	SETTIM	TDISP	SETDAT	D.MY	Y.MD	M.DY	
	CLK12	CLK24				J/G	
<b>CLR:</b>	CL $\Sigma$	CLP	CF	CLMENU	CLCVAR	CLX	almost as in <i>HP-42S</i>
	CLREGS	CLPall	CLFall		CLLCD	CLSTK	
	CLall					RESET	

Menu							Remarks
CNST:							catalog of constants, see pp. 128ff
CPX:	dot	cross	UNITV	Re	conj	Re $\times$ Im	special complex functions and settings
			sign	Im	x	$\neq$	
	CPXi	CPXj			POLAR	RECT	
DISP:	FIX	SCI	ENG	ALL	ROUNDI	ROUND	display rounding and shifts, formats and settings, mostly for reals
	SDL	SDR			RDP	RSD	
	SCIOVR	ENGOVR	MULT $\times$	MULT $\cdot$	RDX.	RDX,	
	GAP					DSTACK	
	CHINA	EUROPE	INDIA	JAPAN	UK	USA	
EQN:	NEW	EDIT	f''	f'	f $\int$	Solver	equations (see the OM, Sect. 4)
	DELETE						
Solver:							show the names of all variables of the current equation and more
f $\int$ :							
f':							
f'':							
EQ.EDI	$\leftarrow$	( )	$\wedge$	:	=	$\rightarrow$	Equation Editor
EXP:	$x^3$	$\sqrt[3]{y}$	$\log_{x}y$	lb x	$2^x$	$x^2$	exponential, logarithmic, and hyperbolic functions
	$\sqrt[3]{x}$			$\ln 1+x$	$e^x-1$		
	sinh	arsinh	cosh	arcosh	tanh	artanh	
FIN:	%	%MRR	%T	% $\Sigma$	%+MG	TVM	financial functions (see the OM, Section 5)
TVM:	n <sub>PER</sub>	i%/a	per/a	PV	PMT	FV	
	Begin					End	
FLAGS:	SF	FS?	FF	STATUS	FC?	CF	
	FS?S	FS?C	FS?F	FC?F	FC?S	FC?C	
						CLFall	

Menu							Remarks
INFO:	SSIZE?	MEM?	RM?	SMODE?	WSIZE?	KTYP?	system information
	LocR?	FLASH?	ULP?	NEIGHB	SDIGS?	BATT?	
	WHO?	VERS?	DIM?	$\pm\infty$ ?	$\alpha$ POS?	$\alpha$ LENG?	
INTS:	A	B	C	D	E	F	digits for <i>short integers</i> with bases >10, integer operations
	IDIV	RMD	MOD	$\times$ MOD	FLOOR	LCM	
	DBL /	DBLR	DBL $\times$	$\wedge$ MOD	CEIL	GCD	
I/O:	BEEP	LOAD	LOADP	LOADR	LOADSS	LOADΣ	data exchange incl. the PRINT commands of HP-42S
	QUIET	TONE			RECV	SEND	
	ADV	CHAR	DLAY	LCD	MODE	PROG	
	r	REGS	STK	TAB	USER	WIDTH	
	Σ	#					
LOOP:	DSE	DSZ	DSL	ISE	ISZ	ISG	
	DEC					INC	
MATX:	NEW	[M] $^{-1}$	M	[M] $^T$	SIM EQ	EDIT	matrix operations (almost as in HP-42S)
	dot	cross	UNITY	DIM	INDEX	EDITN	
	ENORM		STOEL	RCLEL	PUTM	GETM	
	I+	I-	STOIJ	RCLIJ	J-	J+	
	RSUM	RNORM	M.LU	DIM?		R $\leftrightarrow$ R	
	EIGVAL					EIGVEC	
M.EDIT:	$\leftarrow$	$\uparrow$	OLD	GOTO	$\downarrow$	$\rightarrow$	Matrix Editor as in HP-42S
	INSR		DELR		WRAP	GROW	
M.SIMQ:	Mat A	Mat B				Mat X	solver for systems of linear equations
MODE:	DEG	RAD	GRAD	MUL $\pi$	RECT	POLAR	mode settings (top six almost as in HP-42S), second view for <i>short integers</i>
	FAST	SLOW	RM	QUIET	REALRE	CPXRES	
	DENMAX	DENANY	DENFAC	DENFIX	SSIZE4	SSIZE8	
	1COMPL	2COMPL	UNSIGN	SIGNMT	LZON	WSIZE	
	SETSIG				LZOFF		

Menu							Remarks
MyMenu:							will show up outside of AIM <sup>30</sup>
My $\alpha$ :							will show up in AIM <sup>30</sup>
PARTS:	IP ROUNDI	FP ROUND	MANT	EXPT	sign $ x $	DECOMP $\text{Re}$	some overlaps with HP-42S CONVERT $\text{Im}$
PROB:	Norml: LgNrm: NBin: RAN#	t: Cauch: NBin: SEED	$C_{yx}$ Expon: Geom: Hyper:	$P_{yx}$ Logis: Hyper: Binom:	F: Logis: Binom: $\Gamma(x)$	$\chi^2$ : Weibl: Poiss: $\Gamma^{-1}(x)$	15 probability distributions. Selecting one (e.g. Binom) opens a submenu featuring entries for its PDF (or PMF), CDF, error probability, and quantile function
	Binom: Cauch: Expon: F: Geom: Hyper: LgNrm: Logis: NBin: Norml: Poiss: t: Weibl: $\chi^2$ :	Binom <sub>p</sub> Cauch <sub>p</sub> Expon <sub>p</sub> F <sub>p</sub> (x) Geom <sub>p</sub> Hyper <sub>p</sub> LgNrm <sub>p</sub> Logis <sub>p</sub> NBin <sub>p</sub> Norml <sub>p</sub> Poiss <sub>p</sub> t <sub>p</sub> (x) Weibl <sub>p</sub> $\chi^2_p(x)$	Binom Cauch Geom Hyper Binom Cauch <sub>e</sub> Expon <sub>e</sub> F <sub>e</sub> (x) Geom <sub>e</sub> Hyper <sub>e</sub> LgNrm <sub>e</sub> Logis <sub>e</sub> NBin <sub>e</sub> Norml <sub>e</sub> Poiss <sub>e</sub> $t_e(x)$ Weibl <sub>e</sub> $\chi^2_e(x)$		Binom <sup>-1</sup> Cauch <sup>-1</sup> Expon <sup>-1</sup> $F^{-1}(p)$ Geom <sup>-1</sup> Hyper <sup>-1</sup> LgNrm <sup>-1</sup> Logis <sup>-1</sup> NBin <sup>-1</sup> Norml <sup>-1</sup> Poiss <sup>-1</sup> $F^{-1}(p)$ Weibl <sup>-1</sup> $(\chi^2)^{-1}$		

<sup>30</sup> ... as long as no other menu is called (see Section 6 of the OM).

Menu							Remarks
P.FN:	INPUT	END	ERR	TICKS	PAUSE	P.FN2	additional programming functions (avoided multi-view here).
	PSTO	PRCL	$\alpha$ OFF	$\alpha$ ON	CONST	PUTK	
	R-CLR	R-COPY	R-SORT	R-SWAP	LocR	PopLR	
P.FN2:	MENU	KEYG	KEYX	CLMENU	EXITall	RTN+1	
	SDL	SDR	MSG	NOP	VARMNU	MVAR	
	BACK	CASE	SKIP	AGRAPH	PIXEL	POINT	
STAT:	$\Sigma+$	$\bar{x}$	S	G	$s_m$	$x^2$	for sample statistics.
	$\Sigma-$	$\bar{x}_w$	$s_w$	$g_w$	$s_{mw}$	SUM	
	CL $\Sigma$	$\bar{x}_G$	$\varepsilon$	$\varepsilon_p$	$\varepsilon_m$	PLOT	
	L.R.	r	$s_{xy}$	$\hat{x}$	$\hat{y}$	$x^2$	for curve fitting and 2d sample statistics.
		$\bar{x}_H$	COV				
		$\bar{x}_{RMS}$					
	LinF	ExpF	LogF	PowerF		BestF	for choosing the fit model(s)
	OrthoF	GaussF	CauchF	ParabF	HypF	RootF	
STK:	$x\hat{x}$	$y\hat{x}$	$z\hat{x}$	$t\hat{x}$	$\hat{x}$	DROPy	stack related operations.
	SSIZE4					SSIZE8	
SUMS:	n	$\Sigma x$	$\Sigma x^2$	$\Sigma xy$	$\Sigma y^2$	$\Sigma y$	all the sums necessary for the statistics above.
		$\Sigma \ln x$	$\Sigma \ln^2 x$	$\Sigma \ln xy$	$\Sigma \ln^2 y$	$\Sigma \ln y$	
	$\Sigma x^2 y$	$\Sigma x \ln y$		$\Sigma \ln y/x$		$\Sigma y \ln x$	
	$\Sigma x^2/y$	$\Sigma^1/x$	$\Sigma^1/x^2$	$\Sigma x/y$	$\Sigma^1/y^2$	$\Sigma^1/y$	
	$\Sigma x^3$	$\Sigma x^4$					
TEST:	$x < ?$	$x \leq ?$	$x = ?$	$x \neq ?$	$x \geq ?$	$x > ?$	binary test commands.
	INT?	EVEN?	ODD?	PRIME?	LEAP?	FP?	
	ENTRY?	KEY?	LBL?	STRI?	CONVG?	TOP?	
	$x =+0?$	$x =-0?$	$x \approx ?$	MATR?	CPX?	REAL?	
	SPEC?	NaN?		M.SQR?		DBL?	

Menu							Remarks
TRI:	sin	arcsin	cos	arccos	tan	arctan	trigonometric & hyperbolic functions (cf. EXP).
	sinh	arsinh	cosh	arcosh	tanh	artanh	
U→:	E:	P:	year→s	F&p:	m:	x:	unit conversions (see pp. 137ff).
	°C→°F	°F→°C	s→year		V:	A:	
	power ratio → dB	dB → power ratio			field ratio → dB	dB → field ratio	
A:	acre → m <sup>2</sup>	m <sup>2</sup> → acre			acre <sub>US</sub> → m <sup>2</sup>	m <sup>2</sup> → acre <sub>US</sub>	units of area
E:	cal→J	J→cal	Btu→J	J→Btu	Wh→J	J→Wh	units of energy
F&p:	lbf→N	N→lbf	bar→Pa	Pa→bar	psi→Pa	Pa→psi	units of force and pressure
	in.Hg → Pa	Pa → in.Hg	torr → Pa	Pa → torr	atm→Pa	Pa→atm	
m:	lb.→kg	kg→lb.	cwt→kg	kg→cwt	oz→kg	kg→oz	units of mass
	stone → kg	kg → stone	short cwt→kg	kg → sh.cwt	tr.oz → kg	kg → tr.oz	
	ton→kg	kg→ton	short ton → kg	kg → short ton	carat → kg	kg → carat	
P:	hp <sub>E</sub> →W	W→hp <sub>E</sub>	hp <sub>UK</sub> →W	W→hp <sub>UK</sub>	hp <sub>M</sub> →W	W→hp <sub>M</sub>	units of power
V:	gl <sub>UK</sub> →m <sup>3</sup>	m <sup>3</sup> →gl <sub>UK</sub>	qt.→m <sup>3</sup>	m <sup>3</sup> →qt.	gl <sub>US</sub> →m <sup>3</sup>	m <sup>3</sup> →gl <sub>US</sub>	units of volume
	floz <sub>UK</sub> → m <sup>3</sup>	m <sup>3</sup> → floz <sub>UK</sub>	barrel → m <sup>3</sup>	m <sup>3</sup> → barrel	floz <sub>US</sub> → m <sup>3</sup>	m <sup>3</sup> → floz <sub>US</sub>	
X:	au→m	m→au	ly→m	m→ly	pc→m	m→pc	units of length
	mi.→m	m→mi.	nmi.→m	m→nmi.	ft.→m	m→ft.	
	in.→m	m→in.			yd.→m	m→yd.	
	fathom → m	m → fathom	point → m	m → point	survey foot <sub>US</sub> → m	m → survey foot <sub>US</sub>	

Menu							Remarks
X.FN:	AGM	B <sub>n</sub>	B <sub>n</sub> *	erf	erfc	Orthog	advanced mathematical functions like Beta, Bessel, etc.
	FIB	g <sub>d</sub>	g <sub>d</sub> <sup>-1</sup>	I <sub>xyz</sub>	IΓ <sub>p</sub>	IΓ <sub>q</sub>	
	J <sub>y</sub> (x)	lnβ	lnΓ	max	min	NEXTP	
	sinc	W <sub>m</sub>	W <sub>p</sub>	W <sup>-1</sup>	β(x,y)	γ <sub>xy</sub>	
Orthog:	Γ <sub>xy</sub>	ζ(x)	(-1) <sup>x</sup>	→DP	→SP		
	H <sub>n</sub>	L <sub>m</sub>	L <sub>ma</sub>	P <sub>n</sub>	T <sub>n</sub>	U <sub>n</sub>	orthogonal polynomials
	H <sub>np</sub>						
αINTL:	Ā ā	Á á	Ă ď	À à	Ä ä	Ã ã	[α] catalog of international letters. <sup>31</sup> All letters except one in this menu will change when case is switched in AIM – note you will see the individual letters displayed in either case only at one time.
	Â â	Å å	Æ æ	Ą ą	Ć ć	Č č	
	Ҫ ҫ	Đ đ	Đ đ	Ē ē	É é	Ě ě	
	È è	Ë ë	Ê ê	È è	Ë ë	Ę ę	
	Ӯ ӹ	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	
	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	Ӣ Ӣ	
	Ӆ ӑ	ӭ ӭ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	
	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	
	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	
	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	Ӯ Ӯ	

<sup>31</sup> See [https://de.wikipedia.org/wiki/Liste\\_lateinischer\\_Alphabete#Erweiterungen](https://de.wikipedia.org/wiki/Liste_lateinischer_Alphabete#Erweiterungen).

Menu							Remarks
<b>αMATH:</b>	<	≤	=	≈	≥	>	[α] for comparison symbols, parentheses, & more mathematical and related symbols. You can reach every character by three keystrokes maximum.
	{	[	(	)	]	}	
	x / . <sup>32</sup>	÷	∫	∞	∞	∞	
	¬	Λ	∨	≠		&	
	✗	✗	⊥	✗	✓	✗	
	✗	✗	✗	✗	✗	✗	
	:=	≈	≡	ε	ℂ	ℝ	
	⊗	⊗	⊕			⊗	
	±	^	T	-1	ℏ		
<b>α.FN:</b>	x→α	αRL	αRR	αSL	αPOS?	α→x	dedicated functions for <i>alpha</i> strings, plus font browser
					αLENG?		
	FBR						
<b>A...Ω:</b>	Α α	Β β	Γ γ	Δ δ	Ε ε	Ζ ζ	[α] Greek letters. The keyboard grants direct access to 24 of them. <sup>33</sup>
	Η η	Θ θ	Ι ι	Κ κ	Λ λ	Μ μ	
	Ν ν	Ξ ξ	Ο ο	Π π	Ρ ρ	Σ σ	
	Ϛ	Ͳ τ	Ƴ ӯ	Փ Փ	Ҳ Ҳ	Ѱ Ѱ	
	Ω ω	ά	έ	ή	í	ť	Note the two kinds of lowercase Σ. See αINTL for more.
	Ϊ ī	ó	ú	ÿ ü	ö	ó	

<sup>32</sup> With startup default settings, the multiplication dot is found here and the multiplication cross is called via in AIM. If MULT· is set, however, this dot is called via in AIM and the multiplication cross via .

<sup>33</sup> The Greek alphabet (sic!) goes alpha, beta, gamma, delta, e-psilon, zeta, eta, theta, iota, kappa, lambda, my, ny, xi, o-micron, pi, rho, sigma, tau, y-psilon, phi, chi, psi, o-mega. Note ancient Greek H, Θ, and Y are pronounced like Finnish ÄÄ, T, and Y – modern Greek Θ like English Th, H and Y both like Finnish I. Finnish Y is pronounced like German Ü or French U. Think of Nils Holgersson's goose Yksi (coming first before Kaksi, Kolme, Neljä, Viisi, and Kuusi for obvious reasons – there is no goose named Seitsemän).

Menu							Remarks
	!	:	;	'	"	@	[α] for punctuation marks and further special characters.
	ı	ż	#	-	~	\	
	\$	€	%	&	£	¥	
	←	↑	▲	▼	→	↑	
	«	»	ø	⌚	•	*	
	✉	✉	✉	✉	✉	✉	
	→DEG	→RAD	→GRAD		→D.MS	→MULπ	angular conversions, cf. pp. 143f.
	DEG→	RAD→	GRAD→		D.MS→	MULπ→	
	D→R	R→D		D→D.MS	D.MS→D		

## Constants

Your WP 43S contains a *catalog* of 80 physical, astronomical, and mathematical constants sorted alphabetically:

G	G₀	Gc	ge	GM⊕	g⊕	
c₁	c₂	e	e_E	Fα	Fδ	
1/2	a	a₀	a_M	a⊕	c	

Names of astronomical and mathematical constants are printed on colored background in the table starting overleaf. Values of physical constants (including their relative standard deviations in *red print* below) are printed on light background if they are exactly defined or almost exactly known – the darker the background, the less precisely the particular value is known.<sup>34</sup>

<sup>34</sup> For most of the physical constants, their precise numeric values (incl. their units) and their relative standard deviations (SD) are from CODATA 2018, copied in May 2019. These are the best values known in the scientific community, agreed on by the national standards institutes worldwide (e.g. by NIST and PTB). Note that all of them feature less than 16 significant digits.

Here are the contents of CNST (printing commas as radix marks for better visibility and multiplication dots for space reasons). Formulas are printed if applicable.

Name	Numeric value and <i>rel. SD</i>	Remarks
$\frac{1}{2} (0)$ <sup>35</sup>	0,5	Trivial but helpful constant for some iterations.
$a$	365,242 5 d ( <i>per definition</i> )	<i>Gregorian year</i>
$a_0$	$5,291\,772\,109\,03 \cdot 10^{-11}$ m $(1 \cdot 10^{-10})$	<i>Bohr radius</i> $a_0 = \alpha / 4\pi R_\infty$
$a_{\text{Moon}}$	$3,844 \cdot 10^8$ m $(1 \cdot 10^{-3})$	Semi-major axis of the Moon's orbit around the earth $\approx 1,3$ <i>light seconds</i> .
$a_{\oplus}$	$1,495\,979 \cdot 10^{11}$ m $(1 \cdot 10^{-6})$	Semi-major axis of the Earth's orbit around the sun. Within the uncertainty stated here, it equals 1 <i>astronomic unit</i> $\approx 499$ <i>light seconds</i> .

*Relative uncertainties* are included in the printed table here though not contained in CNST. These uncertainties are important for determining the precision of results you obtain using the constants given, through the process of '*error propagation*' going back to *C. F. Gauß* (1777 – 1855). This procedure is essential if your results are to be trustworthy – not only in science (remember each and every scientific result shall include the indication of its uncertainty). Please consult suitable reference (e.g. <http://physics.nist.gov/cgi-bin/cuu/Info/Constants/definitions.html> gives a nice introduction). There is simply no way yardstick measurements can yield results accurate to four decimals.

By the way, the terms *resolution*, *precision*, and *accuracy* are confused frequently in measuring. In a nutshell, *resolution* is the least significant digit a measuring instrument indicates. Using this instrument for measuring the same object under identical conditions multiple times, you get an idea about its *repeatability* (or *precision*); this can be no better than its *resolution* but may be significantly worse – a factor of ten or more may be observed easily in real life. *Accuracy* of a measuring instrument, however, can never be better than its *repeatability*.

Since you cannot know anything about a real-life object or process any better than you can measure it, these considerations are of fundamental importance. We recommend watching them – in your very own interest.

<sup>35</sup> The counting numbers in parentheses are to support determination of parameters for CONST – see the *IOI*.

Name	Numeric value and rel. SD	Remarks
$c$ (5)	$2,997\,924\,58 \cdot 10^8 \text{ m/s}$ <i>(exact)</i>	<b>Speed of light in vacuum</b> $\approx 300\,000 \frac{\text{km}}{\text{s}} = 300 \frac{\text{km}}{\text{ms}} = 300 \frac{\text{m}}{\mu\text{s}} = 30 \frac{\text{cm}}{\text{ns}} = 0,3 \frac{\text{mm}}{\text{ps}}$ etc.
$c_1$	$3,741\,771\,852\ldots \cdot 10^{-16} \text{ W m}^2$ <i>(exact)</i>	First radiation constant $c_1 = 2\pi h c^2$
$c_2$	$0,014\,387\,768\,77\ldots \text{ m}\cdot\text{K}$ <i>(exact)</i>	Second radiation constant $c_2 = hc/k$
$e$	$1,602\,176\,634 \cdot 10^{-19} \text{ A s}$ <i>(exact)</i>	<b>Elementary charge</b> $e = \frac{2}{K_J R_K} = \Phi_0 G_0$
$e_E$	$2,718\,281\,828\,459\,045\,2\ldots$	Euler's $e$ .
$F$	$96\,485,332\,12\ldots \text{ A s/mol}$ <i>(exact)</i>	Faraday constant $F = e N_A$
$F_\alpha$	$2,502\,907\,875\,095\,892\,8\ldots$	
$F_\delta$	$4,669\,201\,609\,102\,990\,6\ldots$	Feigenbaum's $\alpha$ and $\delta$
$G$	$6,674\,30 \cdot 10^{-11} \text{ m}^3/\text{kg s}^2$ <i>(2,2 · 10<sup>-5</sup>)</i>	Newtonian constant of gravitation; also known as $\gamma$ from other authors. See $\mathbf{GM}_\oplus$ below for a more precise value.
$G_0$ (15)	$7,748\,091\,729\ldots \cdot 10^{-5} / \Omega$ <i>(exact)</i>	Conductance quantum $G_0 = 2e^2/h = 2/R_K = eK_j$
$G_C$	$0,915\,965\,594\,177\,219\,0\ldots$	Catalan's constant
$g_e$	$-2,002\,319\,304\,362\,56$ <i>(1,7 · 10<sup>-13</sup>)</i>	Landé's electron g-factor

Name	Numeric value and <i>rel. SD</i>	Remarks
$GM_{\oplus}$	$3,986\,004\,418 \cdot 10^{14} \text{ m}^3/\text{s}^2$ $(2,0 \cdot 10^{-9})$	Newtonian constant of gravitation times the Earth's mass with its atmosphere included (according to WGS84 <sup>36</sup> )
$g_{\oplus}$	$9,806\,65 \text{ m/s}^2$ ( <i>per def.</i> )	Standard earth acceleration
$\hbar$ (20)	$6,626\,070\,15 \cdot 10^{-34} \text{ J s}$ <i>(exact)</i>	<b>Planck constant</b>
$\hbar$	$1,054\,571\,817 \dots \cdot 10^{-34} \text{ J s}$ <i>(exact)</i>	Reduced Planck constant $\hbar = h/2\pi$
$k$	$1,380\,649 \cdot 10^{-23} \text{ J/K}$ <i>(exact)</i>	<b>Boltzmann constant</b> $k = R/N_A$
$K_J$	$4,835\,978\,484 \dots \cdot 10^{14} \text{ Hz/V}$ <i>(exact)</i>	<b>Josephson constant</b> $K_J = 2e/h$
$l_{PL}$	$1,616\,255 \cdot 10^{-35} \text{ m}$ $(1,1 \cdot 10^{-5})$	Planck length $l_{PL} = t_{PL}c$
$m_e$ (25)	$9,109\,383\,701\,5 \cdot 10^{-31} \text{ kg}$ $(3,0 \cdot 10^{-10})$	Electron mass $\cong 511,00 \text{ keV}$
$M_{Moon}$	$7,349 \cdot 10^{22} \text{ kg}$ $(5 \cdot 10^{-4})$	Mass of the Moon
$m_n$	$1,674\,927\,498\,04 \cdot 10^{-27} \text{ kg}$ $(5,7 \cdot 10^{-10})$	Neutron mass $\cong 939,57 \text{ MeV}$
$m_p$	$1,672\,621\,923\,69 \cdot 10^{-27} \text{ kg}$ $(3,1 \cdot 10^{-10})$	Proton mass $\cong 938,27 \text{ MeV}$
$m_{PL}$ (30)	$2,176\,435 \cdot 10^{-8} \text{ kg}$ $(1,1 \cdot 10^{-5})$	Planck mass $m_{PL} = \sqrt{\hbar c/G} \approx 22 \mu\text{g}$

<sup>36</sup> See [http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350\\_2.html](http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html)

Name	Numeric value and rel. SD	Remarks
$m_p/m_e$	1 836,152 673 43 $(6,0 \cdot 10^{-11})$	Proton to electron mass ratio
$m_u$	$1,660\,539\,066\,60 \cdot 10^{-27}$ kg $(3,0 \cdot 10^{-10})$	Atomic mass constant = $10^{-3}$ kg/ $N_A$
$m_u c^2$	$1,492\,418\,085\,60 \cdot 10^{-10}$ J $(3,0 \cdot 10^{-10})$	Energy equivalent of the atomic mass constant $\approx 931,49$ MeV
$m_\mu$	$1,883\,531\,627 \cdot 10^{-28}$ kg $(2,2 \cdot 10^{-8})$	Muon mass $\approx 105,66$ MeV
$M_\odot$ (35)	$1,989\,1 \cdot 10^{30}$ kg $(5 \cdot 10^{-5})$	Mass of the Sun
$M_\oplus$	$5,973\,6 \cdot 10^{24}$ kg $(5 \cdot 10^{-5})$	Mass of the Earth. See $GM_\oplus$ above for a more precise value.
$N_A$	$6,022\,140\,76 \cdot 10^{23}$ / mol <i>(exact)</i>	<b>Avogadro's number</b>
NaN	Not a number	See the corresponding entry in <i>Section 5</i> of the OM.
$p_0$	101 325 Pa <i>(per def.)</i>	Standard atmospheric pressure
R (40)	$8,314\,462\,618\dots$ J/mol K <i>(exact)</i>	Molar gas constant
$r_e$	$2,817\,940\,326\,2 \cdot 10^{-15}$ m $(4,5 \cdot 10^{-10})$	Classical electron radius $r_e = \alpha^2 a_0$
$R_K$	$25\,812,807\,45\dots$ Ω <i>(exact)</i>	Von Klitzing constant $R_K = h/e^2$
$R_{\text{Moon}}$	$1,737\,530 \cdot 10^6$ m $(5 \cdot 10^{-7})$	Mean radius of the Moon

Name	Numeric value and rel. SD	Remarks
$R_\infty$	$10\ 973\ 731\ 568\ 160 \text{ m}$ $(1,9 \cdot 10^{-12})$	Rydberg constant $R_\infty = \frac{\alpha^2 m_e c}{2 h}$
$R_\odot$ (45)	$6,96 \cdot 10^8 \text{ m}$ $(5 \cdot 10^{-3})$	Mean radius of the sun
$R_\oplus$	$6,371\ 010 \cdot 10^6 \text{ m}$ $(5 \cdot 10^{-7})$	Mean radius of the Earth
$S_a$	$6,378\ 137\ 0 \cdot 10^6 \text{ m}$ <i>(per definition)</i>	Semi-major axis
$S_b$	$6,356\ 752\ 314\ 2 \cdot 10^6 \text{ m}$ $(1,6 \cdot 10^{-11})$	Semi-minor axis
$Se^2$	$6,694\ 379\ 990\ 14 \cdot 10^{-3}$ $(1,5 \cdot 10^{-12})$	First eccentricity squared
$Se'^2$ (50)	$6,739\ 496\ 742\ 28 \cdot 10^{-3}$ $(1,5 \cdot 10^{-12})$	Second eccentricity squared
$Sf^{-1}$	$298,257\ 223\ 563$ <i>(per def.)</i>	Flattening parameter
$T_0$	$273,15 \text{ K}$ <i>(per definition)</i>	= $0^\circ\text{C}$ , standard temperature
$T_P$	$1,416\ 785 \cdot 10^{32} \text{ K}$ $(1,1 \cdot 10^{-5})$	Planck temperature $T_P = \frac{c^2}{k} \sqrt{\frac{\hbar c}{G}} = \frac{M_P c^2}{k} = \frac{E_P}{k}$
$t_{PL}$	$5,391\ 245 \cdot 10^{-44} \text{ s}$ $(1,1 \cdot 10^{-5})$	Planck time $t_{PL} = l_{PL}/c$
$V_m$ (55)	$0,022\ 413\ 969\ 54 \dots \text{ m}^3/\text{mol}$ <i>(exact)</i>	Molar volume of an ideal gas at standard conditions $V_m = \frac{RT_0}{p_0} \approx 22,4 \text{ l/mol}$

Name	Numeric value and rel. SD	Remarks
$\alpha$	$7,297\,352\,569\,3 \cdot 10^{-3}$ $(1,5 \cdot 10^{-10})$	Fine-structure constant $\alpha = \frac{e^2}{2\varepsilon_0 h c} \approx \frac{1}{137}$
$\gamma$	$6,674\,30 \cdot 10^{-11} \text{ m}^3/\text{kg s}^2$ $(2,2 \cdot 10^{-5})$	Newtonian constant of gravitation; also known as G from other authors. See $\mathbf{GM}_{\oplus}$ below for a more precise value.
$\gamma_{EM}$	0,577 215 664 901 532 9...	Euler-Mascheroni constant
$\gamma_p$ (60)	$2,675\,221\,874\,4 \cdot 10^8 \text{ Hz/T}$ $(4,2 \cdot 10^{-10})$	Proton gyromagnetic ratio $\gamma_p = 4\pi \mu_p / h$
$\varepsilon_0$	$8,854\,187\,812\,8 \cdot 10^{-12} \frac{\text{A s}}{\text{V m}}$ $(1,5 \cdot 10^{-10})$	Vacuum electric permittivity $\varepsilon_0 = 1/\mu_0 c^2$ (note the so-called Coulomb's constant is just $1/4\pi\varepsilon_0 = \mu_0 c^2 / 4\pi = c^2 10^{-7} \frac{\text{V s}}{\text{A m}}$ $\approx 8,987\,55 \cdot 10^9 \text{ V m/A s})$
$\lambda_c$	$2,426\,310\,238\,67 \cdot 10^{-12} \text{ m}$ $(3,0 \cdot 10^{-10})$	Compton wavelengths of the electron $\lambda_c = h/m_e c$ , neutron $\lambda_{cn} = h/m_n c$ , and proton $\lambda_{cp} = h/m_p c$ , respectively
$\lambda_{cn}$	$1,319\,590\,905\,81 \cdot 10^{-15} \text{ m}$ $(5,7 \cdot 10^{-10})$	
$\lambda_{cp}$	$1,321\,409\,855\,39 \cdot 10^{-15} \text{ m}$ $(3,1 \cdot 10^{-10})$	
$\mu_0$ (65)	$1,256\,637\,062\,12 \cdot 10^{-6} \frac{\text{V s}}{\text{A m}}$ $(1,5 \cdot 10^{-10})$	Vacuum magnetic permeability
$\mu_B$	$9,274\,010\,078\,3 \cdot 10^{-24} \text{ J/T}$ $(3,0 \cdot 10^{-10})$	Bohr magneton $\mu_B = e\hbar/2m_e$

Name	Numeric value and rel. SD	Remarks
$\mu_e$	$-9,284\,764\,704\,3 \cdot 10^{-24} \text{ J/T}$ $(3,0 \cdot 10^{-10})$	Electron magnetic moment
$\mu_e/\mu_B$	$-1,001\,159\,652\,181\,28$ $(1,7 \cdot 10^{-13})$	Ratio of electron magnetic moment to Bohr's magneton
$\mu_n$	$-9,662\,365\,1 \cdot 10^{-27} \text{ J/T}$ $(2,4 \cdot 10^{-7})$	Neutron magnetic moment
$\mu_p$ (70)	$1,410\,606\,797\,36 \cdot 10^{-26} \text{ J/T}$ $(4,2 \cdot 10^{-10})$	Proton magnetic moment
$\mu_u$	$5,050\,783\,746\,1 \cdot 10^{-27} \text{ J/T}$ $(3,1 \cdot 10^{-10})$	Nuclear magneton $\mu_u = e\hbar/2m_p$
$\mu_\mu$	$-4,490\,448\,30 \cdot 10^{-26} \text{ J/T}$ $(2,2 \cdot 10^{-8})$	Muon magnetic moment
$\sigma_B$	$5,670\,374\,419 \dots \cdot 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}$ <i>(exact)</i>	Stefan-Boltzmann constant $\sigma_B = \frac{2\pi^5 k^4}{15h^3 c^2}$
$\Phi$	$1,618\,033\,988\,749\,894\,8\dots$	Golden ratio $\Phi = \frac{1}{2}(1 + \sqrt{5})$
$\Phi_0$ (75)	$2,067\,833\,848 \dots \cdot 10^{-15} \text{ V s}$ <i>(exact)</i>	Magnetic flux quantum $\Phi_0 = \frac{h}{2e}$
$\omega$	$7,292\,115 \cdot 10^{-5} \text{ rad/s}$ $(2 \cdot 10^{-8})$	Angular velocity of the Earth according to WGS84 (see footnote 36 on p. 131)
$-\infty$	$-\infty$	Note both are counted as numeric values in your WP 43S.
$\infty$	$\infty$	
<b>xxx</b>	<b>xxx</b>	Auxiliary numeric constants (cf. WP 34S)

Some orders of magnitude found in nature are not stored in CNST. Although they are known with one or two digits precision only they may be helpful nevertheless:

Radius of an atomic nucleus	$\sim 10^{-15}$ m
Radius of an atom <sup>37</sup>	$\sim 10^{-10}$ m
Radius of the observable universe	$\approx 45 \times 10^9$ l.y. $\approx 4.3 \times 10^{26}$ m
Amount of stars in observable universe	$\sim 10^{23}$
Amount of atoms in the Sun	$\sim 10^{57}$
Amount of atoms in observable universe	$\sim 10^{80}$
Baryonic mass in observable universe	$\sim 10^{53}$ kg

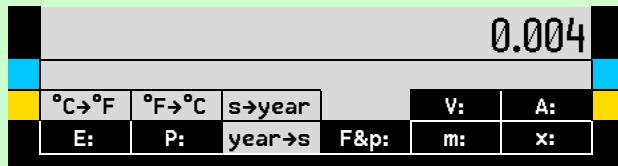
Note these quantities are all well within the range of *SP* numbers on your *WP 43S* (see App. B). Precision of physical constants is seldom better known than twelve digits. Please take these facts into account when assessing small differences as well as talking about very small or very large numbers.

<sup>37</sup> So the nucleus takes far less than a billionth of the volume of an atom. Electrons are even smaller. Thus, an atom is almost completely empty space. Our world as we know and see it every day is built of atoms. Think about it!

By the way, these facts also give some hand-waving arguments why cancer therapy using heavy ion beams works (and significantly better than using X-rays).

## Unit Conversions

Your WP 43S features 14 angular conversions provided in E (see p. 128) and 88 unit conversions in U. The structure of U follows various branches as explained in the OM, Section 5. Its top view looks like this:



with **E:** standing for the *submenu* of energy unit conversions, **P:** for power, **F&p:** for force and pressure, **m:** for mass, **x:** for length, **A:** for area, and **v:** for volume. See pp. 125f for further details of the structure.

Conversions contained in U either begin or end in basic SI units. Beyond them and products or powers of these, knowledge of the following *SI derived units* carrying special names may be helpful in your further calculations and communication:

Quantity	Unit	Symbol and formula
Temperature	degree Celsius	$\theta[\text{°C}] = T[\text{K}] - 273.15$
Force	newton	$1 \text{ N} = 1 \text{ kg m/s}^2$
Pressure	pascal	$1 \text{ Pa} = 1 \text{ N/m}^2 = 1 \frac{\text{kg}}{\text{m s}^2}$
Energy	joule	$1 \text{ J} = 1 \text{ N m} = 1 \text{ kg m}^2/\text{s}^2$
Power	watt	$1 \text{ W} = 1 \text{ V A s} = 1 \frac{\text{J}}{\text{s}}$
Electric potential	volt	$1 \text{ V} = 1 \frac{\text{W}}{\text{A}}$
Charge	coulomb	$1 \text{ C} = 1 \text{ A s}$

Quantity	Unit	Symbol and formula
Capacitance	<i>farad</i>	$1 \text{ F} = 1 \frac{\text{C}}{\text{V}} = 1 \frac{\text{A s}}{\text{V}}$
Conductance	<i>siemens</i>	$1 \text{ S} = 1 \frac{\text{A}}{\text{V}}$
Resistance	<i>ohm</i>	$1 \Omega = 1 \frac{\text{V}}{\text{A}}$
Magnetic flux	<i>weber</i>	$1 \text{ Wb} = 1 \text{ V s}$
Magnetic flux density	<i>tesla</i>	$1 \text{ T} = 1 \frac{\text{Wb}}{\text{m}^2} = 1 \frac{\text{V s}}{\text{m}^2}$
Inductance	<i>henry</i>	$1 \text{ H} = 1 \frac{\text{Wb}}{\text{A}} = 1 \frac{\text{V s}}{\text{A}}$
Frequency	<i>hertz</i>	$1 \text{ Hz} = \frac{1}{\text{s}}$
Absorbed dose	<i>gray</i>	$1 \text{ Gy} = 1 \frac{\text{J}}{\text{kg}}$

For talking about inputs and results, knowing the symbols and names of the SI prefixes as listed here is beneficial:

Prefix symbol	Name	Factor
h	<i>hecto-</i>	$10^2$
k	<i>kilo-</i>	$10^3$
M	<i>mega-</i>	$10^6$
G	<i>giga-</i>	$10^9$
T	<i>tera-</i>	$10^{12}$
P	<i>peta-</i>	$10^{15}$
E	<i>exa-</i>	$10^{18}$

Prefix symbol	Name	Factor
d	<i>deci-</i>	$10^{-1}$
c	<i>centi-</i>	$10^{-2}$
m	<i>milli-</i>	$10^{-3}$
$\mu$	<i>micro-</i>	$10^{-6}$
n	<i>nano-</i>	$10^{-9}$
p	<i>pico-</i>	$10^{-12}$
f	<i>femto-</i>	$10^{-15}$
a	<i>atto-</i>	$10^{-18}$

All conversions featured in **U→** and **←U** are explained in alphabetical order in the following two tables. Therein, numbers are either exact (printed on white background) or generally rounded to six significant digits; they are for your orientation only (your WP 43S uses more precise values). And commas are used as radix marks for better visibility.

Softkey	Calculation	Remarks	Branch
<b>°C→°F</b>	$\times 1,8 + 32$		<b>U→</b>
<b>°F→°C</b>	$- 32 ) / 1,8$		
<b>acre → m<sup>2</sup></b>	$\times 4\,046,86$	These <i>acres</i> are based on the ' <i>international feet</i> ', see below	<b>U→ f A:</b>
<b>acre<sub>us</sub> → m<sup>2</sup></b>	$\times 4\,046,87$	These <i>acres</i> are based on the ' <i>U.S. survey feet</i> ', see below	<b>U→ f V:</b>
<b>atm→Pa</b>	$\times 1,013\,25 \times 10^5$	<i>Atmospheres</i>	<b>U→ F&amp;p:</b>
<b>au→m</b>	$\times 1,495\,98 \times 10^{11}$	<i>Astronomic units</i>	<b>U→ x:</b>
<b>barrel → m<sup>3</sup></b>	$\times 0,158\,987$	<i>Barrel (U.S.)</i> of oil, abbr. <i>bbl</i>	<b>U→ f V:</b>
<b>bar→Pa</b>	$\times 10^5$	1 mbar = 1 hPa	<b>U→ F&amp;p:</b>
<b>Btu→J</b>	$\times 1\,055,06$	<i>British thermal units</i>	<b>U→ E:</b>
<b>cal→J</b>	$\times 4,186\,8$	<i>Calories</i>	
<b>carat → kg</b>	$\times 0,000\,2$		
<b>cwt→kg</b>	$\times 50,802\,4$	( <i>Long</i> ) <i>hundredweight</i> = 112 lbs	<b>U→ m:</b>
<b>dB → field ratio</b>	$10^{R_{dB}/20}$	<i>Decibels</i>	
<b>dB → power ratio</b>	$10^{R_{dB}/10}$		<b>U→ ▼</b>
<b>fathom → m</b>	$\times 1,828\,8$	1 <i>fathom</i> := 6 <i>feet</i>	
<b>ft.→m</b>	$\times 0,304\,8$	The ' <i>international feet</i> ' of 1959 – 1 <i>foot</i> := $1/3$ <i>yard</i>	<b>U→ x:</b>
<b>field ratio→dB</b>	$20 \lg(a_1/a_2)$	Also known as amplitude ratio	<b>U→ ▼</b>

Softkey	Calculation	Remarks	Branch
$\text{floz}_{\text{UK}} \rightarrow \text{m}^3$	$\times 2,841\ 31 \times 10^{-5}$	<i>Fluid ounces</i>	
$\text{floz}_{\text{US}} \rightarrow \text{m}^3$	$\times 2,957\ 35 \times 10^{-5}$		
$\text{gl}_{\text{UK}} \rightarrow \text{m}^3$	$\times 4,546\ 09 \times 10^{-3}$		
$\text{gl}_{\text{US}} \rightarrow \text{m}^3$	$\times 3,785\ 42 \times 10^{-3}$	<i>Gallons</i>	
$\text{hp}_{\text{E}} \rightarrow \text{W}$	$\times 746$	<i>Electric horsepower</i>	
$\text{hp}_{\text{M}} \rightarrow \text{W}$	$\times 735,498\ 8$	'Metric' horsepower (equivalent to PS in German)	
$\text{hp}_{\text{UK}} \rightarrow \text{W}$	$\times 745,699\ 9$	<i>British Imperial horsepower</i>	
$\text{in.} \rightarrow \text{m}$	$\times 0,025\ 4$	$1 \text{ inch} := 1/12 \text{ foot}$ and $1 \text{ inch} := 1\ 000 \text{ mil}$	
$\text{in.Hg} \rightarrow \text{Pa}$	$\times 3\ 386,39$	<i>Inches of mercury</i>	
$\text{J} \rightarrow \text{Btu}$	$/ 1\ 055,06$		
$\text{J} \rightarrow \text{cal}$	$/ 4,186\ 8$	<i>Joule</i>	
$\text{J} \rightarrow \text{Wh}$	$/ 3\ 600$		
$\text{kg} \rightarrow \text{carat}$	$/ 0,000\ 2$		
$\text{kg} \rightarrow \text{cwt}$	$/ 50,802\ 4$		
$\text{kg} \rightarrow \text{oz}$	$/ 0,028\ 349\ 5$		
$\text{kg} \rightarrow \text{lb.}$	$/ 0,453\ 592$		
$\text{kg} \rightarrow \text{sh.cwt}$	$/ 45,359\ 2$		
$\text{kg} \rightarrow \text{short ton}$	$/ 907,185$		
$\text{kg} \rightarrow \text{stone}$	$/ 6,350\ 29$		
$\text{kg} \rightarrow \text{ton}$	$/ 1\ 016,05$		
$\text{kg} \rightarrow \text{tr.oz}$	$/ 0,031\ 103\ 5$		
$\text{lbf} \rightarrow \text{N}$	$\times 4,448\ 22$	<i>Pounds force</i>	
$\text{lb.} \rightarrow \text{kg}$	$\times 0,453\ 592$	<i>Pounds;</i> 1 lb := 16 ounces	

Softkey	Calculation	Remarks	Branch
ly→m	$\times 9,460\ 73 \times 10^{15}$	Light years	
m <sup>2</sup> → acre	/4 046,86	Square meter; 1 a [are] = 100 m <sup>2</sup> , 1 ha [hectare] = 10 000 m <sup>2</sup> , 1 km <sup>2</sup> = 100 ha = 1 000 000 m <sup>2</sup>	
m <sup>2</sup> → acre <sub>us</sub>	/4 046,87		
m <sup>3</sup> → barrel	/0,158 987		
m <sup>3</sup> → floz <sub>UK</sub>	/2,841 31 × 10 <sup>-5</sup>		
m <sup>3</sup> → floz <sub>US</sub>	/2,957 35 × 10 <sup>-5</sup>		
m <sup>3</sup> → gl <sub>UK</sub>	/4,546 09 × 10 <sup>-3</sup>		
m <sup>3</sup> → gl <sub>US</sub>	/3,785 42 × 10 <sup>-3</sup>		
m <sup>3</sup> → qt.	/1,1365 × 10 <sup>-3</sup>		
mi. → m	$\times 1\ 609,344$	1 mile = 1 760 yards	
m → au	/1,495 98 × 10 <sup>11</sup>		
m → fathom	/1,828 8		
m → ft.	/0,304 8		
m → in.	/0,025 4		
m → ly	/9,460 73 × 10 <sup>15</sup>		
m → mi.	/1 609,344		
m → nmi.	/1 852		
m → pc	/3,085 68 × 10 <sup>16</sup>		
m → point	/352,778 × 10 <sup>-6</sup>		
m → survey foot <sub>US</sub>	/0,304 801		
m → yd.	/0,914 4		
nmi. → m	$\times 1\ 852$	Nautical miles	

Softkey	Calculation	Remarks	Branch
N→lbf	/ 4,448 22	Newton	F&p:
oz→kg	× 0,028 349 5	1 ounce := 1/16 pound	m:
Pa→atm	/ 1,013 25×10 <sup>5</sup>		
Pa→bar	/ 10 <sup>5</sup>		
Pa → in.Hg	/ 3 386,39	Pascal; 1 mbar = 1 hPa	F&p:
Pa→psi	/ 6 894,76		
Pa → torr	/ 133,322		
pc→m	× 3,085 68×10 <sup>16</sup>	Parsec	x:
point → m	× 352,778×10 <sup>-6</sup>	(Typographical) point	
power ratio →dB	10 lg(p <sub>1</sub> /p <sub>2</sub> )		▽
psi→Pa	× 6 894,76	Pounds per square inch	F&p:
qt.→m <sup>3</sup>	× 1,1365×10 <sup>-3</sup>	(Imperial) quart	f  V:
short cwt → kg	× 45,359 2	1 short hundredweight = 100 lbs	
short ton → kg	× 907,185	1 short ton = 2 000 lbs	m:
stone → kg	× 6,350 29		
survey foot <sub>us</sub> → m	× 0,304 801	1 U.S. survey foot := $\frac{1200}{3937}$ m	x:
s→year	/ 31 556 952		
ton→kg	× 1 016,05	1 Imperial ton = 200 (long) cwt = 2 240 lbs	m:
torr → Pa	× 133.322	1 torr = 1 mm Hg	F&p:
tr.oz → kg	× 0,031 103 5	Troy ounces	m:
Wh→J	× 3 600	Watt-hours	E:

Softkey	Calculation	Remarks	Branch
$W \rightarrow hp_E$	/746	Watt	
$W \rightarrow hp_M$	/735,498 8		
$W \rightarrow hp_{UK}$	/745,699 9		
$yd \rightarrow m$	$\times 0,914\ 4$	1 yard := 3 feet and 2 yards := 1 fathom	
$year \rightarrow s$	$\times 31\ 556\ 952$	$= 365,242\ 5 \times 24 \times 60^2$	

 ...	Remarks
$DEG \rightarrow$	Takes an integer or real <sup>38</sup> $x$ as an angular input in <i>decimal</i> or <i>sexagesimal degrees</i> , respectively, and converts it to the current ADM.
$D.MS \rightarrow$	
$D.MS \rightarrow D$	Takes an integer or real <sup>38</sup> $x$ as an angular input in <i>sexagesimal degrees</i> (formatted dddd.ddmmsshh) and converts it to an <i>angle</i> in <i>decimal degrees</i> (corresponding to the old command H.MS→H).
$D \rightarrow R$	Takes an integer or real <sup>38</sup> $x$ as an angular ... radians. <sup>39</sup>
$D \rightarrow D.MS$	... sexagesimal degrees (corresponding to the old command H→H.MS ).

<sup>38</sup> If  $x$  is neither integer nor real (i.e. neither *data type* 1, 2, nor 11), error 24 will be thrown. Conversions of integer values to *angles* in *sexagesimal degrees* do not make real sense but are allowed nevertheless.

<sup>39</sup> Note that angles given in *radians* cannot represent full circles (or simple fractions of  $\pi$  like  $\pi/2$ ,  $\pi/4$ ,  $\pi/5$ ,  $\pi/8$ ,  $\pi/10$ , etc.) exactly but with an accuracy of 16 digits “only”. If you want to avoid rounding errors caused by that, *multiples of  $\pi$*  may be a better choice here. This applies especially to large numeric inputs in trigonometric functions since those will be reduced to values between  $-\pi$  and  $+\pi$  before calculating (as mentioned in Section 2 of the OM).

 ...	Remarks
<b>GRAD→</b>	... grad/gon ...
<b>MULπ→</b>	Takes an integer or real <sup>38</sup> $x$ as an angular input in ... ... multiples of $\pi$ ... to the current <b>ADM</b> .
<b>RAD→</b>	... radians <sup>39</sup> ...
<b>R→D</b>	Takes an integer or real <sup>38</sup> $x$ as an angular input in <i>radians</i> and converts it to <i>decimal degrees</i> (equaling the old command R→D). <sup>39</sup>
<b>→DEG</b>	If $x$ is an integer or real ( <i>data type</i> 1, 2, or 11), takes it as an angular input in the current <b>ADM</b> and converts it to <i>decimal degrees, sexagesimal degrees, grad/gon, multiples of π, or radians</i> , respectively.
<b>→D.MS</b>	
<b>→GRAD</b>	
<b>→MULπ</b>	
<b>→RAD</b>	If $x$ is neither of <i>data type</i> 1, 2, 4, nor 11, error 24 will be thrown.

Angular output is tagged always.

## SECTION 3: CALLING AND EXECUTING OPERATIONS

As mentioned at the beginning of *Section 2* and in the *OM*, the number of *items* featured on your *WP 43S* is far too large to fit them on the keyboard. Hence, there are several ways to call such an *item*. You have already learned how to call *items* appearing on the keyboard and in *menus* (including *catalogs*). In *Section 6* of the *OM*, you have seen that you can store *items* in user *menus* and/or assign them to specific locations on your *WP 43S*. In the following you will learn about one more way you can use for calling and executing operations:

- Using **[XEQ]** followed by the name of the operation typed in *AIM*.

Furthermore, we will summarize the functions requiring parameters.

### **Using XEQ for Executing Operations**

Instead of picking an operation from a *menu* or *catalog*, you can also call it by name using **XEQ** as follows:

1. Press **[XEQ]**.
2. Press **[ $\alpha$ ]**. You are in *AIM* thereafter; see *Section 2* of the *OM* for the *virtual keyboard* applying in this mode.
3. Key in the name of the function wanted. Case may be important, subscript or superscript is not.
4. Press **[ENTER $\uparrow$ ]**. Your input will be checked – if the operation specified exists, ...
  - a. it will be checked for required parameters (cf. overleaf);
    - i. if true, you will be prompted for these parameters; then the function will be executed. End.
    - ii. else the function will be executed. End.
  - b. else error 7 (**No such function**) will be thrown (see App. C). End.

## Operations Requiring Trailing Parameters

Many functions require at least one trailing (numeric or alphanumeric) parameter specifying what they shall do precisely (see the OM, Sect. 1). The following three lists summarize these operations:

### Operations requiring one trailing parameter

Operation	Numeric param.	Alpha par.
AGRAPH CONVG? DEC DSE DSL DSZ INC INPUT ISE ISG ISZ KEY? KTYP? PUTK RCL RCLCFG RCLS RCL+ RCL- RCLx RCL/ RCL↑ RCL↓ STO STOCFG STOS STO+ STO- STOx STO/ STO↑ STO↓ t? VIEW x? x=? x≠? x≈? x<? x≤? x≥? x>? y? z? aLEN? aPOS? aRL aRR aSL a→x	Register number	Variable name
ALL ENG FIX GAP RDP RSD SCI SDL SDR	# of decimals	
ASR MASKL MASKR RL RLC RR RRC SL SR WSIZE	Number of bits	
BACK CASE SKIP	# of program steps	
BC? BS? CB FB SB	Bit number	
BestF	Fit model code	
CF FC? FC?C FC?F FC?S FF FS? FS?C FS?F FS?S SF	Flag number	
CONST	Constant number	
DSTACK	# of stack registers	
ERR MSG	Error number	
f'(x) f''(x) GTO LBL LBL? PGMINT PGMSLV XEQ Π <sub>n</sub> Σ <sub>n</sub>		Program label
GTO.	# of program step	Label

### Operations requiring one trailing parameter

Operation	Numeric param.	Alpha par.
INDEX MVAR M.DIM M.EDIN SOLVE VARMNU ∫		Variable name
LocR	# of local registers	
PAUSE ┌DLAY	Number of ticks	
RM ┌MODE	Mode number	
SIM_EQ	# of unknowns	
TDISP	Time format #	
TONE	Tone number	
→INT	Base	
─CHAR	Character code	
─TAB	Column number	
─#	Byte	

Note that for any command XYZ requiring one trailing parameter, you can enter

XYZ → ST.X

and it will take its parameter from X like a good old RPN command instead.

### Operations requiring two trailing parameters

Operation	First parameter	Second parameter
ASSIGN	Item	Sequence of keystrokes
KEYG KEYX	Key number (1 ... 18)	Program label

Operation requiring four trailing parameters	First to fourth parameter
»	Name of stack register

## Operations Changing Data Types

Most functions will return data of the same type they operate on. Some, however, will change the *data type (DT)* of the lowest *stack register(s)* regardless of specific input values, as mentioned at various locations in the OM. These operations are collected in the list here:

Input DT	Operation(s)	Output DT	Output registers involved
1	$1/x$ $\sqrt[3]{x}$ AGM ALL cos ENG erf erfc $e^x$ FIX f' f'' gd gd <sup>-1</sup> IMPFRC $J_y(x)$ LN LNB LNF LOG <sub>10</sub> LOG <sub>2</sub> LOG <sub>x,y</sub> MANT POISS... PROFRC SCI sin tan W <sub>m</sub> W <sub>p</sub> W <sup>-1</sup> $\sqrt{y}$ $\beta(x,y)$ $\Gamma_{xy}$ $\gamma_{xy}$ $\Gamma(x)$ Δ% →REAL % %MRR %T %Σ %+MG $\sqrt{x}$    as well as all unit conversions and all orthogonal polynomials	$2^{40}$	X
	→POL →REC	2	X, Y
	SLVQ	2 or 3	X, Y, Z
	f'(x) f''(x) SOLVE	2	X, Y, Z, T
	all angular conversions	4	X
	→H.MS	5	X
	J→D →DATE	6	X
	x→α	7	X
	M.GET M.NEW	8 or 9	X
	→INT	10	X

<sup>40</sup> The functions printed on yellow background will return *long integers (data type 1)* wherever possible.

Input DT	Operation(s)	Output DT	Output registers involved
2	AND CEIL DATE→ DAY D→J EXPT FLOOR IDIV IDIVR MONTH NAND NEXTP NOR NOT OR ROUNDI SIGN WDAY XNOR XOR YEAR ±∞?	1	X
	DECOMP	1	X, Y
	SLVQ	2 or 3	X, Y, Z
	RE→CX	3	X
	arccos arcsin arctan and all angular conversions	4	X
	→H.MS	5	X
	x→DATE →DATE	6	X
	x→α	7	X
	M.GET M.NEW	8 or 9	X
	→INT	10	X
	→DP	11	X
3	ABS CROSS IM RE  x  4	2	X
	CX→RE	2	X, Y
	SLVQ	2 or 3	X, Y, Z
	→DP	12	X
4	cos sin tan	2	X
5	→HR	2	X
6	DAY D→J MONTH WDAY YEAR	1	X
	DATE→	1	X, Y, Z
	→REAL	2	X

Input DT	Operation(s)	Output DT	Output regis- ters involved
8	M.DIM?	1	X, Y
	DET DOT ENORM $ M $	2	X
	$\Sigma +$	2	X, Y, statistics
	$\sqrt{x}$	4	X
9	M.DIM?	1	X, Y
	ENORM	2	X
	DET DOT $ M $	3	X
	ABS IM RE ROUNDI $ x $	8	X
10	SIGN	1	X
	$e^x$ LN LOG <sub>x</sub> y →REAL	2	X
	$x \rightarrow \alpha$	7	X
11	AND CEIL DATE→ DAY D→J EXPT FLOOR IDIV IDIVR MONTH NEXTP NAND NOR NOT OR ROUNDI SIGN WDAY XNOR XOR YEAR ±∞?	1	X
	DECOMP	1	X, Y
	→SP	2	X
	arccos arcsin arctan	4	X
	→H.MS	5	X
	$x \rightarrow \alpha$	7	X
	→INT	10	X
	RE→CX	12	X
	arccos arcsin arctan →SP	3	X
12	CROSS $ x  \neq$	11	X

## APPENDIX A: HARDWARE

Overall dimensions: wedge-shaped: 77 mm × 144 mm × 13 mm or 8 mm (see p. 152)

Mass with battery: ~100 g

LCD dimensions: about 58.8 mm × 35.3 mm visible area,  
400 × 240 quadratic pixels monochrome

Processor: STMicroelectronics STM32L476 incl. RTC (see <https://www.st.com/en/evaluation-tools/32l476gdiscovery.html> for the development board used by SwissMicros) running at 25 MHz on battery power or 80 MHz connected to USB (see below).

Memory: 1 MB *FM*, 128 kB *RAM* (see App. B on pp. 156ff),  
8 MB additional *FM* on a QSPI chip;  
user *RAM* is some 75 kB, user *FM* is 6 MB.

Power supply: 3 V by one CR2032 coin cell; alternative power supply through USB port; typical average currents drawn for power on and busy: 4.2 mA; idle: 0.1 mA; power off: 3 µA.

Buzzer frequency: ≥ 1 Hz up to > 20 kHz in steps of 1 Hz.

I/O: infrared printer port, standard micro-USB port.

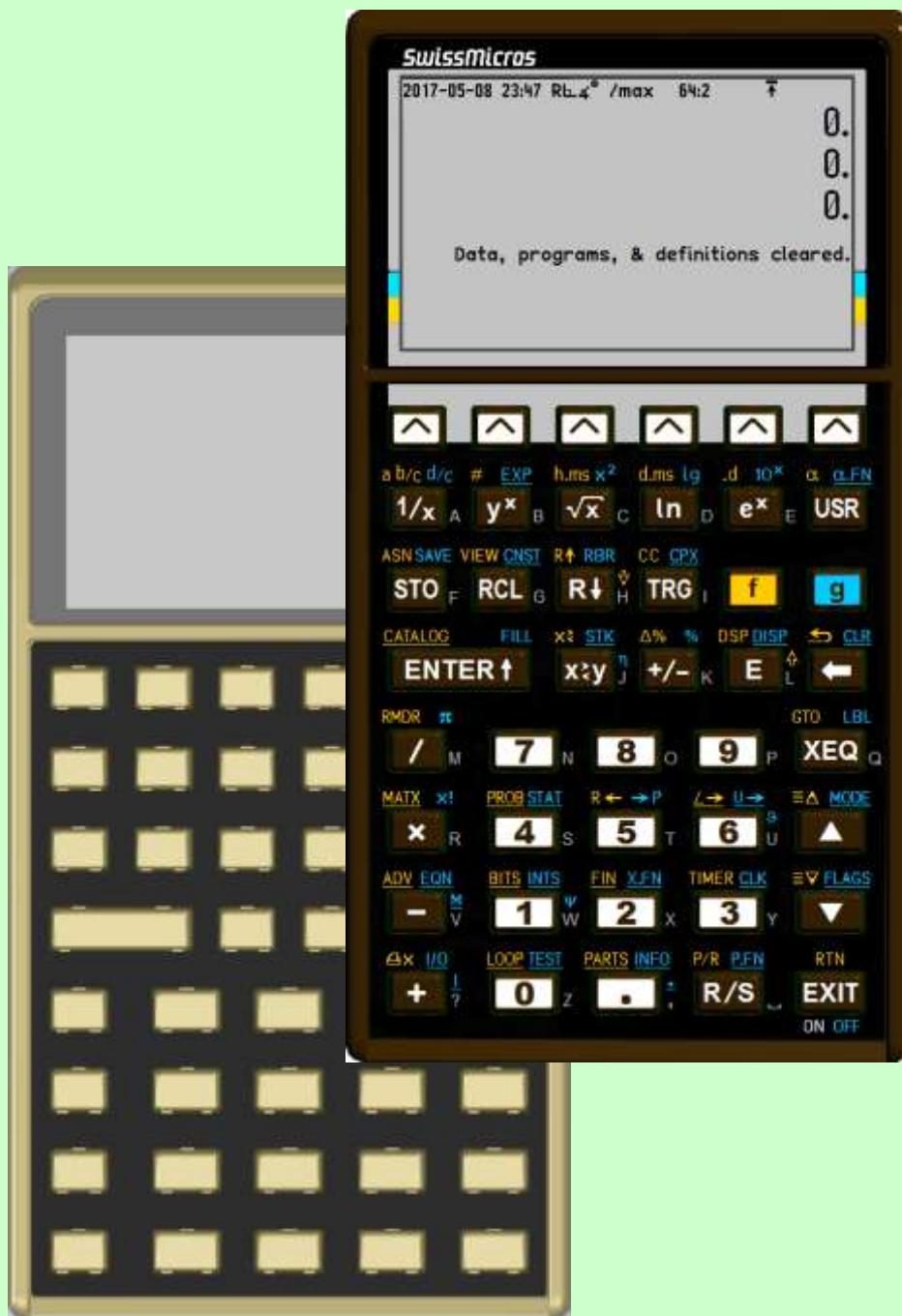
Self-test: initiated by **xxx**

Keyboard overlays: Three short slots on either side of the keyboard are provided in the calculator case for easy fixing overlay sheets with your personal layouts printed on them. See App. F for more.



Six pictures of the hardware are displayed here and on the two pages following. The default keyboard layout as delivered by Swiss-Micros for the DM42 (bottom right) and the front views on next page are printed approximately to scale.







See here the internals, details below. Unfasten two bolts at the top of the calculator backside to get there.

To access the keyboard side of the *PCB* carrying the switching domes, carefully release the *LCD* connection **A**, then unfasten the two Philips bolts **B** pictured left and below. These operations are at your own risk.



Please use the following link to get to a discussion of the various hardware components used on this PCB in February 2018 as pictured above:  
<https://www.hpmuseum.org/forum/thread-10143.html>.

DRAFT

## APPENDIX B: MEMORY MANAGEMENT

### Data Types

There are twelve *data types* you know from *Section 2* of the OM. Some more had to be defined for internal use, e.g.:

- seven-character strings for all kinds of *labels*, also including names of commands and all other *menu items*; this is the reason why such names are confined to 7 characters,
- system integers in the range of  $\pm 2\ 147\ 483\ 648$  (i.e. 32 bits),
- 39-digit reals for internal calculations not exposed to the user,
- *flag* words for storing 128 (i.e. 112 global plus 16 local) user *flags* and the same amount of system *flags*,<sup>41</sup>
- two *data types* for two kinds of *menus*,
- a *data type* of variable length for storing *configurations* (modes and user assignments, see STOCFG and RCLCFG),
- another one for *expressions* in EQN (see *Section 4* of the OM),
- two more for program steps and routines (see *Section 3* of the OM).

A 4-byte *header* is specified for each object of each *data type*:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
pointer to the data															
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
pointer to the variable name				0	0	data information <sup>42</sup>				data type (as specified below) - 1					

<sup>41</sup> Up to 256 flags would be possible.

<sup>42</sup> E.g. base of a *short integer*, angular unit for an *angle*.

Data type number and meaning		Size [bytes]
1	$\mathbb{Z}$ Long integer <sup>43</sup>	$\geq 4 + 2 + 4 = 14 \dots 1030$
2	$\mathbb{R}$ Real number <sup>44</sup>	$4 + 8 = 12$
3	$\mathbb{C}$ Complex number	$4 + 2 \times 8 = 20$
4	Angle <sup>45</sup>	$4 + 8 = 12$
5	Time <sup>46</sup>	$4 + 8 = 12$
6	Date <sup>47</sup>	$4 + 4 = 8$
7	Alpha string (each character requires 16 bits) <sup>48</sup>	$4 + 2 + n \times 2$
8	Real matrix (featuring $n$ rows and $m$ columns)	$4 + n \times m \times 8$
9	Complex matrix (featuring $n$ rows and $m$ columns)	$4 + n \times m \times 16$
10	Short integer <sup>49</sup>	$\leq 4 + 8 = 8 \text{ or } 12$
11	Double precision real number	$4 + 2 \times 8 = 20$
12	Double precision complex number	$4 + 2 \times 16 = 36$
13	Double precision angle	$4 + 2 \times 8 = 20$

<sup>43</sup> This *data type* is for number theory kind of problems. 2 *bytes* are for the size (in *bits*) of the integer following. 4 *bytes* allow for signed integers up to  $2^{31} \approx 2 \times 10^9$ , 8 *bytes* for  $2^{63} \approx 9 \times 10^{18}$ . Size is increased in steps of 4 *bytes* if required (look up the display limits further below). Maximum integer size is 8192 *bits* (= 1024 *bytes*) equivalent to 2466 decimal digits.

<sup>44</sup> As in the WP 34S, standard SP reals feature 64 *bits* and 16 digits precision. See the chapter after next.

<sup>45</sup> A tagged *angle* is stored as a real number, just with a specific header.

<sup>46</sup> A *time* or time interval is stored as a real number of *seconds* internally, just with a specific header. A day corresponds to 86 400 s, a year to 31 556 952 s.

<sup>47</sup> A *date* is stored as its Julian day number internally. Four *bytes* do for  $>10^7$  years.

<sup>48</sup> 2 *bytes* are for the size (in *bytes*) of the string following, including the trailing zero. The size must be even.

<sup>49</sup> This *data type* is for computer science problems. Most probably, such a storage space will be either 4 + 4 or 4 + 8 *bytes* long.

Data type number and meaning		Size [bytes]
14	Double precision mathematical constant	$4 + 2 \times 8 =$ 20
15	Extended precision real (for internal use only)	36
16	<i>Label</i> (each character requires 16 bits)	$4 + 7 \times 2 =$ 18
17	System integer (for internal use only)	$4 + 4 =$ 8
18	System and user <i>flags</i> (128 <i>flags</i> each)	$4 + 2 =$ 6
19	User-created <i>menu</i> (limited to 1 view)	$4 + 18 \times 7 \times 2 =$ 256
20	Predefined <i>menu</i> (featuring <i>n</i> views)	$4 + n \times 18 \times 14$
21	<i>Configuration</i> (as stored by STOCFG) <sup>50</sup>	$4 + M$
22	Program step, may be stored as <i>alpha string</i> (7) <sup>51</sup>	$4 + M$
23	Program, containing <i>n</i> program steps	$4 + M$
24	<i>Expression</i> (for members of EQN), may be stored as <i>alpha string</i> (7)	$4 + M$
25	Directory (proposed by P. 2012-12)	$4 + M$
26		

Data types 7 - 9 and 20ff are of ‘infinite’ size limited by available memory (M) only. Individual size of each object is fixed though.

As mentioned above, any object of any *data type* will take one storage space only: one *register* or one variable. In consequence, *register* lengths in your WP 43S may vary considerably. You do not have to bother – the operating system of your WP 43S will take care of all the necessary administration. Thus, the amount of *RAM* required for data storage is not fixed. Data and programs allocate their memory from the same large pool.

<sup>50</sup> The size will vary according to the number of user assignments being part of the configuration (see Section 6 of the OM).

<sup>51</sup> The size will vary depending on parameters. Exact limits and methods are not decided yet.

## Statistical Summation Registers

Your *WP 43S* features a block of 23 special *registers* for storing statistical sums (like the *WP 34S* and *WP 31S* had 14 before). These statistical *registers* neither overlap nor interfere with any general purpose *registers* unlike they did on *HP's* pocket calculators. The contents of these *registers* can be recalled using their names; please see pp. 59 and 93f.

And like on our calculators before, this block of *registers* is allocated from the pool of free memory available as soon as the first statistical data are entered via **[Σ+]** or **[Σ-]**; it is de-allocated and the memory is returned to the pool by **[CLΣ]**.

## Range of Standard (SP) Real Numbers

Your *WP 43S* can calculate with reals of more than 750 orders of magnitude. Floating point numbers within  $10^{-383} \leq |x| < 10^{+385}$  may be entered directly easily.

Within this range, your *WP 43S* calculates with 16 digits precision (thus, it can display up to 16 digits in *startup default* display format). Results should be accurate within  $\pm 1 \times 10^{-15}$  (e.g. **n** **1/x** **2n** **x**) returns a plain 2 for all primes  $< 500$  – just **7** **1/x** **1** **4** **x** returns  $2 + 1 \times 10^{-15}$ ; the same results for 79 and 89, and for 97 a  $2 - 1 \times 10^{-15}$  is returned). Results  $|x| < 10^{-398}$  are set to zero. For results  $|x| \geq 10^{+385}$ , error 4 or 5 will appear unless *flag D* is set (see App. C).

All these effects are caused by the **internal representation of reals**: *Standard floating point numbers* are stored in eight bytes using an internal format as follows:

- Real zero is stored as integer zero, i.e. all bits cleared.
- The mantissa of a real number (also known as *significand* in this context) is encoded in five groups of three digits. Each such group is packed into 10 bits straight forward, meaning e.g.  $555_{10} = 10\ 0010\ 1100_2$  or  $999_{10} = 11\ 1110\ 0111_2 = 3E7_{16}$ . So the 15 rightmost decimal digits of the *significand* take the least

significant 50 bits. Trailing zeroes are omitted, so the *significand* will be right adjusted.

- The most significant (64<sup>th</sup>) bit takes the sign of the mantissa.
- The remaining 13 bits are used for the exponent and the leftmost digit of the mantissa. Of those 13, the lowest 8 are reserved for the exponent. For the top 5 bits it becomes complicated.<sup>52</sup> If they read
  - 00ttt, 01ttt, or 10ttt then ttt takes the leftmost digit of the *significand* ( $0 - 7_{10}$ ), and the top two bits will be the most significant bits of the exponent;
  - 11uut then t will be added to 1000<sub>2</sub> and the result ( $8_{10}$  or  $9_{10}$ ) will become the leftmost digit of the *significand*. If uu reads 00, 01, or 10 then these two will be the most significant bits of the exponent. If uu reads 11 instead, there are codes left for encoding special numbers (e.g. infinities).

In total, we get 16 digits for the mantissa and a bit less than 10 bits for the exponent: its maximum is 10 1111 1111<sub>2</sub> (i.e.  $767_{10}$ ). For reasons becoming obvious below, 398 must be subtracted from the value in this field to get the true exponent of the number represented. The 16 digits of the *significand* allow for a range from 1 to almost  $10^{16}$ .

Rewarding your patience so far, we will show you some illustrative **examples** of the encoding in your WP 43S instead of telling you more theory:

Floating point number	Hexadecimal value stored	Bottom bits in groups of 10	Top 14 bits in binary representation	Stored exponent
1.	22 38 00 00 00 00 00 01		0010 0010 0011 10	398
-1.	A2 38 00 00 00 00 00 01		1010 0010 0011 10	398
111.	22 38 00 00 00 00 00 6F	06F	0010 0010 0011 10	398

<sup>52</sup> Don't blame us – this part follows the standard IEEE 754.

Floating point number	Hexadecimal value stored	Bottom bits in groups of 10	Top 14 bits in binary representation	Stored exponent
111.111	22 2C 00 00 00 01 bC 6F	06F 06F	0010 0010 0010 11	395
-123.000123	A2 20 00 00 07 b0 00 7b	07b 000 07b	1010 0010 0010 00	392
$9.99 \times 10^{99}$	23 bc 00 00 00 00 03 E7	3E7	0010 0011 1011 11	495
$1 \times 10^{-99}$	20 AC 00 00 00 00 00 01		0010 0000 1010 11	299
$1 \times 10^{-383}$	00 3C 00 00 00 00 00 01		0000 0000 0011 11	15
0.000 000 $000 01 \times 10^{-383}$	00 04 00 00 00 00 00 01		0000 0000 0001 00	4

This last number is the smallest that can be entered directly from the keyboard. Dividing it by  $10^4$  results in  $1 \times 10^{-398}$ , being stored as hexadecimal 1. Divide this by 1.999 999 999 99 and the result will remain  $1 \times 10^{-398}$  in default rounding mode (and in RM 1, 2, 3, and 5, see the command RM). Divide it by 2 instead and the result will become zero.

Let us look at the high end of our numeric range now:

Floating point number	Hexadecimal value stored	Bottom bits in groups of 10	Top 14 bits	Stored exp.
$9.999\ 999\ 999\ 99 \times 10^{384}$	77 FF E7 F9 FE 7F 78 00	9 3E7 3E7 3E7 3dE 000	0111 0111 1111 11	767

This number (featuring 12 times the digit 9) is the maximum which can be keyed in directly. Adding  $9.999 \times 10^{372}$  to it will display  $1 \times 10^{385}$  ...

Floating point number	Hexadecimal value stored	Bottom bits in groups of 10	Top 14 bits	Stored exp.
$1 \times 10^{385}$	77 FF E7 F9 FE 7F 9F E7	9 3E7 3E7 3E7 3E7 3E7	0111 0111 1111 11	767

... being stored as  $9.999\ 999\ 999\ 999\ 999 \times 10^{384}$ . This is the greatest number representable in this format. Thus, the greatest *significand* possible is  $9\ 999\ 999\ 999\ 999\ 999 = 10^{16} - 1$ ;

All this follows *decimal64* floating point format, though not exactly. Additionally, your WP 43S features three ‘special reals’:

Floating point ‘number’	Hexadecimal value stored	Top byte in binary representation
$+\infty$	78 00 00 00 00 00 00 00	0111 1000
$-\infty$	F8 00 00 00 00 00 00 00	1111 1000
NaN	7C 00 00 00 00 00 00 00	0111 1100

An exponent is not applicable here. These ‘three special reals’ may be legal results of your WP 43S if flag D is set – no error will be thrown then. ‘Not a number’ (NaN) covers outputs exceeding real domain or being undefined – see examples in next chapter. Note that  $+\infty$  and  $-\infty$  may be also legal inputs while NaN is not.

## Special Results

The following monadic functions work with  $\infty$  and  $-\infty$ , returning numeric results within real domain (with R lit, i.e. flag I cleared):

Input	Operation(s)	Output
$-\infty$	$\arctan$	$-90^\circ$ or equivalents in other ADM
$-\infty$	$e^x$ , $10^x$ , $2^x$	0.
$-\infty$ or $\infty$	$1/x$ , $\text{sinc}$	0.
$-\infty$ or $\infty$	$x^2$	$\infty$
$\infty$	$\tanh$	1.
$\infty$	$\arctan$	$90^\circ$ or equivalents
$\infty$	$\ln$ , $e^x$ , $\sqrt{x}$ , $\lg$ , $10^x$ , $\text{lb } x$ , $\sinh$ , $\cosh$	$\infty$
0. or 0	$1/x$	$\infty$
0. or 0	$\ln$ , $\lg$ , $\text{lb } x$	$-\infty$
1. or 1	$\text{artanh}$	$\infty$
$-90^\circ \pm n \times 360^\circ$ or equivalents	$\tan$	$-\infty$
$90^\circ \pm n \times 360^\circ$ or equivalents	$\tan$	$+\infty$
...		

The following dyadic functions work alike under these conditions:

$y$	Input $x$	Operation	Output
$\infty$	arbitrary $x \neq -\infty$	$+$	$\infty$ <sup>53</sup>
$-\infty$	arbitrary $x \neq \infty$	$+$	$-\infty$ <sup>53</sup>
$\infty$	arbitrary $x > 0$	$\times$	$\infty$ <sup>53</sup>
$-\infty$	arbitrary $x > 0$	$\times$	$-\infty$ <sup>53</sup>

<sup>53</sup> Swapping  $x$  and  $y$  will return the same result here.

Input		Operation	Output
$y$	$x$		
$\infty$	arbitrary $x < 0$	$\times$	$-\infty^{53}$
$-\infty$	arbitrary $x < 0$	$\times$	$\infty^{53}$
$\infty$	arbitrary $x \neq \infty$	$-$	$\infty^{54}$
$-\infty$	arbitrary $x \neq -\infty$	$-$	$-\infty^{54}$
arbitrary $y > 0$	0. or 0	/	00
arbitrary $y < 0$	0. or 0	/	$-\infty$
$-\infty$	odd $x > 0$	$y^x$	$-\infty$
$-\infty$	even $x > 0$	$y^x$	00
$\infty$	arbitrary $x > 0$	$y^x$	00
0. or 0	$-\infty$	$y^x$	00
0. or 0	$\infty$	$y^x$	0.
arbitrary $y \neq 0$	$-\infty$	$y^x$	0.
arbitrary $y \neq 0$	$\infty$	$y^x$	00

The following functions return **NaN** under these conditions:

Input		Operation(s)	Output
$y$	$x$		
$-\infty$ or $\infty$	0. or 0	$y^x$	NaN
$-\infty$ or $\infty$	$-\infty$ or $\infty$	/	NaN
$-\infty$ or $\infty$	0. or 0	$\times$	NaN <sup>53</sup>
$-\infty$	$\infty$	+	NaN <sup>53</sup>
$-\infty$	$-\infty$	-	NaN
$\infty$	$\infty$		NaN

<sup>54</sup> Swapping  $x$  and  $y$  will return the result times -1.

Input		Operation(s)	Output
$y$	$x$		
0. or 0	0. or 0	$y^x$ , $\sqrt{x}$	NaN
$y < 0$	non-integer $x$	$y^x$ , $\sqrt[3]{y}$	NaN
n/a	$-\infty$ or $\infty$	$\cos$ , $\sin$ , $\tan$ , $\text{arcosh}$ , $\text{arsinh}$ , $\text{artanh}$	NaN
n/a	$ \text{Re}(x)  > 1$	$\text{arccos}$ , $\text{arcsin}$	NaN
n/a	$\text{Re}(x) < 1$	$\text{arcosh}$	NaN
n/a	$\text{Re}(x) \geq 1$	$\text{artanh}$	NaN
n/a	$x < 0$	$\sqrt{x}$ , $\ln$ , $\lg$ , $\text{lb } x$	NaN
$y < 0$	$x > 0$ and even	$\sqrt[3]{y}$	NaN

The functions printed on light red background will return NaN with C lit (i.e. flag I set) as well. The others will change their output when complex results become allowed:

Input	Op.	Output
$-\infty$	$\ln$	$0 + i \times 3.141\ 592\ 653\ 589\ 793 = \infty + i\pi$
$\infty + i \times \pi$	$e^x$	$-\infty + i \times \infty$
$-\infty$	$\lg$	$0 + i \times 1.364\ 376\ 353\ 841\ 841 = \infty + i\pi/\ln(10)$
$-\infty$	$\text{lb } x$	$0 + i \times 1.570\ 796\ 326\ 794\ 896 = \infty + i\pi/2$
$-\infty$	$\sqrt{x}$	$0 + i \times \infty$
$0 + i \times \infty$	$x^2$	$-\infty + i \times 0. - \text{present output: } -\infty + i \times \text{NaN}$

## Calculations with Double Precision (DP) Real Numbers

Your *WP 43S* uses *single precision* (*data type 2*) in real number calculations per default, wherein 16 digit precision is reached in all calculations. Additionally, you may use *double precision* reals (*data type 11*), allowing for 34 digits instead of 16 (see below).

- ☞ Matrix commands will not work with *DP* reals.
- ☞ *DP* allows for more precise calculations. While some computations will reach high accuracy, we do not warrant 34 digit precision in all calculations with *DP* reals.<sup>55</sup>

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<sup>55</sup> Not all functions are expanded to *DP*, some stay in *single precision* or merely a little bit more.

The *WP 43S* software is based on the *decNumber* library supporting arbitrary precision *BCD* numbers. As mentioned at some places in the *IOP*, internal computations are carried out with 39 digits. Actually this is the minimum; some modulo calculations are performed with a few hundreds of digits to avoid cancellation (e.g.  $2\pi$  features 451 digits for proper reduction to the standard range for trigonometric functions).

More elaborate algorithms are coded as *DP* keystroke programs to save flash space (for the cost of execution speed and the loss of a few digits of accuracy in *DP* mode). The internal formats used for storing numbers in your *WP 43S* (as shown just above for *single precision* and below for *DP*) need to be converted back and forth from and to the *decNumber* format. This is a lot of overhead and doesn't come for free in terms of execution speed.

There is a quasi standard to find out about processors and test accuracy of calculators to some extent – compute  $\arcsin\{\arccos[\arctan(\tan\{\cos[\sin(9^\circ)]\})]\}$ . An ideal calculator with an infinite internal precision would return exactly 9 without cheating. Real calculators (all computing with a finite number of digits) deviate. Your *WP 43S* returns

- $9,000\,000\,000\,029\,361 = 9 + 3 \cdot 10^{-11}$  for an *SP* argument and
- $8,999\,999\,999\,999\,999\,999\,999\,999\,999\,937\,535 = 9 - 6,246\,5 \cdot 10^{-29}$  for a *DP* argument.

*WP 34S* and *Free42* concur. If you are interested how other calculators have performed in that test, look at <http://www.rskey.org/~mwsebastian/miscprj/results.htm>.

Another simple test discussed in the internet: Enter 1,000 000 1 and then execute  $x^2$  just 27 times. Your *WP 43S* will return

- 674 530,470 539 687 4 for an *SP* argument and
- 674 530,470 741 084 559 382 689 184 727 772 2 for a *DP* argument.

*DP* reals are stored coarsely following *decimal128* packed coding, though with some exceptions. The lowest 110 bits take the rightmost 33 digits of the *significand*. Going left, a 12 bit exponent field follows, then 5 bits used and coded exactly as in *SP*, and finally the sign bit. The maximum absolute value of the stored exponent is  $10\ 1111\ 1111\ 1111_2 = 12\ 287_{10}$ . For reasons analogous to those explained on pp. 159ff, 6176 must be subtracted from this value to get the true exponent of the floating point number represented. Thus, *data type 11* could support 34-digit numbers within  $10^{-6143} \leq |x| < 10^{+6145}$  (whether such a number range makes sense for real-world problems is questionable, cf. p. 136). Coding works in full analogy to the way described for *SP* in previous chapter.

Even smaller numbers may be entered using a decimal mantissa, but you will lose one digit per factor of 10. The same happens if you divide  $10^{-6143}$  by 10 several times. At  $10^{-6176}$ , only one digit will be left, stored as hexadecimal 1. Divide it by 1.999 999 999 99 and the result will remain  $10^{-6176}$ . Divide it by 2 instead and the result will become zero.

Full 34-digit precision of a *DP* number in **X** may be displayed by SHOW as a *temporary information* in small font. Remember not every such number may be true to 34 digits – cf. p. 166. And errors accumulate as explained in footnote 34.

Returning to *SP* (via →SP) with input exceeding the *SP* number range explained on pp. 159ff will cause 0 or  $\pm\infty$  (or an overflow) being displayed instead.

As mentioned above, some calculations are executed in “*internal high precision*” even for *SP* arguments. “*Internal high precision*” means even more digits than *DP* – it may go up to some hundred digits in special cases.

☞ Rounding mode settings (see RM) may affect results of high precision calculations!

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The latter is the most precise result known of a pocket calculator so far (*WP 34S* and *Free42* concur, computing with 34 digits as well). Nevertheless, “only” the first 25 digits of this output are correct! Calculating with unlimited precision instead returns here 674 530,470 741 084 559 382 689 178 029 746 812 844 4 for the first 40 of the  $10^9$  digits of the complete result.

Please take this information into account when assessing small deviations or many decimals returned by your *WP 34S*.

## **Program Step Size**

Program step size is assumed to be 4 *bytes* typically.

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## APPENDIX C: MESSAGES AND ERROR CODES

There are some commands generating *temporary information* (as specified in Section 2 of the OM), e.g. CORR, DAY, ERR, L.R., MSG, RBR, s, STATUS, VERS, WDAY,  $\bar{x}$ ,  $\hat{x}$ ,  $\hat{y}$ ,  $\Sigma^+$ ,  $\Sigma^-$ ,  $\sigma$ ,  $\rightarrow$ POL,  $\rightarrow$ REC, and the binary test commands.

Furthermore, there are a number of error messages issued by the operating system. Depending on conditions, the following messages will be displayed. They are listed below in alphabetical order (*EC* means *error code*):

	EC	Explanations, countermeasures and examples
An argument exceeds the function domain	1	{1, 2, 3} An argument exceeds the domain of the mathematical function called. May be caused by roots of negative numbers or logs of $x \leq 0$ (unless CPXRES or <i>flag I</i> is set), by $0^0$ , $x/0$ , $0/0$ , $\Gamma(0)$ , $\tan(\pm 90^\circ)$ and equivalents, by $\text{artanh}(x)$ for $ \text{Re}(x)  \geq 1$ , by $\text{arcosh}(x)$ for $\text{Re}(x) < 1$ , etc. <sup>56</sup>
Bad time or date input	2	{2, 6} Invalid date format or incorrect <i>date</i> or time in input, e.g. month > 12, day > 31. Will be thrown as soon as the input is closed.
Cannot delete a predefined item	27	Self-explanatory.
Distribution parameter out of valid range	16	{1, 2, 11} A parameter specified in <b>I</b> , <b>J</b> , or <b>K</b> is out of valid range for the distribution function called (e.g. if LGNRM is called with $j < 0$ ).
Flash memory is full	23	Delete a program from <i>FM</i> to regain space.

<sup>56</sup> Note that e.g.  $\tan(90^\circ)$ , logs of 0, and  $1/0$  are legal operations on {1, 2, 3} if *flag D* is set. See the end of this appendix.

	EC	Explanations, countermeasures and examples
<b>Flash memory is write protected</b>	19	Attempt to edit or delete program steps in <i>FM</i> . See PRCL and PSTO.
<b>Function to be coded for that data type</b>	30	During FW development.
<b>Illegal digit in integer input for this base</b>	9	{10} E.g. 2 in binary or 9 in octal input. Will be thrown as soon as the respective base is entered (i.e. as soon as input is closed).
<b>Illegal input data type for this operation</b>	24	... called. Convert what is necessary. Cf. " <i>operation is undefined in this mode</i> ".
<b>Input is too long</b>	10	Keyboard input is too long for the buffer. (This error is not used currently. Only alpha input is limited presently.)
<b>Invalid or corrupted data</b>	18	Set when there is a checksum error either in <i>FM</i> or as part of a serial download. Also set if a <i>FM</i> segment is otherwise not usable.
<b>Item to be coded</b>	29	During FW development.
<b>I/O error</b>	17	See Section 3 of the OM.
<b>Matrix mismatch</b>	21	{8, 9} <ul style="list-style-type: none"> <li>A matrix isn't square although it should be.</li> <li>Matrix sizes aren't miscible.</li> </ul>
<b>No root found</b>	20	{2} The <i>Solver</i> did not converge.
<b>No such function</b>	7	Returned when calling a nonexistent function via <b>XEQ</b> <b>α</b> ... <b>ENTER↑</b> (check for typos!) or running a routine containing a nonprogrammable command.

	EC	Explanations, countermeasures and examples
No such label found	6	Attempt to address an undefined label.
Operation is undefined in this mode	13	Caused e.g. by calling a real number operation in AIM. Cf. " <i>illegal input data type for this operation</i> ".
Out of range	8	<p>{1, 2, 3}</p> <ul style="list-style-type: none"> <li>A number exceeds the valid range. This can be caused by specifying decimals &gt; 16, <i>word size</i> &gt; 64, negative <i>flag</i> numbers, integers <math>\geq 2^{64}</math>, <i>hours</i> or <i>degrees</i> &gt; 9 000, invalid <i>dates</i> or <i>times</i>, denominators <math>\geq 9\,999</math>, etc.</li> <li>A <i>register</i> or <i>flag</i> address exceeds the valid range of currently allocated <i>registers</i> or <i>flags</i>. May also happen in indirect addressing or when calling nonexistent local addresses.</li> <li>An R-operation (e.g. R-COPY) attempts accessing invalid <i>register</i> addresses.</li> </ul>
Overflow at $+\infty$	4	<p>{1, 2, 3, 8, 9, 11, 12} unless <i>flag D</i> is set</p> <ul style="list-style-type: none"> <li>Division of a number <math>&gt; 0</math> by 0.</li> <li>Divergent sum or product or integral.</li> <li>Positive overflow (see p. 159).</li> </ul>
Overflow at $-\infty$	5	<p>{1, 2, 3, 8, 9, 11, 12} unless <i>flag D</i> is set</p> <ul style="list-style-type: none"> <li>Division of a number <math>&lt; 0</math> by 0.</li> <li>Divergent sum or product or integral.</li> <li>Negative overflow (see p. 159).</li> <li>Logarithm of 0 (note a logarithm of <math>-0</math> returns NaN).</li> </ul>
Please enter a NEW name	26	Trying to define a new variable or user <i>menu</i> with a name already in use.

	EC	Explanations, countermeasures and examples
RAM is full	11	May be caused by attempts to write too large routines, allocate too many variables, and the like (see pp. 156ff for the space required by different <i>data types</i> ). May happen also in program execution due to dynamic allocations (see Sect. 3 of the OM).
Singular matrix	22	{8, 9} <ul style="list-style-type: none"> <li>Attempt to use a LU decomposed matrix for solving a system of equations.</li> <li>Attempt to invert a matrix which isn't of full rank.</li> </ul>
Stack clash	12	STOS or RCLS attempts using <i>registers</i> that would overlap the <i>stack</i> (see Section 1 of the OM). Will happen with e.g. SSIZE8 and STOS 94 .
Too few data points for this statistic	15	{2} A statistical calculation was attempted with too few data, e.g. <i>regression</i> or <i>standard deviation</i> for less than 2 points.
Undefined op-code	3	An instruction with an undefined operation code occurred. Should never happen – but who knows?
Word size is too small	14	{10} Input or <i>register</i> content is too great to be handled by the word size currently set.
	25	Left unused for WP 34S compatibility

If flag **D** is set, errors 4 and 5 will not occur at all, and error 1 will happen less frequently, since  $\pm\infty$  and NaN are legal results then (cf. the corresponding entries in CNST on pp. 128ff and the tables on pp. 162ff). E.g., **0 In** will return  $-\infty$  then.

Each error message will be displayed in second numeric row and is *temporary information* (see Section 2 of the OM). So **C** or **EXIT** will erase it and allow continuation most easily. Any other key pressed will erase the message as well, but will also – if applicable – execute with the *stack* contents present.

## APPENDIX D: EMULATING A WP 43S ON YOUR COMPUTER

Under Windows, you can ...

- a) use **MSYS2 MinGW 64-bit**, a runtime environment for gcc. You get it here (download the latest version): <https://sourceforge.net/projects/mingw-w64/files/External%20binary%20packages%20%28Win64%20hosted%29/MSYS%20%2832-bit%29/>. Install. Then start it. It opens a DOS window. Enter therein:

**cd wp43s** for changing to the proper directory.  
**git pull** for pulling the changed files from gitlab repository.<sup>57</sup>  
**make** for building a new **wp43s.exe**.<sup>58</sup>  
**rm backup.bin** for starting with the simulator reset to default.  
**./wp43s** for starting the simulator.

The simulator window will open (looking like one of the pictures overleaf though larger).

- b) alternatively do the following:

Open the folder

[https://gitlab.com/Over\\_score/wp43s/tree/master/windows%20binaries](https://gitlab.com/Over_score/wp43s/tree/master/windows%20binaries).

Open **README.md** and proceed as described therein.

Eventually run **wp43s.exe**.

The simulator window will open (looking like one of the pictures overleaf though larger).

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<sup>57</sup> Sometimes, this step may terminate with an error due to conflicting local changes. The message reads “Please commit or stash your changes before you merge” (or a bad translation of it into your language). Then enter **git reset --hard** and try again thereafter.

<sup>58</sup> There may be files updated by **git pull** but no new build possible sometimes. Then **make** will throw a corresponding message. – There may be other obstacles; then **make mrproper** will clean the field for a subsequent **make**.

**DRAFT**

(The pictures printed here show an earlier keyboard layout. The landscape window will open if screen resolution does not suffice for portrait display.)

Operate the simulator with the mouse. Digits, **[.**, **[ENTER]**, **[+]**, **[−]**, **[X]**, and **[/]** may also be entered via the numeric keypad directly, **[← Backspace]**, **[XEQ]** via **x**, **[↑]** and **[↓]** via the cursor keys. Further computer keyboard shortcuts to simulator keys are listed in the table printed overleaf.



↑	↑	↑	↑	↑	↑
F1	F2	F3	F4	F5	F6
$1/x$	$y^x$	TRI	In	$e^x$	$\ln$
i	y	t	l	e	q
STO	RCL	R↓	CC	f	g
s	r	Page↓	C	f	g
		$x \geq y$	+/-	E	
		tab	c	E	
				R/S	EXIT
				ctrl	esc

Pressing **h** copies the entire simulator screen image to the clipboard.

Current content of *register L* is shown top left in the simulator window. Instead of the low battery indicator making no sense on a PC application, 'SL' is displayed far right in the *status bar* whenever *automatic stack lift* is enabled (cf. Section 1 of the OM).

xxx



## APPENDIX E: COMPARISON TO THE FUNCTION SETS OF HP-42S, HP-16C, HP-21S, AND WP 34S

In the *IOI*, the corresponding functions of vintage *HP* calculators were mentioned under the respective entry of your *WP 43S*. The tables below revert this in a way. The first table shows the functions of the *HP-42S* and the corresponding ones of your *WP 43S* unless they carry identical names and are either both keyboard accessible or both stored in a *catalog* or *menu*. There is an analog table for *HP-16C* functions starting on p. 184, one for the *HP-21S* on p. 186, and another one for the *WP 34S* on p. 187. Functions newly introduced with *WP* calculators are compiled on pp. 191ff.

**Functional differences of homonymous commands are covered in the *IOI* (on pp. 12ff).**

### **Corresponding Operations on HP-42S**

Remarks printed on light grey indicate commands being either default settings or keyboard accessible on your *WP 43S* while you must use a *menu* on the *HP-42S*.

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
ACOSH	<b>arcosh</b>	In <u>EXP</u>
ADV	<b>■ADV</b>	In <u>I/O</u>
AIP	Dispensable	You can merge text and numeric data easily as described in <i>Section 2</i> of the <i>OM</i> .
ALENG	<b>αLENG</b>	In <u>α.FN</u>
ALLΣ	Dispensable	Your <i>WP 43S</i> runs in ALLΣ mode always. The summation <i>registers</i> do not overlap with general purpose <i>registers</i> .
<b>ALPHA</b>	<b>α</b>	See the description of A/M in Sect. 2 of the <i>OM</i> .

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
AOFF	$\alpha\text{OFF}$	In <u><math>\alpha\text{FN}</math></u>
AON	$\alpha\text{ON}$	
ARCL	Disposable	Any register or variable can take an <i>alpha string</i> . Simply press <b>RCL</b> instead.
AROT	$\alpha\text{RL}$ or $\alpha\text{RR}$	
ASHF	$\alpha\text{SL}$	
ASINH	<b>arsinh</b>	In <u>EXP</u>
ASTO	Disposable	Any register or variable can take an <i>alpha string</i> . Simply press <b>STO</b> instead.
ATANH	<b>artanh</b>	In <u>EXP</u>
ATOX	$\alpha\rightarrow x$	In <u><math>\alpha\text{FN}</math></u>
AVIEW	Disposable	Any register or variable can take an <i>alpha string</i> . Simply press <b>VIEW</b> instead.
<b>BASE</b>	<b>INTS</b> or <b>BITS</b>	
BASE+	Disposable	Your WP 43S executes these arithmetic commands automatically for <i>short integer</i> inputs.
BASE-		
BASE $\times$		
BASE $\div$		
BASE $+\text{-}$		
BINM	Disposable	Press <b># 2</b> for converting any closed integer number or integer part in $x$ to binary.
BIT?	<b>BS?</b>	In <u>BITS</u>
<b>BST</b>	 (  )	Shortcut works if no <i>multi-view menu</i> is open.
CLA	<b>0</b> <b>STO</b> <b>K</b>	
CLD	Disposable	Any keystroke will clear <i>temporary information</i> .
<b>CLEAR</b>	<b>CLR</b>	
CLKEYS	n/a	See <i>Section 6</i> of the OM.
CLRG	<b>CLREGS</b>	In <u>CLR</u>
CLST	<b>CLSTK</b>	Press <b>0</b> <b>FILL</b> in run mode.

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
CLV	See remark	Variables are cleared as specified in <i>Section 6</i> of the OM.
<b>COMPLEX</b>	<b>CC</b>	You can also enter complex numbers directly using <b>CC</b> as explained in <i>Section 2</i> of the OM.
<b>CONVERT</b>	<b>L<math>\leftrightarrow</math></b> & <b>PARTS</b>	
<b>CUSTOM</b>	n/a	You can create as many <i>menus</i> as memory will hold – not only one <b>CUSTOM menu</b> . See <i>Section 6</i> of the OM.
DECM	Disposable	Any input featuring a <b>.</b> or an <b>E</b> is interpreted as a real (decimal) number.
DEL	n/a	Not featured. Too dangerous, in our opinion.
DELAY	<b>DLAY</b>	In <u>I/O</u>
DELR	<b>M.DELR</b>	
DET	<b> M </b>	
DIM	<b>M.DIM</b>	
DIM?	<b>M.DIM?</b>	
EDIT	<b>M.EDI</b>	
EDITN	<b>M.EDIN</b>	
FCSTX	<b><math>\hat{x}</math></b>	
FCSTY	<b><math>\hat{y}</math></b>	
FNRN	<b>ENORM</b>	In <u>MATX</u> . Euclid is older than Frobenius.
GAMMA	<b><math>\Gamma(x)</math></b>	In <u>PROB</u>
GETKEY	<b>KEY?</b>	In <u>P.FN</u>
GETM	<b>M.GET</b>	
GROW	<b>M.GROW</b>	
HEXM	Disposable	Press <b># H</b> for converting any closed integer number or integer part in $x$ to hexadecimal.
H.MS+	Disposable	Your WP 43S executes the respective command automatically for sexagesimal times in $x$ and $y$ when <b>+</b> or <b>-</b> is pressed.
H.MS-		

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
INSR	M.INSR	In <u>MATX</u>
INTEG	∫	In <u>ADV</u>
INVRT	[M] <sup>-1</sup>	In <u>MATX</u>
KEYASN	Disposable	Not needed since no CUSTOM menu is featured (see CUSTOM).
LASTx	RCL L	
LBL		Press <u>LBL</u> .
LCLBL	Disposable	Obsolete since no CUSTOM menu is featured (see CUSTOM). Nevertheless, your WP 43S provides local labels (see Section 3 of the OM).
LINΣ	Disposable	Your WP 43S runs in ALLΣ mode always.
LIST	n/a	Use <u>PROG</u> instead.
LOG	LOG <sub>10</sub>	Press <u>Ig</u> .
MAN	CF T	Manual print mode is <i>startup default</i> here.
MAT?	MATR?	In <u>TEST</u>
MEAN	Ȑ	In <u>STAT</u>
MODES	MODE	
N!	x!	
NEWMAT	M.NEW	In <u>MATX</u>
NORM	n/a	Not featured.
OCTM	Disposable	Press <u>#</u> <u>8</u> for converting any closed integer number or integer part in <i>x</i> to octal.
OLD	M.OLD	In <u>MATX</u>
ON	n/a	Programmable ON is not featured.
PGM.FCN	P.FN	<u>GTO</u> , <u>LBL</u> , <u>RTN</u> , <u>VIEW</u> are on the keyboard.
PI	π	Press <u>Π</u> .
POSA	αPOS	In <u>α.FN</u>
PRA	└r K	In <u>I/O</u>

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
<b>PRGM</b>	<b>P/R</b>	
<b>PRINT</b>	<b>I/O</b>	<b>[x]</b> is on the keyboard.
PRLCD	<b>LCD</b>	In <u>I/O</u>
PROFF	<b>CF [T]</b>	
PROMPT	Disposable	Use <b>VIEW</b> , <b>STOP</b> instead.
PRON	<b>SF [T]</b>	
PRP	<b>PROG</b>	
PRSTK	<b>STK</b>	
PRUSR	<b>USER</b>	
PRV	<b>r</b>	
PRX	<b>r [X]</b>	Press <b>[x]</b> .
PRΣ	<b>Σ</b>	In <u>I/O</u>
PUTM	<b>M.PUT</b>	In <u>MATX</u>
PWRF	<b>PowerF</b>	In <u>STAT</u>
RAN	<b>RAN#</b>	In <u>PROB</u>
RND	<b>ROUND</b>	In <u>PARTS</u>
RNRM	<b>RNORM</b>	In <u>MATX</u>
ROTXY	<b>RL, RLC, RR, and RRC</b>	In <u>BITS</u>
<b>RTN</b>		Press <b>RTN</b> .
SDEV	<b>s</b>	In <u>STAT</u>
SIZE	Disposable	There are 100 global general purpose <i>registers</i> always.
SLOPE	<b>L.R.</b>	In <u>STAT</u>
SOLVE	<b>SLV</b>	In <u>ADV</u>
SQRT	<b>✓</b>	
<b>SST</b>	<b>≡▼ ( ▾ )</b>	Shortcut works if no <i>multi-view menu</i> is open.
STR?	<b>STRI?</b>	In <u>TEST</u>

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
<b>TOP.FCN</b>	Disposable	Obsolete since no top functions are overwritten.
TRACE	SF <b>T</b>	
TRANS	<b>[M]<sup>T</sup></b>	In <u>MATX</u>
UVEC	<b>UNITV</b>	In <u>MATX</u> and <u>CPX</u>
VARMENU	<b>VARMNU</b>	Truncated to 6 characters to fit the <i>menu</i> space.
VIEW		Press <b>VIEW</b> .
WMEAN	<b><math>\bar{x}_w</math></b>	In <u>STAT</u>
WRAP	<b>M.WRAP</b>	In <u>MATX</u>
XTOA	<b><math>x \rightarrow \alpha</math></b>	The conversion is done in X.
X<0?, X<Y?	<b>x&lt; ?</b>	In <u>TEST</u>
X≤0?, X≤Y?	<b>x≤ ?</b>	
X=0?, X=Y?	<b>x= ?</b>	
X≠0?, X≠Y?	<b>x≠ ?</b>	
X≥0?, X≥Y?	<b>x≥ ?</b>	
X>0?, X>Y?	<b>x&gt; ?</b>	
YINT	<b>L.R.</b>	In <u>STAT</u>
<b>y<sup>x</sup></b>		Press <b>y<sup>x</sup></b> .
<b>ΣREG</b>	Disposable	There are 100 global general purpose <i>registers</i> always. Statistical registers are separate.
<b>ΣREG?</b>		
→DEC	<b>→INT 10</b>	Press <b># 1 0</b>
→HR		Press <b>.d</b>
→H.MS		Press <b>h.ms</b> ... for closed input.
→OCT	<b>→INT 8</b>	Press <b># 8</b>
→POL		Press <b>→P</b> .
→REC		Press <b>R↔</b> .
%CH	<b>Δ%</b>	Press <b>Δ%</b> .
<b>÷</b>	<b>/</b>	Cf. ISO 80000-2: "The symbol <b>÷</b> should not be used."

## Corresponding Operations on HP-16C

The table for the functions of the *HP-16C* is sorted following their appearance on its keyboard, starting top left. As for the *HP-42S*, only functions carrying different names on both calculators are listed.

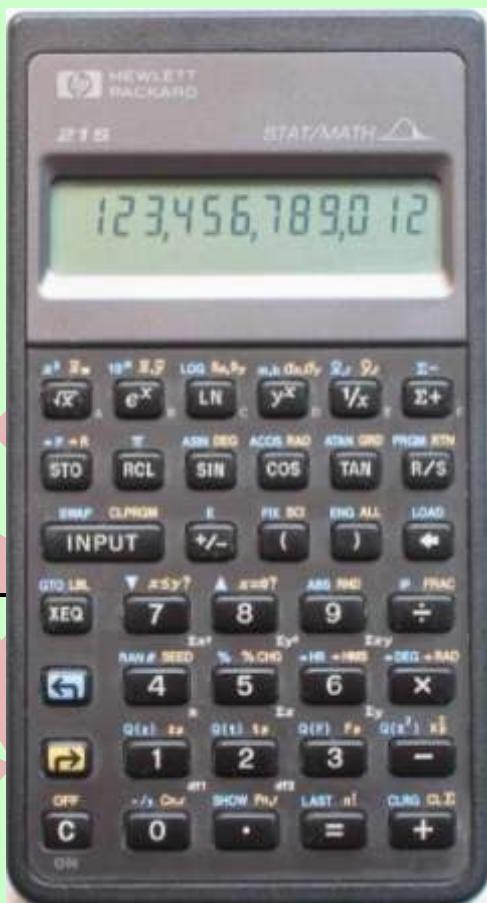
<b>HP-16C</b>	<b>WP 43S</b>	<b>Remarks</b>
<b>RL</b> , <b>RLn</b>	<b>RL</b>	
<b>RR</b> , <b>RRn</b>	<b>RR</b>	
<b>RLC</b> , <b>RLCn</b>	<b>RLC</b>	In <u>BITS</u>
<b>RRC</b> , <b>RRCn</b>	<b>RRC</b>	
<b>÷</b>	<b>/</b>	
<b>DBL÷</b>	<b>DBL/</b>	In <u>INTS</u> (see also ISO 80000-2: "The symbol $\div$ should not be used.")
<b>x<math>\geq</math>(i)</b>		
<b>x<math>\geq</math></b>		Any register may be used for indirection.
<b>SHOW HEX</b>		
<b>SHOW DEC</b>		n/a
<b>SHOW OCT</b>		
<b>SHOW BIN</b>		
<b>B?</b>	<b>BS?</b>	In <u>BITS</u>
<b>GSB</b>	<b>XEQ</b>	
<b>HEX</b>	<b># H</b>	
<b>DEC</b>	<b># D</b>	
<b>OCT</b>	<b># 8</b>	
<b>BIN</b>	<b># 2</b>	
<b>SF 3</b>	<b>LZON</b>	In <u>DISPL.</u> Control display of leading zeros.
<b>CF 3</b>	<b>LZOFF</b>	
<b>SF 4</b> , <b>CF 4</b>	<b>SF C</b> , <b>CF C</b>	Carry. SF and CF live in <u>FLAGS</u> .
<b>SF 5</b> , <b>CF 5</b>	<b>SF B</b> , <b>CF B</b>	Overflow.
<b>F?</b>	<b>FS?</b>	In <u>FLAGS</u>

<b>HP-16C</b>	<b>WP 43S</b>	<b>Remarks</b>
(i)	Disposable	Any register may be used for indirection.
I		
<b>CLEAR PRGM</b>	<b>CLP</b>	In <u>CLR</u> . Note here is also CLPALL.
<b>CLEAR REG</b>	<b>CLREGS</b>	In <u>CLR</u>
<b>CLEAR PREFIX</b>	Disposable	See Section 2 of the OM.
<b>WINDOW</b>	Disposable	64 bits can be displayed in one row.
<b>SET COMPL 1S</b>	<b>1COMPL</b>	In <u>MODE</u> and <u>BITS</u> . Note here is also <u>SIGNMT</u> .
<b>SET COMPL 2S</b>	<b>2COMPL</b>	
<b>SET COMPL UNSGN</b>	<b>UNSIGN</b>	
<b>SST</b>		(▼) works if no multi-view menu is open.
<b>BSP</b>		
<b>BST</b>		(▲) works if no multi-view menu is open.
<b>x≤y</b>	<b>x≤ ?</b>	In <u>TEST</u> . Note far more tests are covered here.
<b>x&lt;0</b>	<b>x&lt; ?</b>	
<b>x&gt;y</b>	<b>x&gt; ?</b>	
<b>x&gt;0</b>		
<b>FLOAT</b>	<b>FIX</b>	In <u>DISP</u>
<b>MEM</b>	<b>STATUS</b>	In <u>FLAGS</u>
<b>CHS</b>		
<b>◀, ▶</b>	Disposable	64 bits can be displayed in one row.
<b>LSTX</b>	<b>RCL L</b>	
<b>x≠y</b>	<b>x≠ ?</b>	In <u>TEST</u> . Note far more tests are covered here.
<b>x≠0</b>		
<b>x=y</b>	<b>x= ?</b>	
<b>x=0</b>		

## Corresponding Operations on HP-21S

The table for the functions of *HP-21S* (starting overleaf) follows the same rules as the one for *HP-16C*. The *HP-21S*, however, is an algebraic calculator; hence its keys **INPUT**, **(**, **)**, and **=** have no direct equivalent on your *WP 43S*.

Consult the *HP-21S OM* for additional information about the four most important continuous statistical distributions and their applications.



<i>HP-21S</i>	<i>WP 43S</i>	Remarks
<b><math>\bar{x}_w</math></b>	$\bar{x}_w$	
<b><math>\bar{x}, \bar{y}</math></b>	$\bar{x}$	
<b><math>S_x, S_y</math></b>	$S$	
<b>m.b</b>	L.R.	In <u>STAT</u>
<b><math>\sigma_x, \sigma_y</math></b>	$\sigma$	
<b><math>\hat{x}, r</math></b>	$r, \hat{x}$	
<b><math>\hat{y}, r</math></b>	$r, \hat{y}$	
<b>PRGM</b>	<b>P/R</b>	
<b>SWAP</b>	$x \leftrightarrow y$	
<b>CLPRGM</b>	<b>CLP</b>	In <u>CLR</u>
<b>LOAD</b>	n/a	Loads predefined programs in the <i>HP-21S</i> . Also your <i>WP 43S</i> features a command called LOAD but this recalls data from backup.
<b>ABS</b>	<b> x </b>	
<b>RND</b>	<b>ROUND</b>	In <u>PARTS</u>

HP-21S	WP 43S	Remarks
[FRAC]	FP	
÷	/	Cf. ISO 80000-2: "The symbol ÷ should not be used."
[SEED]	SEED	In PROB
[%CHG]	Δ%	
[Q(z)]	Norm <sub>e</sub>	In submenus of PROB.
[Zp]	Norm <sub>l</sub> <sup>-1</sup>	
[Q(t)]	t <sub>e</sub> (x)	
[tp]	t <sup>-1</sup> (p)	
[Q(F)]	F <sub>e</sub> (x)	
[Fp]	F <sup>-1</sup> (p)	
[Q(x <sup>2</sup> )]	x <sup>2</sup> <sub>e</sub> (x)	
[X <sup>2</sup> p]	(x <sup>2</sup> ) <sup>-1</sup>	
[Cn.r]	COMB	
[Pn.r]	PERM	In PROB
[LAST]	[RCL] L	
[n!]	[x!]	
[CLRG]	CLREGS	In CLR

## Corresponding Operations on WP 34S

The WP 34S and WP 43S share over 90% of their function sets. It was our objective that your WP 43S is equal or better than the WP 34S in every aspect. Most of the discrepancies between both calculators are caused by their different displays. Thus, your WP 43S allows for *softkeys* – the WP 34S can only carry four *hotkeys* instead. Also dealing with matrices is greatly eased by the large high resolution dot matrix display of your WP 43S; thus some elementary matrix commands of the WP 34S are not required anymore on your WP 43S.

Remarks printed on light grey indicate commands being either default settings or obsolete on your *WP 43S* while you must use them on the *WP 34S*.

<i>WP 34S</i>	<i>WP 43S</i>	Remarks
ANGLE	<del>4</del>	
Binom <sub>u</sub>	<del>Binom<sub>e</sub></del>	
Cauch <sub>u</sub>	<del>Cauch<sub>e</sub></del>	
CL $\alpha$	<del>0 [STO] [K]</del>	Check the OM for the conditions when this register is used.
CONST	<del>CNST</del>	For keyboard space reasons.
DBLOFF	Disposable	Your <i>WP 43S</i> features <i>DP data types</i> – it does neither need nor feature a <i>DP mode</i> . Use $\rightarrow$ <i>DP</i> to convert individual data to <i>DP</i> ; use $\rightarrow$ <i>SP</i> to reconvert <i>DP</i> data to <i>SP</i> .
DBLON		
Expon <sub>u</sub>	<del>Expon<sub>e</sub></del>	
F <sub>u</sub> (x)	<del>F<sub>e</sub>(x)</del>	
dRCL	Disposable	Your <i>WP 43S</i> features various <i>data types</i> .
gCLR, gDIM, gDIM?, gFLP, gPIX?, gPLOT, gSET	n/a	The <i>LCD</i> of your <i>WP 43S</i> features $240 \times 400$ px rows compared to $6 \times 43$ px of <i>HP-30b</i> – the graphic paradigm of <i>WP 34S</i> makes no sense on your <i>WP 43S</i> . On the other hand, it was not our objective designing a graphing calculator. Thus, we include just the basic graphic support of the <i>HP-42S</i> (AGRAPH, CLLCD, PIXEL) plus POINT.
Geom <sub>u</sub>	<del>Geom<sub>e</sub></del>	
GTO $\alpha$	Disposable	Use <del>GTO</del> with an appropriate parameter instead.
H.MS+, H.MS-	Disposable	Your <i>WP 43S</i> features a dedicated <i>data type</i> for <i>times</i> , so $+$ and $-$ suffice for adding or subtracting sexagesimal times, respectively.
INTM?	Disposable	Your <i>WP 43S</i> features dedicated <i>data types</i> for integers – it does neither need nor feature an integer mode.

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
iRCL	Disposable	Your WP 43S features various <i>data types</i> .
$I_x$	$I_{xyz}$	This is a triadic function after all.
$Lgnrm_u$	$LgNrm_e$	
$L_n$	$L_m$	Renamed to avoid search conflict with LN.
$L_{na}$	$L_{ma}$	Renamed in consequence to $L_m$ .
Logis <sub>u</sub>	Logis <sub>e</sub>	
MROW+ $\times$ , MROW $\times$	Disposable	Obsolete matrix commands.
MROW $\Leftarrow$	<del>M.R<sub>R</sub>R</del>	
M+ $\times$	Disposable	Obsolete matrix command.
$M^{-1}$	$[M]^{-1}$	
M-ALL, M-COL, M-DIAG, M-ROW	Disposable	Obsolete matrix commands.
M $\times$	Disposable	Your WP 43S features two dedicated <i>data types</i> for matrices. Thus you can simply multiply two matrices using $\times$ and copy matrices like any other objects.
M.COPY		
M.IJ, M.REG	Disposable	Obsolete matrix commands.
nBITS	#B	
nCOL, nROW	Disposable	Obsolete matrix commands.
Norml <sub>u</sub>	Norml <sub>e</sub>	
Poiss <sub>u</sub>	Poiss <sub>e</sub>	
REALM?	Disposable	Your WP 43S features a dedicated <i>data type</i> for reals – it does not need a real mode.
REGS, REGS?	Disposable	The number of global general purpose <i>registers</i> is fixed to 100 on your WP 43S.

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
SENDA, SENDP, SENR, SENDΣ	<b>SEND</b>	SEND combines all those four commands of the WP 34S.
SEPOFF, SEPON	<b>GAP</b>	
SHOW	<b>RBR</b>	
sRCL	Dispensable	Your WP 43S features various <i>data types</i> .
TRANSP	<b>[M]<sup>T</sup></b>	
TSOFF	<b>GAP 0</b>	
TSON	<b>GAP 3</b>	
$t_u(x)$	<b><math>t_e(x)</math></b>	
VIEWa, VWa+	Dispensable	Simply use <b>VIEW</b> instead; <i>alpha strings</i> are just another <i>data type</i> . You can combine text and numeric data easily using <b>+</b> as shown in Sect. 2 of the OM.
Weibl <sub>u</sub>	<b>Weibl<sub>e</sub></b>	
XEQa	Dispensable	Use <b>XEQ</b> with an appropriate parameter instead.
XTAL?	Dispensable	A quartz crystal is installed by default.
YDOFF, YDON	Dispensable	Your WP 43S displays <i>y</i> whenever possible and wanted.
αDATE, αDAY	Dispensable	You can combine text and numeric data easily using <b>+</b> as shown in Section 2 of the OM.
αGTO	Dispensable	Use <b>GTO</b> with an appropriate parameter instead.
αIP, αMONTH	Dispensable	You can combine text and numeric data easily using <b>+</b> as shown in Section 2 of the OM.
αRCL, αRC#	Dispensable	Your WP 43S features various <i>data types</i> and 'knows' which type is in the <i>register</i> specified. Appending <i>alpha strings</i> is done by <b>+</b> .
αSTO	Dispensable	Simply press <b>STO</b> instead (any <i>register</i> can take an <i>alpha string</i> ).

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
$\alpha\text{TIME}$	Disposable	See $\alpha\text{DATE}$ .
$\alpha\text{XEQ}$	Disposable	Use $\text{XEQ}$ with an appropriate parameter instead.
$\beta$	$\beta(x,y)$	
$\Gamma$	$\Gamma(x)$	
$\Delta\text{DAYS}$	Disposable	Simply subtract two <i>dates</i> .
$\zeta$	$\zeta(x)$	
$\Phi(x) \dots$	Disposable	Use NORML... with $\mu=0$ and $\sigma=1$ instead.
$\chi^2_u(x)$	$\chi^2_e(x)$	
$\rightarrow H$	$\rightarrow HR$	
$\blacksquare\text{PLOT}$	n/a	See gCLR.
$\blacksquare^C r_{XY}$	Disposable	Use $\blacksquare r$ instead. $\blacksquare x$ is on the keyboard.
$\blacksquare a,$ $\blacksquare a+,$ $\blacksquare +a$	Disposable	You can combine text and numeric data easily using $\blacksquare +$ as shown in Section 2 of the OM. Then use $\blacksquare r$ . $\blacksquare x$ is on the keyboard.
$\blacksquare ?$	Disposable	A quartz crystal and the proper firmware for printing are installed by default.

## New Commands on your WP 43S

The following table lists the commands and pseudo-commands created for your *WP 43S* (and for preceding *WP* calculators, if applicable), offering new or extended functionality compared to earlier *HP RPN* and algebraic pocket calculators. In total, these are more than 340 operations, not counting the unit conversions and constants provided; 55 of them are even new or extended compared to earlier *WP* calculators. The commands are printed below as spelled on your *WP 43S*.

Command	WP 43S	WP 31S	WP 34S
2 <sup>x</sup> AGM	●	—	new
ALL	●	●	extended
AND ASR NOT OR XOR	●	—	extended
BACK CASE SKIP	●	—	new
BATT?	●	●	new
BC? FB	●	—	new
BestF	extended	●	●
Binom Binom <sub>p</sub> (of Binomial distribution)	●	●	new
B <sub>n</sub> B <sub>n</sub> * CEIL FLOOR	●	—	new
Cauch Cauch <sub>p</sub> Cauch <sub>e</sub> Cauch <sup>-1</sup>	●	●	new
CauchF GaussF HypF ParabF RootF	new	—	—
CLCVAR	new	—	—
CLFall CLK12 CLK24 CLPall CONJ CONVG? COV	●	—	new
CPXi CPXj CX→RE RE→CX	new	—	—
DATE TIME	●	—	(●)
DATE→ DAY MONTH YEAR →DATE	●	—	new
DBL?	modified	—	new
DEC DSL INC ISE	●	—	new
DECOMP	●	●	new
DEG→ D.MS→ GRAD→ RAD→	●	—	new
DROP	●	—	new
DROPy DSTACK	new	—	—
D→J J→D	●	—	new
EIGVAL EIGVEC	new	—	—
ENGOVR SCIOVR	●	—	new
ENTRY?	●	—	new
EQ.DEL EQ.EDI EQ.NEW	new	—	—

Command	WP 43S	WP 31S	WP 34S
erf erfc ERR MSG	●	—	new
EVEN? ODD?	●	—	new
Expon Expon <sub>p</sub> Expon <sub>e</sub> Expon <sup>-1</sup>	●	●	new
EXPT MANT	●	—	new
FAST SLOW	●	—	new
FBR	new	—	—
FC?F FC?S FF FS?F FS?S	●	—	new
FIB	●	—	new
FILL	●	●	new
FLASH? FP?	●	—	new
F <sub>p</sub> (x) F(x) (of F distribution)	●	●	new
f' f''	new	—	—
f'(x) f''(x)	extended	—	new
GAP	extended	●	new
GCD LCM	●	●	new
g <sub>d</sub> g <sub>d</sub> <sup>-1</sup>	●	—	new
Geom Geom <sub>p</sub> Geom <sub>e</sub> Geom <sup>-1</sup>	●	—	new
H <sub>n</sub> H <sub>nP</sub> L <sub>m</sub> L <sub>ma</sub> P <sub>n</sub> T <sub>n</sub> U <sub>n</sub>	●	—	new
Hyper Hyper <sub>p</sub> Hyper <sub>e</sub> Hyper <sup>-1</sup>	new	—	—
IDIV	●	—	new
IDIVR IM RE	new	—	—
IMPFRC PROFRC	●	●	new
INT? I <sub>xyz</sub> IΓ <sub>p</sub> IΓ <sub>q</sub>	●	—	new
J <sub>y</sub> (x)	new	—	—
J/G	extended	●	new
KEY? KTyp? LBL? LEAP?	●	—	new
LgNrm LgNrm <sub>p</sub> LgNrm <sub>e</sub> LgNrm <sup>-1</sup>	●	—	new

Command	WP 43S	WP 31S	WP 34S
LN $\beta$ LN $\Gamma$ LOADP LOADR LOADSS LOAD $\Sigma$ LocR LocR? LOG <sub>2</sub> LOG <sub>xy</sub>	●	—	new
LOAD SAVE	●	●	new
Logis Logis <sub>p</sub> Logis <sub>e</sub> Logis <sup>-1</sup>	●	●	new
max min MIRROR	●	—	new
MOD	●	●	new
MULT $\times$ MULT $\cdot$ MULT $\pi$ MULT $\pi\rightarrow$	new	—	—
M.LU M.SQR? NAND NaN? NEIGHB NOR	●	—	new
NBin NBin <sub>p</sub> NBin <sub>e</sub> NBin <sup>-1</sup>	new	—	—
NEXTP PRIME?	●	●	new
Norml Norml <sub>p</sub> Norml <sub>e</sub> Norml <sup>-1</sup>	●	●	new
n $\Sigma$ (callable by name)	●	●	new
OrthoF PLOT POINT	new	—	—
PAUSE	●	—	extended
Poiss Poiss <sub>p</sub> Poiss <sub>e</sub> Poiss <sup>-1</sup>	●	●	new
PopLR PRCL PSTO PUTK	●	—	new
RBR	●	●	new
RCLCFG STOCFG	extended	—	new
RCLS STOS	●	—	new
RCL $\uparrow$ RCL $\downarrow$ ST0 $\uparrow$ ST0 $\downarrow$	●	—	new
RDP RECV SEND	●	—	new
Re $\Re$ Im	new	—	—
RJ	●	—	new
RL RLC RR RRC	●	—	extended
RMD	●	●	extended
RM RM? ROUNDI RSD RTN+1 R-CLR R-COPY R-SORT R-SWAP	●	—	new
SDIGS? SETSIG	new	—	—

Command	WP 43S	WP 31S	WP 34S
SDL SDR SETCHN SETEUR SETIND SETJPN SETUK SETUSA	●	—	new
SETDAT SETTIM	●	—	(●)
SIGNMT sinc	●	—	new
SL SR	●	—	extended
SLVQ SMODE? SPEC?	●	—	new
S <sub>MW</sub> S <sub>W</sub>	●	●	new
SSIZE4 SSIZE8 SSIZE?	●	●	new
STATUS	extended	—	extended
S <sub>XY</sub>	●	—	new
TDISP	new	—	—
TICKS	●	—	new
TIMER	●	—	(●)
TOP? ULP?	●	—	new
t <sub>p</sub> (x) t(x) (of t distribution)	●	●	new
t <sub>x</sub> y <sub>x</sub> z <sub>x</sub> $\zeta_x$	●	—	new
undo (UNDO)	●	new	—
V <sub>4</sub>	new	—	—
VERS? WDAY WHO?	●	●	new
Weibl Weibl <sub>p</sub> Weibl <sub>e</sub> Weibl <sup>-1</sup>	●	●	new
W <sub>m</sub> W <sub>p</sub> W <sup>-1</sup> WSIZE? $\bar{x}_G$ XNOR	●	—	new
x→DATE	new	—	—
x< ? x≤ ? x= ? x≠ ? x≥ ? x> ?	●	—	extended
x=+0? x=-0? x≈ ?	●	—	new
Y.MD	●	●	new
αLENG?	extended	—	●
αPOS?	extended	—	—
αRL αRR αSL αSR	●	—	extended
β(x,y) γ <sub>xy</sub> Γ <sub>xy</sub> ε ε <sub>m</sub> ε <sub>p</sub> ζ(x) Π Σ σ <sub>w</sub>	●	—	new

Command	WP 43S	WP 31S	WP 34S
$\Sigma^1/x$ $\Sigma^1/x^2$ $\Sigma^1/y$ $\Sigma^1/y^2$ $\Sigma \ln y/x$ $\Sigma x^2/y$ $\Sigma x^3$ $\Sigma x^4$ $\Sigma x/y$	new	—	—
$\Sigma \ln^2 x$ $\Sigma \ln^2 y$ $\Sigma \ln x$ $\Sigma \ln xy$ $\Sigma \ln y$ $\Sigma x$ $\Sigma x^2$ $\Sigma x^2 y$ $\Sigma x \ln y$ $\Sigma xy$ $\Sigma y$ $\Sigma \ln x$ $\Sigma y^2$ (callable by names)	•	•	new
$\chi^2_p(x)$ $\chi^2(x)$ (of chi-square distribution)	•	•	new
$(-1)^x$ $x \text{MOD}$ $y \text{MOD}$	•	—	new
$\pm\infty?$	new	—	—
$\rightarrow \text{DEG}$ $\rightarrow \text{RAD}$	•	•	new
$\rightarrow \text{DP}$ $\rightarrow \text{SP}$	new	—	—
$\rightarrow \text{D.MS}$ $\rightarrow \text{MUL}\pi$	new	—	—
$\rightarrow \text{GRAD}$	•	—	new
$\rightarrow \text{INT}$ $\rightarrow \text{REAL}$	new	—	—
$\blacksquare \text{ADV}$ $\blacksquare \text{CHAR}$ $\blacksquare r$ $\blacksquare \text{REGS}$ $\blacksquare \text{TAB}$ $\blacksquare \#$ $\blacksquare \text{MODE}$	•	—	(new)
$\blacksquare \text{WIDTH}$	extended	—	(new)
	•	•	new

The statements in parentheses in the rightmost column refer to the *WP 34S* with optional quartz and capacitors installed.

## Reference Literature

As mentioned above, some advanced functionality of your *WP 43S* is taken over from previous *HP* calculators. The following vintage *HP* material is recommended as source of in-depth information (as far as calculating, programming, and applications are concerned) about the topics listed, from a calculator point of view. The manuals listed below are entirely contained in a document set distributed by the *Museum of HP Calculators* (see <http://www.hpmuseum.org/cd/cddesc.htm> ).

Depending on your educational background and professional qualification, textbooks about various mathematical, scientific, or engineering topics may be helpful in addition. Ensure you know enough about what you compute (and check footnote 61 on p. 212 below as well as the last paragraph on p. 16 of the OM).

Topic	Recommended literature
General calculation examples and applications	All vintage <i>HP</i> calculator manuals can be recommended
Root finding and numeric integration	<i>HP-34C OH and Programming Guide</i> <i>HP-15C Owner's Handbook</i> <i>HP-15C Advanced Functions Handbook</i> <i>HP-42S Programming Examples and Techniques</i>
Statistical distributions and their application	<i>HP-21S Owner's Manual</i>
Financial calculations	<i>HP-17BII+ User's Guide</i>
Manipulating <i>short integers</i>	<i>HP-16C Owner's Handbook</i>
Programming	<i>HP-42S Owner's Manual</i> <i>HP-42S Programming Examples and Techniques</i>

## **APPENDIX F: FLASHING AND UPDATING YOUR WP 43S**

### **How to Flash Your WP 43S**

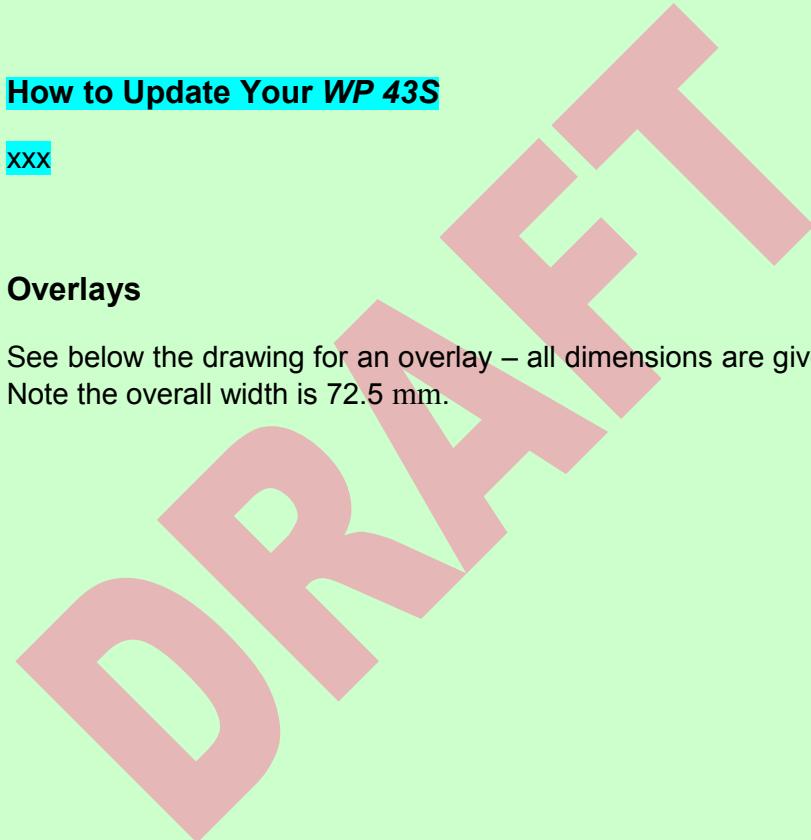
xxx

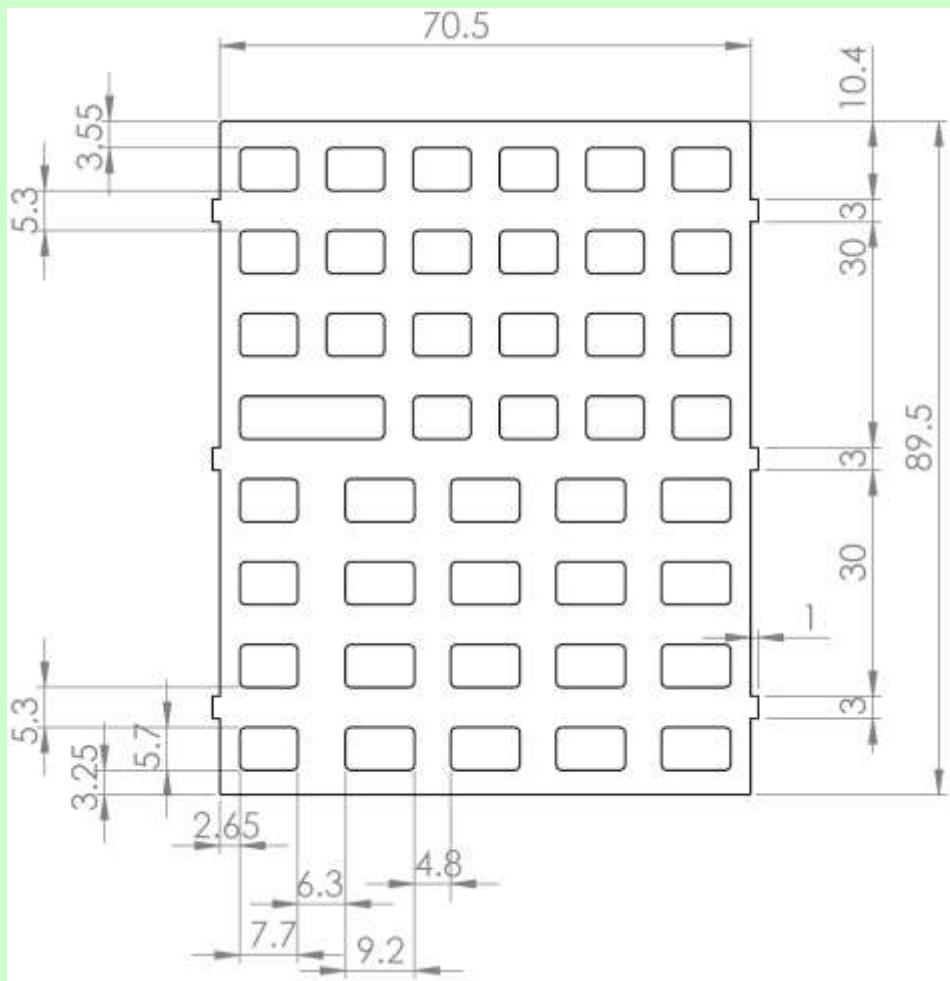
### **How to Update Your WP 43S**

xxx

### **Overlays**

See below the drawing for an overlay – all dimensions are given in mm.  
Note the overall width is 72.5 mm.





## **APPENDIX G: TROUBLESHOOTING GUIDE**

XXX

DRAFT

## APPENDIX H: ADVANCED MATHEMATICAL FUNCTIONS AND TASKS

Your *WP 43S* contains several operations covering advanced mathematics. Most of them are taken over from *WP 34S*, some are implemented here for the first time on an *RPN* calculator. Find those functions collected here and described in more detail than in the *IOI*, together with a few traditional pocket calculator functions matching the topic.

For reasons explained in *Section 1*, we assume you are able to read and understand mathematical formulas for real domain functions.

Wherever complex numbers may be valid input or output, the command name is printed on light yellow background. Ensure you understand the respective fundamental mathematical concepts; else leave these functions aside. By experience, it is only beneficial to use something you overview and know the background of – otherwise it may even become dangerous for you and your fellow men.

### Number Generating Functions

The following are all *monadic* functions except COMB and PERM.

Name	Remarks (see pp. 12ff for general information)
$B_n$	$B_n$ returns the Bernoulli number for an integer $n > 0$ given in <b>X</b> : $B_n = (-1)^{n+1} \cdot n \cdot \zeta(1 - n)$ $B_n^*$ works with the old definition instead:
$B_n^*$	See p. 236 for $\zeta(x)$ .

Name	Remarks (see pp. 12ff for general information)
COMB, PERM	<p>For <math>y \geq x \geq 0</math> and <math>x, y \in \mathbb{N}</math>, <math>C_{y,x} = \binom{y}{x} = \frac{y!}{x!(y-x)!}</math> is the number of <i>combinations</i> and <math>P_{y,x} = \frac{y!}{(y-x)!} = x! \cdot C_{y,x}</math> the number of <i>permutations</i> of <math>x</math> and <math>y</math> as explained in the IOP (see pp. 26 and 60, respectively).</p> <p>Note <math>C_{y,0} = 1</math>, <math>C_{y,1} = y</math>, and <math>C_{y,2} = \frac{1}{2}y(y-1)</math>.</p> <p><math>C_{y,x}</math> applies to the <i>binomial distribution</i> (see p. 203): In a <i>Galton box</i><sup>59</sup> (a.k.a. <i>bean machine</i>) featuring <math>y</math> rows of pins and fed with <math>2^y</math> balls, <math>C_{y,x}</math> is the number of balls expected in column <math>x</math> of that box (start column counting with zero).</p> <p><math>P_{y,x} = \frac{\Gamma(y+1)}{\Gamma(y-x+1)}</math> and <math>C_{y,x} = \frac{\Gamma(y+1)}{\Gamma(x+1) \cdot \Gamma(y-x+1)}</math> work also for non-integer numbers and in complex domain, too.</p>
FIB	<p>For integers, FIB returns the Fibonacci number <math>f_n</math> with <math>n = x</math>. These numbers are defined as <math>f_0 = 0</math>, <math>f_1 = 1</math>, and <math>f_n = f_{n-1} + f_{n-2}</math> for <math>n \geq 2</math>. With UNSIGNED, <math>f_{93}</math> is the maximum before an overflow occurs.</p> <p>Else FIB returns the extended Fibonacci number</p> $F_x = \frac{1}{\sqrt{5}} [\Phi^x - \Phi^{-x} \cos(x\pi)]$ <p>for an arbitrary real or complex number <math>x</math>, with <math>\Phi = \frac{1+\sqrt{5}}{2}</math> denoting the golden ratio.</p>

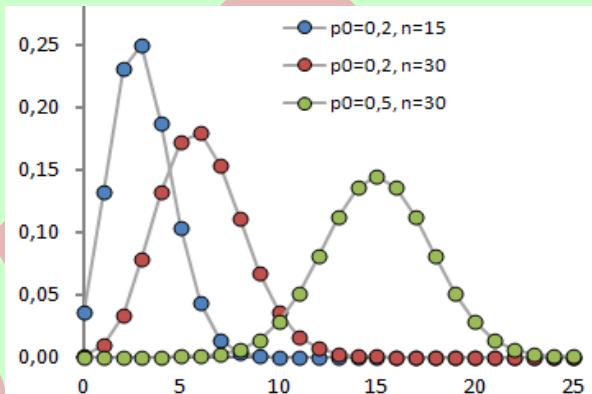
<sup>59</sup> Translator's note: This is called «Planche de Galton» in French, “Galtonbrett” in German, and “macchina di Galton” in Italian. Note the subtle differences in naming. Galton invented his box in 1889.

## Statistical Distributions

Stack-wise, the following are all *monadic* functions, stored in PROB. Actually, they feature more parameters though. Those are supplied in the *registers I, J, and K* as applicable and mentioned below.

In the following text, the five **discrete distributions** are covered first, the continuous ones thereafter. Typical plots are shown for the *PMF's* or *PDF's*.

**Binom:** *Binomial distribution with the number of successes g in X, the gross probability of a success p<sub>0</sub> in I and the sample size n in J.*



BINOM<sub>P</sub> returns

$$p_B(g; n; p_0) = \binom{n}{g} \cdot p_0^g \cdot (1 - p_0)^{n-g} = C_{n,g} \cdot p_0^g \cdot (1 - p_0)^{n-g} \quad (\text{see COMB on p. 202 for the explanation of the notation}).$$

BINOM returns  $F_B(m; n; p_0) = \sum_{g=0}^m p_B(g; n; p_0)$  with the maximum number of successes **m** in X.

The *binomial distribution* is fundamental for error statistics in industrial sampling, e.g. for designing test plans.

**Example:** What is the probability for finding no faulty item in a sample of 15 items drawn from a batch of 300 wherein you expect 3% defective items overall? This will tell you:

.03 [STO] J 15 [STO] K 0 [PROB] g Binom: Binom

returning 0.633 – so the odds are almost two out of three that you will not detect any defect in your sample! <sup>60</sup>

Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda366i.htm>.

**Geom:** *Geometric distribution:*

GEOM<sub>P</sub> returns

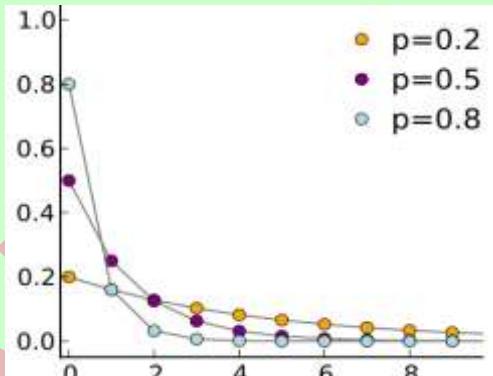
$$p_{Ge}(n) = p_0(1 - p_0)^n$$

GEOM returns

$$F_{Ge}(m) = 1 - (1 - p_0)^{m+1},$$

being the probability for a first success after  $m = x$  Bernoulli experiments.

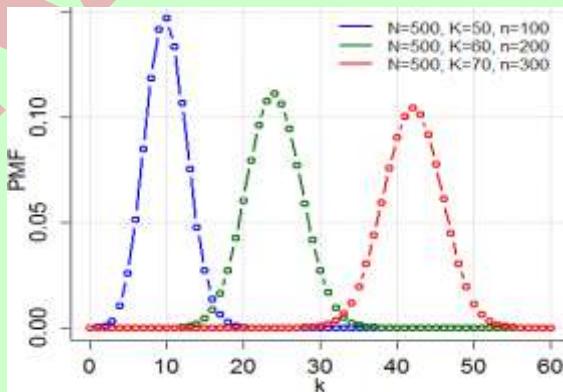
The probability  $p_0$  for a success in each such experiment must be specified in I.



Start reading here for more:

[http://en.wikipedia.org/wiki/Geometric\\_distribution](http://en.wikipedia.org/wiki/Geometric_distribution).

**Hyper:** *Hypergeometric distribution* with the number of successes  $g$  in X, gross probability of a success  $p_0$  in I, sample size  $n$  in J, and batch size  $n_0$  in K (in the diagram,  $g=k$ ,  $p_0=K/N$ , and  $n_0=N$ ).



<sup>60</sup> The exact result for said boundary conditions is 0.626, calculated using the hypergeometric distribution. These results show nicely that two significant digits are a typical accuracy of theoretical statistical statements – frequently the (often simplified) statistical model used matches reality no better than that.

HYPER<sub>P</sub> returns  $p_H(g; n; p_0; n_0) = \frac{\binom{n_0 p_0}{g} \cdot \binom{n_0(1-p_0)}{n-g}}{\binom{n_0}{n}}$  (see COMB on p. 202 for the explanation of the notation).

While the *binomial distribution* assumes that each sample part is returned to the batch after checking, the *hypergeometric distribution* lets you keep your samples out of the batch. This is found more often in real life, but may be neglected in 'large' batches ( $n_0 > 10$ ) and small sample sizes (<10% of  $n_0$ ).

Start reading here for more:

[http://en.wikipedia.org/wiki/Hypergeometric\\_distribution](http://en.wikipedia.org/wiki/Hypergeometric_distribution).

**NBin:** Negative binomial distribution with the total number of failures  $f$  (in  $n$  draws) in X, the gross probability of a success in a single draw  $p_0$  in I, and  $n$  in J.

NBIN<sub>P</sub> returns  $p_{NB}(f; n; p_0) = \binom{n-1}{f-1} \cdot p_0^f \cdot (1-p_0)^{n-f}$   
 $= C_{n-1, f-1} \cdot p_0^f \cdot (1-p_0)^{n-f}$  (see COMB on p. 202 for the explanation of the notation and cf. BINOM).

Start reading here for more:

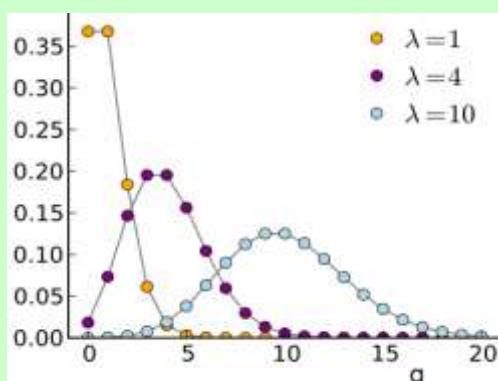
[http://en.wikipedia.org/wiki/Negative\\_binomial\\_distribution](http://en.wikipedia.org/wiki/Negative_binomial_distribution).

**Poiss:** Poisson distribution with the number of successes  $g$  in X and the Poisson parameter  $\lambda$  in J.

POISS<sub>P</sub> computes

$$p_P(g; \lambda) = \frac{\lambda^g}{g!} e^{-\lambda}$$

and POISS returns the corresponding CDF for the



maximum number of successes  $m$  in X.

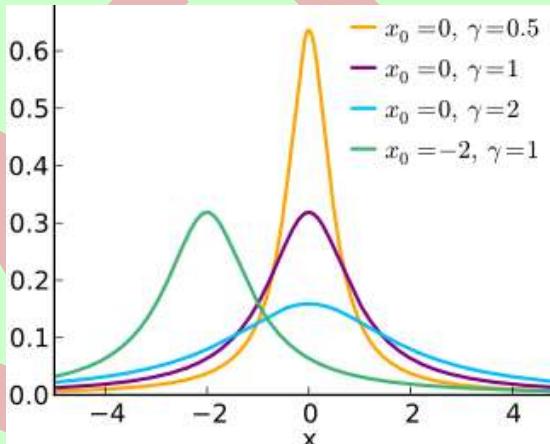
The *Poisson distribution* provides the mathematically simplest model for industrial sampling tests – use  $\lambda = np_0$  with the gross error probability  $p_0$  and the sample size  $n$  (cf. BINOM). For the example introduced with BINOM above, POISS returns 0.638.

Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda366j.htm>.

### Continuous distributions:

**Cauch:** Cauchy-Lorentz distribution (also known as Lorentz or Breit-Wigner distribution) with the location  $x_0$  specified in I and the shape  $\gamma$  in J.



CAUCH<sub>P</sub> returns  $f_{Ca}(x) = \left\{ \pi\gamma \cdot \left[ 1 + \left( \frac{x - x_0}{\gamma} \right)^2 \right] \right\}^{-1}$ ,

CAUCH returns  $F_{Ca}(x) = \frac{1}{2} + \frac{1}{\pi} \arctan\left(\frac{x - x_0}{\gamma}\right)$ ,

CAUCH<sup>-1</sup> returns  $F_{Ca}^{-1}(p) = x_0 + \gamma \tan\left[\pi \cdot \left(p - \frac{1}{2}\right)\right]$ .

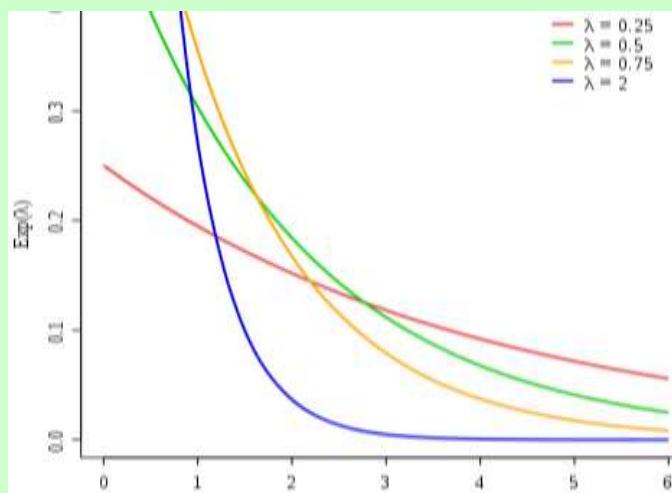
This distribution is quite popular in physics. It is a special case of Student's t distribution. Start reading here for more:

[http://en.wikipedia.org/wiki/Cauchy\\_distribution](http://en.wikipedia.org/wiki/Cauchy_distribution).

**Expon:** Exponential distribution with the rate  $\lambda$  in **I**.

$\text{EXPON}_P$  returns  $f_{\text{Ex}}(x) = \lambda \cdot e^{-\lambda x}$ .

$\text{EXPON}$  returns  $F_{\text{Ex}}(x) = 1 - e^{-\lambda x}$ .



Read here for  
more informa-  
tion:

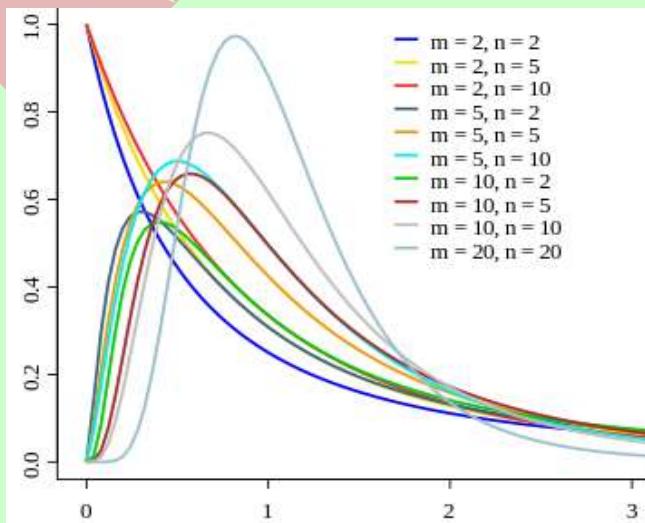
<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3667.htm>

**F(x):** Fisher's F distribution with the degrees of freedom in **I** and **J**.

It is used e.g. for  
analyses of var-  
iance (ANOVA).

The diagram  
shows the PDF plotted for dif-  
ferent degrees of  
freedom  $m$  and  
 $n$  corresponding  
to  $i$  and  $j$ .

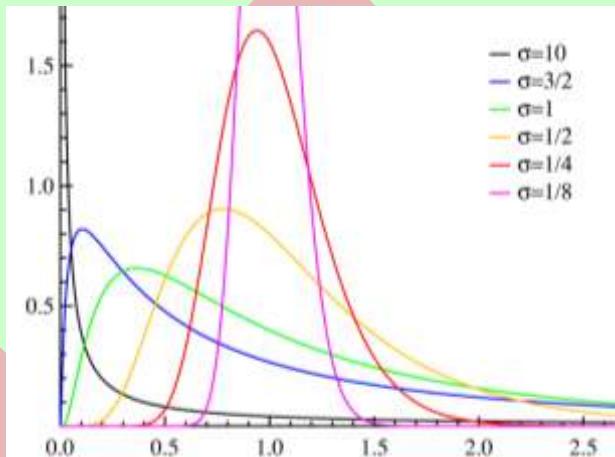
Read here for  
more informa-  
tion:



**LgNrm:** Log-normal distribution with the parameters  $\mu = \ln \bar{x}_g$  in **I** and  $\sigma = \ln \varepsilon$  in **J** (see some PDF plots below).

LGNRM<sub>P</sub> returns  $f_{Ln}(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{[\ln(x)-\mu]^2}{2\sigma^2}}$ .

LGNRM returns  $F_{Ln}(x) = \Phi\left(\frac{\ln(x)-\mu}{\sigma}\right)$  with  $\Phi(z)$  denoting the *standardized normal CDF* as presented on p. 211.



Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3669.htm>

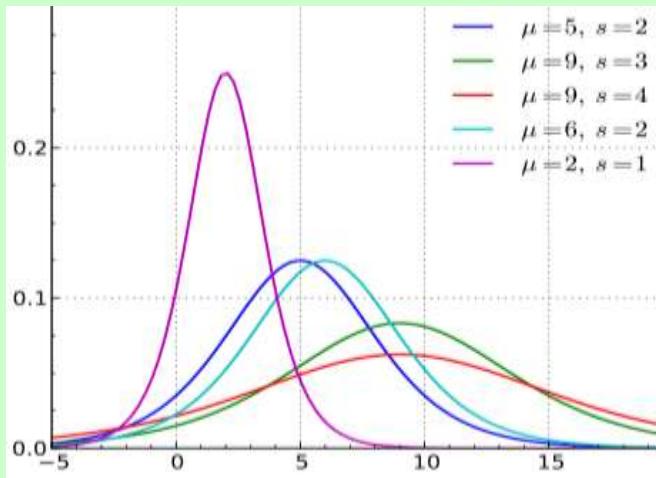
**Logis:** Logistic distribution with an arbitrary *mean*  $\mu$  given in **I** and a *scale parameter*  $s$  in **J**.

Substituting  $\xi = \frac{x-\mu}{s}$ ,

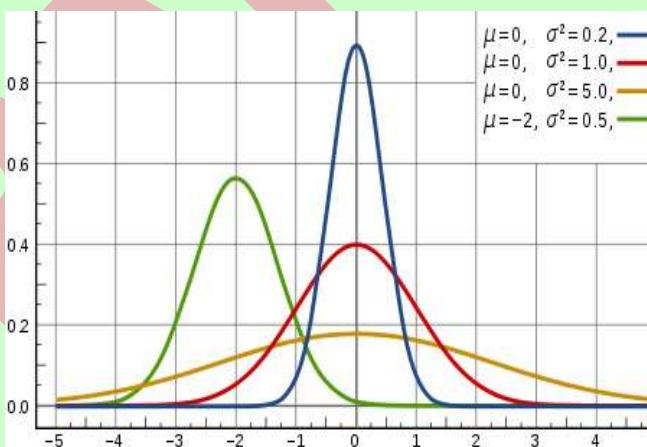
LOGIS<sub>P</sub> returns  $f_{Lg}(x) = \frac{e^{-\xi}}{(1+e^{-\xi})^2 s}$  (plotted overleaf) and

LOGIS returns  $F_{Lg}(x) = \frac{1}{1+e^{-\xi}}$ .

LOGIS<sup>-1</sup> returns  $F_{Lg}^{-1}(p) = \mu + s \ln\left(\frac{p}{1-p}\right)$ .



**Normal:** Normal distribution with an arbitrary mean  $\mu$  given in I and an arbitrary standard deviation  $\sigma$  in J. The red curve (for  $\mu = 0$  and  $\sigma = 1$ ) is the standardized normal (a.k.a. Gaussian) distribution  $\varphi$ .



NORML<sub>P</sub> returns  $f_N(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} = \varphi\left(\frac{x-\mu}{\sigma}\right)$  and

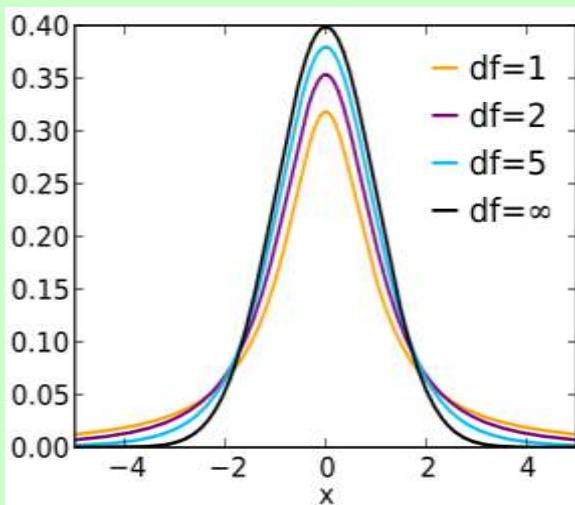
NORML returns  $F_N(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$  with  $\Phi(z)$  denoting the standard normal (or Gaussian) CDF as presented on p. 211.

Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3661.htm>

$t(x)$ : Standardized Student's  $t$  distribution with its *degrees of freedom* in

I. It is used for hypothesis testing and calculating confidence intervals e.g. for means. The picture shows its *PDF* plotted for different *degrees of freedom*. For  $df \rightarrow \infty$ , the shoulders of  $t(x)$  shrink and it approaches the *PDF* of the *standard normal distribution* (compare the red *Gaussian curve* at NORML on p. 209).



Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3664.htm>

**Weibl**: Weibull distribution with its *shape parameter*  $b$  in I and its *characteristic lifetime*  $T$  in J.

WEIBL<sub>P</sub> returns  $f_W(t) = \frac{b}{T} \cdot \left(\frac{t}{T}\right)^{b-1} e^{-(t/T)^b}$  for  $t \geq 0$ , else 0. This is a very flexible function – see the curves plotted overleaf.

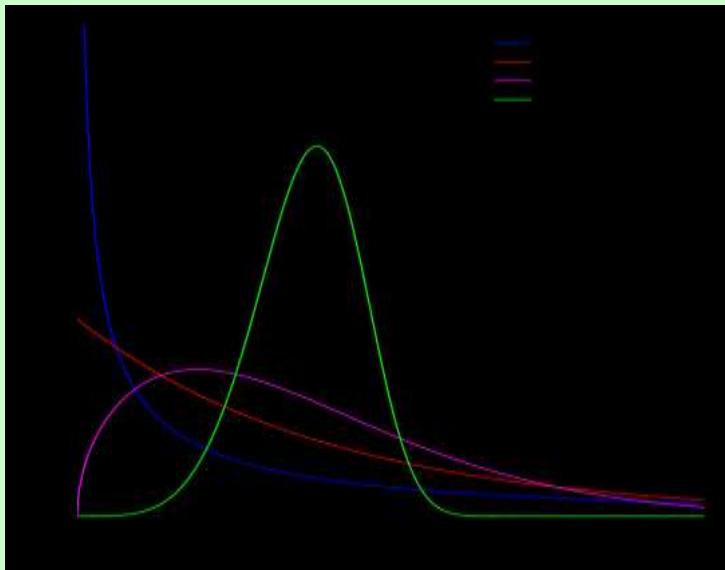
WEIBL returns  $F_W(t) = 1 - e^{-(t/T)^b}$

This distribution is widely used e.g. for analyzing tool and product lifetimes.

Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3668.htm>.

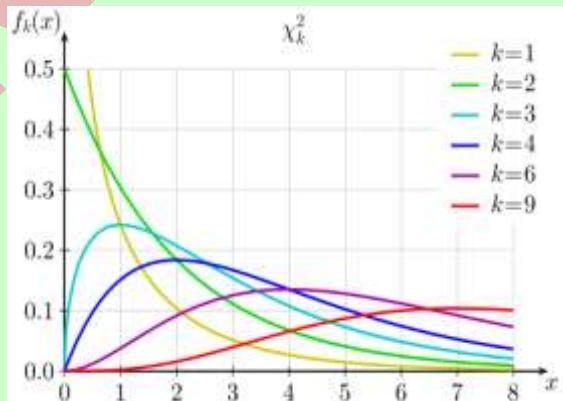
You may even find some more application fields mentioned in [https://en.wikipedia.org/wiki/Weibull\\_distribution#Applications](https://en.wikipedia.org/wiki/Weibull_distribution#Applications).



$\varphi(x)$  and  $\Phi(x)$ :  $\varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$  is the *standardized normal PDF* (i.e. the famous *Gaussian bell curve* as drawn in red under NORML on p. 209), while  $\Phi(x) = \int_{-\infty}^x \varphi(\tau) d\tau$  is the corresponding *CDF* (cf. the *error function* on p. 233). Take NORML instead.

$\chi^2(x)$ : *Chi-square distribution with its degrees of freedom given in I.*

It is used for calculating confidence intervals for *standard deviations, variances, process and machine capabilities*, and the like. The diagram shows *PDF's for different degrees of freedom*.



Read here for more information:

<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3666.htm>

## More Statistical Formulas, also for Fitting

The following equations are for data measured at samples of  $n$  specimens (i.e.  $n$  is the *sample size*). Note that complete measurement results must include both: information about the expected value and about its uncertainty.

- For samples drawn out of a *Gaussian* (additive) process, the expected value is the *arithmetic mean* (or *average*) and its uncertainty is given by its *standard error* (see  $\bar{x}$  and  $s_m$ ).
- For samples drawn out of a *log-normal* (multiplicative) process, the expected value is the *geometric mean* and its uncertainty is given by its *scattering factor* (see  $\bar{x}_g$  and  $\varepsilon_m$ ).
- For samples drawn out of other kinds of processes other measures apply.

Be assured not everything is *Gaussian* in real world!<sup>61</sup> Process features can be detected (and should be checked well in advance of calculating e.g. means) using suitable tests – turn to applicable statistical reference literature.

The following functions as named in the left column (sorted alphabetically) are all found in STAT:

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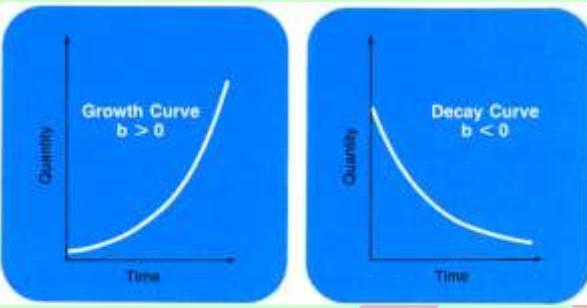
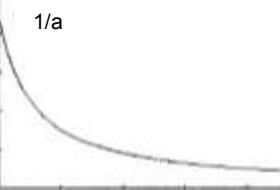
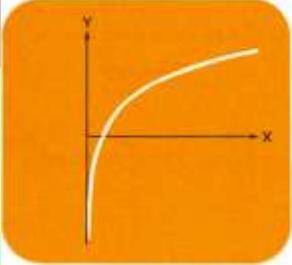
<sup>61</sup> Generally, the statistical model shall be chosen that matches observations best – within their statistical errors. In real life cases, however, dramatic deviations from the model distribution are frequently found – then you cannot expect the calculated consequences matching reality any better.

As mentioned in the main text, we recommend you look deeply into statistics textbooks to ensure you fully understand what you do with the functions provided in your WP 43S. The real world shows lots of sad examples where people full of good will caused large damages by applying tools they did not know sufficiently – or applied standard tools in areas where those are not applicable. “*Wenn Dumme fleißig werden, wird's gefährlich*” (i.e. ~ “It's getting dangerous when fools become busy”), a former boss of mine used to say (cf. also D.T. recently).

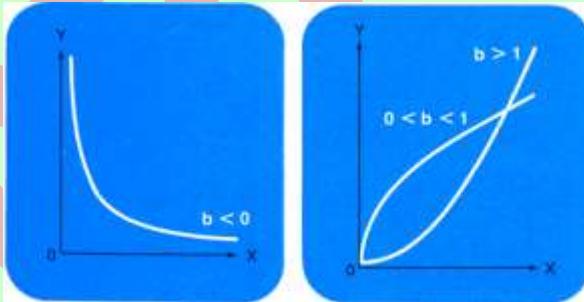
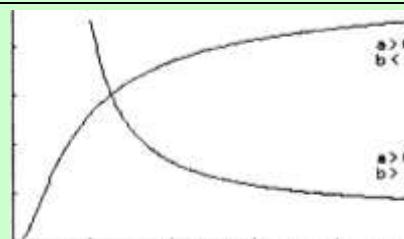
By the way: Since the *PDF* of the *Gaussian* distribution will never reach zero, this statistical model tells you to expect individual items far, far away from the mean value when your sample becomes large enough. This, however, does not match reality. So we must conclude nothing at all is really *Gaussian* in real world. Nevertheless, the *Gaussian* distribution is a very successful model describing a lot of real world observations very well. Just never forget the limits of such models.

Name	Remarks (see pp. 12ff for general information)
CauchF	Selects a Cauchy (a.k.a. Lorentz, Breit-Wigner) peak fit model $R(x) = \frac{1}{[a_0(x + a_1)^2 + a_2]}$ for least squares regression. <sup>62</sup> See p. 206 for the shapes of such peaks.
CORR	<p>For any set of data points <math>(x_i, y_i)</math>, the <i>coefficient of correlation</i> is <math>r = \frac{s_{xy}}{s_x \cdot s_y}</math>. See <math>s_{XY}</math> and <math>s</math> below.</p> <p>For an arbitrary fit model <math>R(x)</math>, <math>r^2 = 1 - \frac{\sum [R(x_i) - y_i]^2}{\sum (\bar{y} - y_i)^2}</math> is its <i>coefficient of determination</i> indicating the fraction of the variation of the dependent data <math>y</math> determined by the variation of the independent data <math>x</math>. For <math>r^2 = 1</math>, <math>y</math> is fully determined by <math>x</math>; for <math>r^2 = 0</math>, <math>y</math> is completely independent of <math>x</math>; and e.g. <math>r^2 = 0.85</math> means 85% of the variation of <math>y</math> is due to <math>x</math>. Note BESTF picks the fit model showing the maximum <math>r^2</math> out of the models allowed.</p> <p>A two-parameter regression (like the majority of the fit models provided on your WP 43S) is said being (statistically) <i>significant</i> if</p> $\sqrt{\frac{r^2}{1 - r^2}(n - 2)} > t_{n-2}^{-1}(0.99)$ <p>with the right side being the inverse of the <i>t distribution</i> for the <i>degrees of freedom</i> <math>n - 2</math> and <i>confidence level</i> 99% (see p. 210).</p>
COV	<p>For any set of data points <math>(x_i, y_i)</math>, the <i>population covariance</i> is</p> $COV_{xy} = \frac{1}{n^2} \left( n \sum x_i y_i - \sum x_i \sum y_i \right)$ <p>Compare <math>s_{XY}</math> below.</p>

<sup>62</sup> Note that *least squares regression* is best for data point errors in direction  $y$  being significantly greater than errors in direction  $x$ . See pp. 219ff for the formulas and more.

Name	Remarks (see pp. 12ff for general information)
ExpF	Selects the exponential curve fit model $R(x) = a_0 e^{a_1 x}$ for least squares regression. <sup>62</sup> Generally, this will be a good choice if the measured data follow the shape of one of the two curves pictured here (think of human population growth or nuclear decay, for instance). <sup>63</sup> 
GaussF	Selects a Gauss peak fit model $R(x) = a_0 e^{\frac{(x-a_1)^2}{a_2}}$ for least squares regression. <sup>62</sup> See p. 209 for the shapes of such peaks.
HypF	 Selects the hyperbolic fit model $R(x) = \frac{1}{(a_0 + a_1 x)}$ for least squares regression. <sup>62</sup>
LinF	Selects the linear fit model $R(x) = a_0 + a_1 x$ for least squares regression. <sup>62</sup> Generally, this will be a good choice if the measured data follow a straight line, raising or falling (but compare ORTHOF).
LogF	 Selects the logarithmic curve fit model $R(x) = a_0 + a_1 \ln(x)$ for least squares regression. <sup>62</sup> Generally, this will be a good choice if the measured data follow a curve looking like drawn at left.

<sup>63</sup> Color plots on this page and the next are taken from the HP-27 manual;  $b = a_1$  on your WP 43S.

Name	Remarks (see pp. 12ff for general information)
L.R.	<p>Uses the fit model selected and computes the two or three parameters of the regression for the data accumulated.</p> <p>For all curve fit models provided on your WP 43S, a regression parameter is (statistically) <i>significant</i> if</p> $\left  \frac{a_i}{s(a_i)} \right  > t_{n-2}^{-1}(0.995),$ <p>with the right side being the inverse of the <i>t distribution</i> for the <i>degrees of freedom</i> <math>n - 2</math> and 99% <i>confidence</i> (cf. p. 210).</p>
OrthoF	Selects the linear fit model $R(x) = a_0 + a_1x$ like LINF, but assuming data point errors in $x$ are equal to those in $y$ (precisely: their variances are equal). The sum of squared distances of the data points to the fit line will be minimized. This model is called <i>orthogonal regression</i> . See pp. 219ff and the OM for more.
ParabF	Selects a parabolic fit model $R(x) = a_0 + a_1x + a_2x^2$ for least squares regression. <sup>62</sup>
PowerF	<p>Selects the power curve fit model <math>R(x) = a_0 x^{a_1}</math> for least squares regression.<sup>62</sup></p>  <p>Generally, this will be a good choice if measured data follow the shape of one of the curves pictured here (look for <i>Tower of Pisa</i> in the OM).<sup>63</sup></p>
RootF	 <p>Selects the root curve fit model <math>R(x) = a * b^{1/x} = a_0 a_1^{1/x}</math> for a least squares regression.<sup>62</sup></p>

Name	Remarks (see pp. 12ff for general information)
$s_{XY}$	<p>For any set of data points <math>(x_i, y_i)</math>, the <i>sample covariance</i> is</p> $s_{xy} = \frac{1}{n(n-1)} \left( n \sum x_i y_i - \sum x_i \sum y_i \right)$ <p style="text-align: right;">Compare COV above.</p>
$s, s_m$	<p>The <i>sample standard deviation (SD)</i> is the positive square root of the <i>sample variance</i></p> $s_x^2 = \frac{1}{n(n-1)} \left[ n \sum x_i^2 - \left( \sum x_i \right)^2 \right] = \frac{1}{n-1} \left( \sum x_i^2 - n \bar{x}^2 \right)$ <p>And the <i>standard error</i> (i.e. the <i>SD</i> of the <i>mean</i> <math>\bar{x}</math>) is <math>s_{mx} = s_x / \sqrt{n}</math></p>
$s_w, s_{mw}$	<p>The <i>sample SD</i> for <u>weighted</u> data (where the weight <math>y_i</math> of each data point <math>x_i</math> was entered via <math>\Sigma +</math>) is</p> $s_w = \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i (\sum y_i - 1)}}$ <p>And the corresponding <i>standard error</i> (the <i>SD</i> of the <i>mean</i> <math>\bar{x}_w</math>) is</p> $s_{mw} = \frac{1}{\sum y_i} \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i - 1}}$
$\bar{x}$	The <i>arithmetic mean</i> is calculated as $\bar{x} = \frac{1}{n} \sum x_i$
$\bar{x}_G$	The <i>geometric mean</i> is calculated as $\bar{x}_G = \sqrt[n]{(\prod x_i)} = e^{\left[\frac{1}{n} \sum \ln(x_i)\right]}$
$\bar{x}_H$	The <i>harmonic mean</i> is calculated as $\bar{x}_H = \frac{n}{\sum \frac{1}{x_i}}$
$\bar{x}_{RMS}$	The <i>quadratic mean</i> is calculated as $\bar{x}_{RMS} = \sqrt{\frac{1}{n} \sum x_i^2}$ .

Name	Remarks (see pp. 12ff for general information)
$\bar{x}_w$	The <i>arithmetic mean</i> for <u>weighted</u> data (where the weight $y_i$ of each data point $x_i$ was entered via <b>(Σ+)</b> ) is $\bar{x}_w = \frac{\sum x_i y_i}{\sum y_i}$
$\varepsilon$	The <i>scattering factor</i> $\varepsilon_x$ for a sample of <i>log-normally</i> distributed data is calculated via: $\ln(\varepsilon_x) = \sqrt{\frac{1}{n-1} \left[ \sum \ln^2(x_i) - 2n \ln(\bar{x}_G) \right]}$ Compare s.
$\varepsilon_m$	The <i>scattering factor</i> of the <i>geometric mean</i> is $\varepsilon_m = \varepsilon^{\frac{1}{\sqrt{n}}}$ . Compare s <sub>m</sub> .
$\varepsilon_p$	The <i>scattering factor</i> $\varepsilon_p$ for a population of <i>log-normally</i> distributed data is calculated via: $\ln(\varepsilon_p) = \sqrt{\frac{n-1}{n}} \ln(\varepsilon_x)$ Compare σ.
$\sigma$	The <i>SD</i> of a population of <i>normally</i> distributed data is calculated via: $\sigma_x = \sqrt{\frac{1}{n} \sum x_i^2 - n \bar{x}^2} = \sqrt{\frac{n-1}{n}} s_x$
$\sigma_w$	The <i>SD</i> of the population for <u>weighted</u> data (where the weight $y_i$ of each data point $x_i$ was entered via <b>(Σ+)</b> ) is $\sigma_w = \sqrt{\frac{\sum y_i (x_i - \bar{x}_w)^2}{\sum y_i}}$

## About Error Propagation

Experimental data are always attended with errors (cf. footnote 34), caused by e.g. the uncertainty of the measuring method, the instrument used, and environmental variations. Even under controlled environmental and measuring conditions, random errors remain. These errors must be taken into account for a proper estimation of the uncertainty of your results computed using those experimental data. For about 200 years, Gauß' *least squares method* can be employed for this task.

Assume you know that your result  $R$  depends on several experimental parameters  $x_1$  through  $x_n$ . Each such parameter  $x_i$  has an uncertainty or error  $\Delta x_i$ . Now, if  $R = f(x_1, \dots, x_n)$  then

$$\begin{aligned}\Delta R &= f(x_1 \pm \Delta x_1, \dots, x_n \pm \Delta x_n) - f(x_1, \dots, x_n) \\ &= \pm \sqrt{\left(\frac{df}{dx_1}\right)^2 \Delta x_1^2 + \dots + \left(\frac{df}{dx_n}\right)^2 \Delta x_n^2}\end{aligned}$$

Often, however, the differential terms under the square root are tedious to determine analytically.

But this root can be written simpler:  $\Delta R = \pm \sqrt{\Delta f_1^2 + \dots + \Delta f_n^2}$ .

And with your *WP 43S*, the following algorithm will do for computing  $\Delta R$ , even if  $f$  is 'strongly curved':

1. Program the function  $R = f(x_1, x_2, \dots, x_n)$  in a way you can vary its parameters easily.
2. Let your *WP 43S* compute  $f(x_1, x_2, \dots, x_n)$ .
3. Let it compute  $R_{1+} = f(x_1 + \Delta x_1, x_2, \dots, x_n)$  and  $\Delta R_{1+} = R_{1+} - R$ .
4. Let it compute  $R_{1-} = f(x_1 - \Delta x_1, x_2, \dots, x_n)$  and  $\Delta R_{1-} = R_{1-} - R$ .
5. Let it compute  $R_{2+} = f(x_1, x_2 + \Delta x_2, \dots, x_n)$  and  $\Delta R_{2+} = R_{2+} - R$ .
6. Let it compute  $R_{2-} = f(x_1, x_2 - \Delta x_2, \dots, x_n)$  and  $\Delta R_{2-} = R_{2-} - R$ .
7. Repeat the last two steps for each remaining parameter.

Being through with all  $n$  parameters, you will end with

$$\Delta R = \pm \sqrt{\frac{1}{2} (\Delta R_{1+}^2 + \Delta R_{1-}^2 + \Delta R_{2+}^2 + \Delta R_{2-}^2 + \cdots + \Delta R_{n+}^2 + \Delta R_{n-}^2)}$$

So the terms under the square root have become simple differences which are determined most easily with the help of your *WP 43S*.

For ‘small’ errors or less curvature, the following simpler algorithm will do, requiring down to half as many steps only:

1. Program the function  $R = f(x_1, x_2, \dots, x_n)$  in a way you can vary its parameters easily.
2. Let your *WP 43S* compute  $= f(x_1, x_2, \dots, x_n)$ .
3. Let it compute  $R_1 = f(x_1 + \Delta x_1, x_2, \dots, x_n)$  and  $\Delta R_1 = R_1 - R$ .
4. Let it compute  $R_2 = f(x_1, x_2 + \Delta x_2, \dots, x_n)$  and  $\Delta R_2 = R_2 - R$ .
5. Repeat the last step for each remaining parameter.

Being through with all  $n$  parameters, you will end with

$$\Delta R = \pm \sqrt{\Delta R_1^2 + \Delta R_2^2 + \cdots + \Delta R_n^2}$$

You might know this formula from your university or lab classes.

## About the Curve Fitting Models Provided

Actually, a proper linear regression is computed for LINF and ORTHOF only. For the other three standard models (EXPF, LOGF, and POWERF) the same method is applied to transformed data. Your data might follow a straight line if you plot...

- the logarithm of your **y**-data over your **x**-data (then EXPF will fit);
- the logarithm of your **y**-data over the logarithm of your **x**-data (then POWERF will fit);
- your **y**-data over the logarithm of your **x**-data (then LOGF will fit).

This is what your WP 43S does when you enter statistical data points and compute a fit curve thereafter:

1. It accumulates the 22 sums listed on pp. 93f and increments  $n$ .
2. The evaluation depends on the fit model you select (cf. pp. 214ff):
  - a. If you choose LINF then the least squares regression line parameters  $a_0$  and  $a_1$  will be computed following the formulas:

$$a_0 = \frac{\sum x_i^2 \cdot \sum y_i - \sum x_i \cdot \sum x_i y_i}{n \sum x_i^2 - (\sum x_i)^2}$$

$$a_1 = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{n \sum x_i^2 - (\sum x_i)^2} = \frac{s_{xy}}{s_x^2} = r \frac{s_y}{s_x}$$

Their *standard errors* can be calculated using the formulas

$$s(a_1) = \frac{s_y}{s_x} \sqrt{\frac{1-r^2}{n-2}} \text{ and } s(a_0) = s(a_1) \cdot \sqrt{\frac{n-1}{n} s_x^2 + \bar{x}^2} \text{ with}$$

$$r = \frac{n \sum x_i y_i - \sum x_i \sum y_i}{\sqrt{n \sum x_i^2 - (\sum x_i)^2} \cdot \sqrt{n \sum y_i^2 - (\sum y_i)^2}}$$

- b. If you choose EXPF then the least squares regression line parameters for the transformed data  $x_i, \ln(y_i)$  will be computed using

$$a_{0,tEXP} = \frac{\sum x_i^2 \cdot \sum \ln(y_i) - \sum x_i \cdot \sum x_i \ln(y_i)}{n \sum x_i^2 - (\sum x_i)^2}$$

$$a_{1,tEXP} = \frac{n \sum x_i \ln(y_i) - \sum x_i \sum \ln(y_i)}{n \sum x_i^2 - (\sum x_i)^2}$$

$$r_{tEXP} = \frac{n \sum x_i \ln(y_i) - \sum x_i \sum \ln(y_i)}{\sqrt{n \sum x_i^2 - (\sum x_i)^2} \cdot \sqrt{n \sum \ln^2(y_i) - [\sum \ln(y_i)]^2}}$$

The standard errors of  $a_{0,tEXP}$  and  $a_{1,tEXP}$  can be calculated using

the formulas for LINF on p. 220 with the transformed results.

The parameters of the fit curve  $R(x) = a_0 e^{a_1 x}$  turn out being  $a_0 = e^{a_{0,tEXP}}$  and  $a_1 = a_{1,tEXP}$ .

c. If you choose POWERF then the least squares regression line parameters for the transformed data  $\ln(x_i)$ ,  $\ln(y_i)$  will be computed in analogy to the method shown for EXPF. Thus they will be

$$a_{0,tPOW} = \frac{\sum \ln^2(x_i) \cdot \sum \ln(y_i) - \sum \ln(x_i) \cdot \sum \ln(x_i) \ln(y_i)}{n \sum \ln^2(x_i) - [\sum \ln(x_i)]^2}$$

$$a_{1,tPOW} = \frac{n \sum \ln(x_i) \ln(y_i) - \sum \ln(x_i) \sum \ln(y_i)}{n \sum \ln^2(x_i) - [\sum \ln(x_i)]^2}$$

$$r_{tPOW} = \frac{n \sum \ln(x_i) \ln(y_i) - \sum \ln(x_i) \sum \ln(y_i)}{\sqrt{n \sum \ln^2(x_i) - [\sum \ln(x_i)]^2} \cdot \sqrt{n \sum \ln^2(y_i) - [\sum \ln(y_i)]^2}}$$

The standard errors of  $a_{0,tPOW}$  and  $a_{1,tPOW}$  can be calculated using the formulas for LINF on p. 220 with the transformed results.

The parameters of the fit curve  $R(x) = a_0 x^{a_1}$  turn out being  $a_0 = e^{a_{0,tPOW}}$  and  $a_1 = a_{1,tPOW}$ .

d. If you choose LOGF then the least squares regression line parameters for the transformed data  $\ln(x_i)$ ,  $y_i$  will be computed in analogy to the method shown for EXPF. Thus they will be

$$a_{0,tLOG} = \frac{\sum \ln^2(x_i) \cdot \sum y_i - \sum \ln(x_i) \cdot \sum y_i \ln(x_i)}{n \sum \ln^2(x_i) - [\sum \ln(x_i)]^2}$$

$$a_{1,tLOG} = \frac{n \sum y_i \ln(x_i) - \sum \ln(x_i) \sum y_i}{n \sum \ln^2(x_i) - [\sum \ln(x_i)]^2}$$

$$r_{tLOG} = \frac{n \sum y_i \ln(x_i) - \sum \ln(x_i) \sum y_i}{\sqrt{n \sum \ln^2(x_i) - [\sum \ln(x_i)]^2} \cdot \sqrt{n \sum y_i^2 - [\sum y_i]^2}}$$

The standard errors of  $a_{0,tLOG}$  and  $a_{1,tLOG}$  can be calculated using the formulas for LINF on p. 220 with the transformed results.

The parameters of the fit curve  $R(x) = a_0 + a_1 \ln(x)$  are just  $a_0 = a_{0,tLOG}$  and  $a_1 = a_{1,tLOG}$ .

- e. If you choose HYPF then the parameters of the least squares regression curve  $R(x) = \frac{1}{a_0 + a_1 x}$  are computed to be

$$a_{0,HYP} = \frac{\sum x_i^2 \cdot \sum \frac{1}{y_i} - \sum x_i \cdot \sum \frac{x_i}{y_i}}{n \sum x_i^2 - (\sum x_i)^2} \text{ and } a_{1,HYP} = \frac{n \sum \frac{x_i}{y_i} - \sum x_i \cdot \sum \frac{1}{y_i}}{n \sum x_i^2 - (\sum x_i)^2}$$

$$r_{HYP}^2 = \frac{a_{0,HYP} \sum \frac{1}{y_i} + a_{1,HYP} \sum \frac{x_i}{y_i} - \frac{1}{n} \left( \sum \frac{1}{y_i} \right)^2}{\sum \frac{1}{y_i^2} - \frac{1}{n} \left( \sum \frac{1}{y_i} \right)^2}$$

- f. If you choose ROOTF then the least squares regression curve parameters will be computed using

$$A = n \sum \frac{1}{x_i^2} - \left( \sum \frac{1}{x_i} \right)^2$$

$$B = \frac{1}{A} \left[ \sum \frac{1}{x_i^2} \cdot \sum \ln(y_i) - \sum \frac{1}{x_i} \cdot \sum \frac{\ln(y_i)}{x_i} \right]$$

$$C = \frac{1}{A} \left[ n \sum \frac{\ln(y_i)}{x_i} - \sum \frac{1}{x_i} \cdot \sum \ln(y_i) \right]$$

The parameters of the fit curve  $R(x) = a_0 a_1^{1/x}$  turn out being just  $a_{0,t\sqrt{-}} = e^B$  and  $a_{1,t\sqrt{-}} = e^C$ .

$$r_{t\sqrt{-}}^2 = \frac{B \sum \ln(y_i) + C \sum \frac{\ln(y_i)}{x_i} - \frac{1}{n} [\sum \ln(y_i)]^2}{\sum [\ln(y_i)]^2 - \frac{1}{n} [\sum \ln(y_i)]^2}$$

g. If you choose PARABF then the least squares regression curve parameters will be computed using

$$A = n \sum x_i^2 - \left( \sum x_i \right)^2, \quad B = n \sum x_i^2 y_i - \sum x_i^2 \cdot \sum y_i,$$

$$C = n \sum x_i^3 - \sum x_i^2 \cdot \sum x_i, \quad D = n \sum x_i y_i - \sum x_i \cdot \sum y_i,$$

$$E = n \sum x_i^4 - \left( \sum x_i^2 \right)^2$$

The parameters of the fit curve  $R(x) = a_0 + a_1 x + a_2 x^2$  will then be

$$a_{2,PAR} = \frac{A B - C D}{A E - C^2}, \quad a_{1,PAR} = \frac{D - a_2 C}{A},$$

$$\text{and } a_{0,PAR} = \frac{1}{n} \left( \sum y_i - a_{2,PAR} \sum x_i^2 - a_{1,PAR} \sum x_i \right).$$

$$\text{And } r_{PAR}^2 = \frac{a_{0,PAR} \sum y_i + a_{1,PAR} \sum x_i y_i + a_{2,PAR} \sum x_i^2 y_i - \frac{1}{n} (\sum y_i)^2}{\sum y_i^2 - \frac{1}{n} (\sum y_i)^2}$$

h. If you choose GAUSSF then the least squares regression curve parameters will be computed using the auxiliary terms A, B, C, D, and E exactly as for PARABF. Furthermore,

$$F = \frac{A B - C D}{A E - C^2}, \quad G = \frac{D - F C}{A},$$

$$\text{and } H = \frac{1}{n} \left( \sum \ln(y_i) - F \sum x_i^2 - G \sum x_i \right).$$

The parameters of the fit curve  $R(x) = a_0 e^{(x-a_1)^2/a_2}$  will then be

$$a_{2,GAU} = \frac{1}{F}, \quad a_{1,GAU} = -\frac{G}{2} a_{2,GAU} \quad \text{and} \quad a_{0,GAU} = e^{H - F a_{1,GAU}^2}.$$

$$r_{GAU}^2 = \frac{H \sum \ln(y_i) + G \sum x_i \ln(y_i) + F \sum x_i^2 \ln(y_i) - \frac{1}{n} [\sum \ln(y_i)]^2}{\sum [\ln(y_i)]^2 - \frac{1}{n} [\sum \ln(y_i)]^2}$$

- i. If you choose CAUCHF then the least squares regression curve parameters will be computed using the auxiliary terms A and E exactly as in PARABF. The other terms will be

$$B = n \sum \frac{x_i^2}{y_i} - \sum x_i^2 \cdot \sum \frac{1}{y_i}$$

$$C = n \sum x_i^3 - \sum x_i \cdot \sum x_i^2$$

$$D = n \sum \frac{x_i}{y_i} - \sum x_i \cdot \sum \frac{1}{y_i}$$

F and G will be calculated as for GAUSSF but with the components computed here; and

$$H = \frac{1}{n} \left( \sum \frac{1}{y_i} - R_{12} \sum x_i - R_{13} \sum x_i^2 \right)$$

The fit curve  $R(x) = 1/[a_0(x + a_1)^2 + a_2]$  will be specified by:

$$a_{0,CAU} = F, \quad a_{1,CAU} = \frac{G}{2a_0}, \quad \text{and} \quad a_{2,CAU} = H - F a_1^2.$$

$$r_{CAU}^2 = \frac{H \sum \frac{1}{y_i} + G \sum \frac{x_i}{y_i} + F \sum \frac{x_i^2}{y_i} - \frac{1}{n} \left( \sum \frac{1}{y_i} \right)^2}{\sum \left( \frac{1}{y_i} \right)^2 - \frac{1}{n} \left( \sum \frac{1}{y_i} \right)^2}$$

- j. If you choose BESTF then the correlation coefficient will be computed with your data for model a and with the transformed data for models b through i, if allowed (cf. the *|OI|*). The model delivering the greatest absolute  $r$  value will be selected.
- k. If you choose ORTHOF then the least squares regression line parameters  $a_0$  and  $a_1$  will be computed following the formulas:

$$a_1 = \frac{1}{2s_{xy}} \left[ s_y^2 - s_x^2 \pm \sqrt{(s_y^2 - s_x^2)^2 + 4s_{xy}^2} \right] \quad \text{and} \quad a_0 = \bar{y} - a_1 \bar{x}$$

The other formulas can be taken from model a (i.e. LINF).

## Solving Differential Equations

The method applied to the examples in the respective chapter in *Section 3* of the OM develops as explained below:

First, we solve one-dimensional problems of the kind

$$\frac{d^2f}{dt^2} = a - b \left( \frac{df}{dt} \right)^2$$

This is the equation for a body (of mass  $M$ ) falling through a medium featuring drag proportional to the velocity squared of said body. For earthly problems, take  $a = 9.81 \frac{m}{s^2} = g$  and  $b = \delta/M$  with the constant parameter  $\delta$  taking care of the viscosity of the medium as well as size and shape of the falling body as a whole.

For a first guess, let us assume  $b = 0$ . So there will be no drag at all, the body will be just accelerated by  $a = g$ . Then for two arbitrary subsequent points in time,

- vertical velocity will develop like  $\left( \frac{df}{dt} \right)_{i+1} \approx \left( \frac{df}{dt} \right)_i + a\Delta t$  and
- position over ground like  $f_{i+1} \approx f_i + \left( \frac{df}{dt} \right)_i \Delta t$ .

Proceeding from time zero in small, constant time steps  $\Delta t = t_{i+1} - t_i$ :

$$f_1 = f_0 + \left( \frac{df}{dt} \right)_0 \text{ and } \left( \frac{df}{dt} \right)_1 = \left( \frac{df}{dt} \right)_0 + a\Delta t ,$$
$$f_2 = f_1 + \left( \frac{df}{dt} \right)_1 \text{ and } \left( \frac{df}{dt} \right)_2 = \left( \frac{df}{dt} \right)_1 + a\Delta t , \text{ etc.}$$

Principally, a better approximation of the slope of  $f$  is achieved using the so-called *half-step method*:

$$\left( \frac{df}{dt} \right)_{1/2} \approx \left( \frac{df}{dt} \right)_0 + a \frac{\Delta t}{2}$$

$$\left( \frac{df}{dt} \right)_{i+\frac{1}{2}} \approx \left( \frac{df}{dt} \right)_{i-\frac{1}{2}} + a\Delta t$$

$$f_{i+1} \approx f_i + \left( \frac{df}{dt} \right)_{i+1/2} \Delta t$$

Proceeding from time zero in small steps  $\Delta t$  again, we get

$$\left( \frac{df}{dt} \right)_{1/2} = \left( \frac{df}{dt} \right)_0 + a \frac{\Delta t}{2}$$

$$f_1 = f_0 + \left( \frac{df}{dt} \right)_{1/2} \text{ and } \left( \frac{df}{dt} \right)_{3/2} = \left( \frac{df}{dt} \right)_{1/2} + a \Delta t$$

$$f_2 = f_1 + \left( \frac{df}{dt} \right)_{3/2} \Delta t, \text{ etc.}$$

Let us drop the restriction for  $b$  now. Replacing  $a$  in the previous set of equations by the right side of the differential equation on p. 225, we will get the following new set:

$$\frac{df}{dt}_{1/2} \approx \frac{df}{dt}_0 + \left[ a - b \left( \frac{df}{dt} \right)_0^2 \right] \frac{\Delta t}{2}$$

$$\left( \frac{df}{dt} \right)_{i+1/2} \approx \left( \frac{df}{dt} \right)_{i-\frac{1}{2}} + \left[ a - b \left( \frac{df}{dt} \right)_{i-\frac{1}{2}}^2 \right] \Delta t$$

$$f_{i+1} \approx f_i + \left( \frac{df}{dt} \right)_{i+1/2} \Delta t$$

Proceeding from time zero in small steps  $\Delta t$  again, we get

$$\left( \frac{df}{dt} \right)_{1/2} = \left( \frac{df}{dt} \right)_0 + \left[ a - b \left( \frac{df}{dt} \right)_0^2 \right] \frac{\Delta t}{2}$$

$$f_1 = f_0 + \left( \frac{df}{dt} \right)_{1/2} \text{ and } \left( \frac{df}{dt} \right)_{3/2} = \left( \frac{df}{dt} \right)_{1/2} + \left[ a - b \left( \frac{df}{dt} \right)_{1/2}^2 \right] \Delta t$$

$$f_2 = f_1 + \left( \frac{df}{dt} \right)_{3/2} \Delta t, \text{ etc.}$$

This half-step method as explained above can be applied easily to all ordinary differential equations of second order which can be written like

$$\frac{d^2 f}{dt^2} = h \left( t, f, \frac{df}{dt} \right)$$

with an arbitrary real function  $h$  depending on **time**, the **function itself** and **its first derivative**. The equations applicable in this general case are

$$\begin{aligned} \left( \frac{df}{dt} \right)_{1/2} &= \left( \frac{df}{dt} \right)_0 + h \left( t_0, f_0, \left[ \frac{df}{dt} \right]_0 \right) \frac{\Delta t}{2} \\ \left( \frac{df}{dt} \right)_{i+1/2} &= \left( \frac{df}{dt} \right)_{i-1/2} + h \left( t_{i-1/2}, f_{i-1/2}, \left[ \frac{df}{dt} \right]_{i-1/2} \right) \Delta t \\ f_{i+1} &= f_i + \left[ \frac{df}{dt} \right]_{i-1/2} \Delta t \end{aligned}$$

For solving a 2D problem like e.g. finding the orbit of a satellite in the gravitational field of the earth, we need two differential equations, one for  $x$  and one for  $y$ :

$$\frac{d^2 x}{dt^2} = \frac{F_x}{m} = -\frac{F}{m} \frac{x}{\sqrt{x^2 + y^2}} \quad \text{and} \quad \frac{d^2 y}{dt^2} = \frac{F_y}{m} = -\frac{F}{m} \frac{y}{\sqrt{x^2 + y^2}}.$$

And we know  $F = G m M / (x^2 + y^2)$ , thus

$$\frac{d^2 x}{dt^2} = -\frac{GM}{(x^2 + y^2)^{3/2}} x = K_x \quad \text{and} \quad \frac{d^2 y}{dt^2} = -\frac{GM}{(x^2 + y^2)^{3/2}} y = K_y$$

This is a pair of coupled differential equations. It is solved as follows:

$$\left( \frac{dx}{dt} \right)_{1/2} \approx \left( \frac{dx}{dt} \right)_0 + K_x \frac{\Delta t}{2} \quad \left( \frac{dy}{dt} \right)_{1/2} \approx \left( \frac{dy}{dt} \right)_0 + K_y \frac{\Delta t}{2}$$

$$\left( \frac{dx}{dt} \right)_{i+1/2} \approx \left( \frac{dx}{dt} \right)_{i-1/2} + K_x \Delta t \quad \left( \frac{dy}{dt} \right)_{i+1/2} \approx \left( \frac{dy}{dt} \right)_{i-1/2} + K_y \Delta t$$

$$x_{i+1} \approx x_i + \left( \frac{dx}{dt} \right)_{i+1/2} \Delta t \quad y_{i+1} \approx y_i + \left( \frac{dy}{dt} \right)_{i+1/2} \Delta t$$

## Orthogonal Polynomials

The following polynomials are all collected in X.FN'ORTHO.

Name	Remarks (see pp. 12ff for general information)
$H_n$	<p><b>Hermite polynomials</b> for <u>probability</u>: <math>H_n(x) = (-1)^n \cdot e^{x^2/2} \cdot \frac{d^n}{dx^n} \left( e^{-x^2/2} \right)</math></p> <p>with <math>n</math> in <b>Y</b>, solving the differential equation</p> $f''(x) - 2x \cdot f'(x) + 2n \cdot f(x) = 0 .$ <p>See the first five polynomials plotted overleaf.</p>

Name	Remarks (see pp. 12ff for general information)
$H_{np}$	<p><b>Hermite polynomials for physics:</b> <math>H_{np}(x) = (-1)^n \cdot e^{x^2} \cdot \frac{d^n}{dx^n} (e^{-x^2})</math></p> <p>with <math>n</math> in <b>Y</b>, solving the same differential equation. See the first five polynomials plotted below.</p>

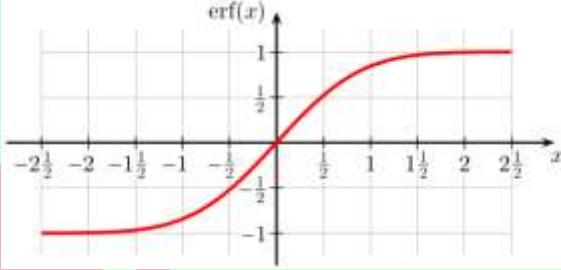
Name	Remarks (see pp. 12ff for general information)
$L_m$	<p><b>Laguerre polynomials</b> (compare <math>L_{n\alpha}</math> below):</p> $L_n(x) = \frac{e^x}{n!} \cdot \frac{d^n}{dx^n} (x^n e^{-x}) = L_n^{(0)}(x)$ <p>with <math>n</math> in <math>\mathbb{Y}</math>, solving the differential equation <math>x \cdot f''(x) + (1-x) \cdot f'(x) + n \cdot f(x) = 0</math>.</p> <p>See the first five Laguerre polynomials plotted here.</p>
$L_{m\alpha}$	<p><b>Laguerre's generalized polynomials</b> (compare <math>L_n</math> above):</p> $L_n^{(\alpha)}(x) = \frac{x^{-\alpha} e^x}{n!} \cdot \frac{d^n}{dx^n} (x^{n+\alpha} e^{-x})$ <p>with <math>n</math> in <math>\mathbb{Y}</math> and <math>\alpha</math> in <math>\mathbb{Z}</math>. Some of them are plotted below (<math>k = \alpha</math>).</p>

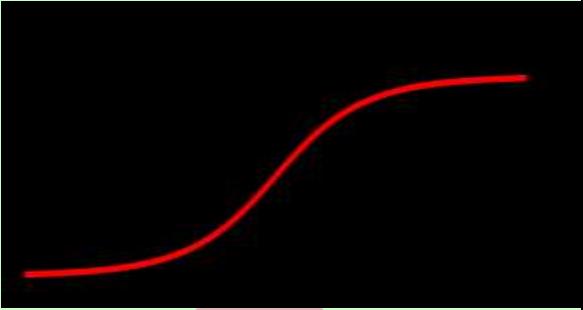
Name	Remarks (see pp. 12ff for general information)
$P_n$	<p><b>Legendre polynomials:</b> <math>P_n(x) = \frac{1}{2^n n!} \cdot \frac{d^n}{dx^n} [(x^2 - 1)^n]</math> with <math>n</math> in Y, solving the differential equation</p> $\frac{d}{dx} \left[ (1-x^2) \cdot \frac{d}{dx} f(x) \right] + n(n+1)f(x) = 0.$ <p>See the first six polynomials plotted here.</p>
$T_n$	<p><b>Chebyshev (a.k.a. Čebyšev, Tschebyschow, Tschebyscheff) polynomials of first kind</b></p> <p><math>T_n(x) = \begin{cases} \cos(n \arccos(x)) &amp; \text{for } -1 \leq x \leq 1 \\ \cosh(n \operatorname{arcosh}(x)) &amp; \text{for } x &gt; 1 \\ (-1)^n \cosh(n \operatorname{arcosh}(-x)) &amp; \text{for } x &lt; -1 \end{cases}</math> with <math>n</math> in Y,</p> <p>solving the differential equation</p> $f''(x) - \frac{x}{1-x^2} f'(x) + \frac{n^2}{1-x^2} f(x) = 0$ <p>The plot overleaf shows <math>T_0(x) \dots T_5(x)</math>.</p>

Name	Remarks (see pp. 12ff for general information)
	<p>The graph shows the Chebyshev polynomials of the first kind, <math>T_n(x)</math>, for <math>n = 0, 1, 2, 3, 4, 5</math>. The x-axis is labeled <math>x</math> and ranges from -1.0 to 1.0. The y-axis is labeled <math>T_n(x)</math> and ranges from -1.0 to 1.0. The curves are symmetric about the y-axis. The legend indicates the following curves:      - <math>n=0</math>: A constant red line at <math>y=1</math>.      - <math>n=1</math>: A black curve passing through <math>(-1, -1)</math> and <math>(1, 1)</math>.      - <math>n=2</math>: A blue curve with two extrema at <math>x = \pm\sqrt{3}/2</math>.      - <math>n=3</math>: An orange curve with three extrema at <math>x = \pm\sqrt{5}/2</math> and <math>x = 0</math>.      - <math>n=4</math>: A green curve with four extrema at <math>x = \pm\sqrt{7}/2</math> and <math>x = \pm\sqrt{3}/2</math>.      - <math>n=5</math>: A black curve with five extrema at <math>x = \pm\sqrt{9}/2</math>, <math>x = \pm\sqrt{5}/2</math>, and <math>x = 0</math>.</p>
$U_n$	<p><b>Chebyshev polynomials of second kind</b> <math>U_n(x)</math> with <math>n</math> in <math>\mathbb{Y}</math>, solving the differential equation</p> $f''(x) - \frac{3x}{1-x^2} f'(x) + \frac{n(n+2)}{1-x^2} f(x) = 0$ <p>The plot below shows <math>U_0(x) \dots U_5(x)</math>:</p> <p>The graph shows the Chebyshev polynomials of the second kind, <math>U_n(x)</math>, for <math>n = 0, 1, 2, 3, 4, 5</math>. The x-axis is labeled <math>x</math> and ranges from -1.0 to 1.0. The y-axis is labeled <math>U_n(x)</math> and ranges from -1.5 to 1.5. The curves are antisymmetric about the origin. The legend indicates the following curves:      - <math>n=0</math>: A constant red line at <math>y=1</math>.      - <math>n=1</math>: A black curve passing through <math>(-1, 0)</math> and <math>(1, 0)</math>.      - <math>n=2</math>: A blue curve with two extrema at <math>x = \pm\sqrt{3}/2</math>.      - <math>n=3</math>: An orange curve with three extrema at <math>x = \pm\sqrt{5}/2</math> and <math>x = 0</math>.      - <math>n=4</math>: A green curve with four extrema at <math>x = \pm\sqrt{7}/2</math> and <math>x = \pm\sqrt{3}/2</math>.      - <math>n=5</math>: A black curve with five extrema at <math>x = \pm\sqrt{9}/2</math>, <math>x = \pm\sqrt{5}/2</math>, and <math>x = 0</math>.</p>

## Even More Mathematical Functions

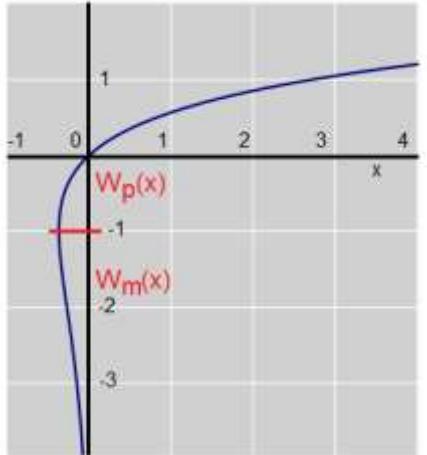
All the following functions are found in X.FN. Some of them are for pure mathematics only but were useful at some stages of the *WP 34S* or *WP 43S* projects, so we made them accessible for the public.

Name	Remarks (see pp. 12ff for general information)
AGM	Returns the <i>arithmetic-geometric mean</i> . Find more about it here: <a href="http://mathworld.wolfram.com/Arithmetic-GeometricMean.html">http://mathworld.wolfram.com/Arithmetic-GeometricMean.html</a> .
erf	Returns the <i>error function</i> $\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-\tau^2} d\tau$ .  <p>Note that <math>\text{erf}\left(\frac{x}{\sqrt{2}}\right) = 2 \cdot \Phi(x) - 1</math> with <math>\Phi(x)</math> representing the <i>standard normal CDF</i> as described on p. 211. Beyond statistics, the <i>error function</i> may be helpful in heat conduction and diffusion problems, for instance.</p>
erfc	This command returns the <i>complementary error function</i> $\text{erfc}(x) = 1 - \text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-\tau^2} d\tau$ . This function is related to the <i>error probability</i> of the <i>standard normal distribution</i> .

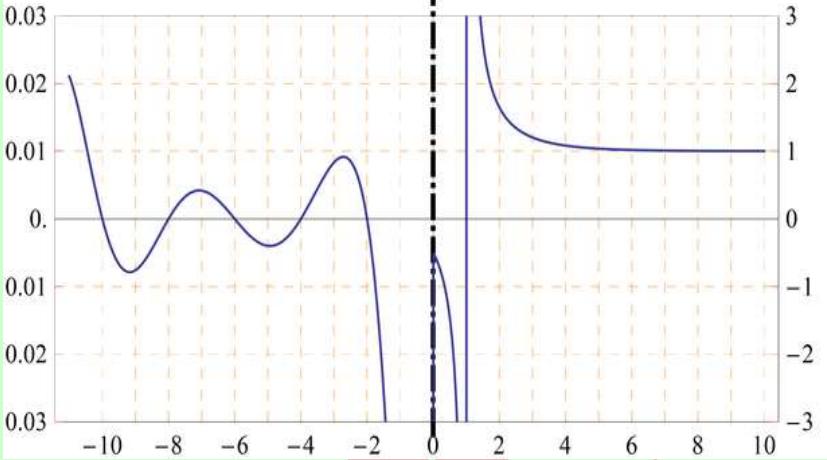
Name	Remarks (see pp. 12ff for general information)
$g_d$	<p>Returns the <i>Gudermannian function</i></p> $g_d(x) = \int_0^x \frac{d\xi}{\cosh \xi}$ <p>linking hyperbolic and trigonometric functions. See the plot for its real values. The <i>inverse Gudermannian function</i> is</p> $g_d^{-1}(x) = \int_0^x \frac{d\xi}{\cos \xi}.$ <p>Start reading here for more:  <a href="http://en.wikipedia.org/wiki/Gudermannian_function">http://en.wikipedia.org/wiki/Gudermannian_function</a>.</p> 
$I_{xyz}$	<p>Returns the <i>regularized (incomplete) Beta function</i> <math>\frac{\beta_x(x, y, z)}{B(y, z)}</math> with</p> $\beta_x(x, y, z) = \int_0^x t^{y-1} (1-t)^{z-1} dt$ <p>being the <i>incomplete Beta function</i> and <math>B(y, z)</math> being <i>Euler's Beta function</i> (see p. 90 and <a href="https://en.wikipedia.org/wiki/Beta_function">https://en.wikipedia.org/wiki/Beta_function</a>).</p>
$I\Gamma_p$	<p>Returns the <i>regularized Gamma function</i> <math>P(x, y) = \frac{\gamma(x, y)}{\Gamma(x)}</math></p> <ul style="list-style-type: none"> <li>See <math>\gamma_{XY}</math> below for <math>\gamma(x, y)</math> and p. 91 for <math>\Gamma(x)</math>.</li> </ul>
$I\Gamma_q$	<p>Returns the <i>regularized Gamma function</i> <math>Q(x, y) = \frac{\Gamma_u(x, y)}{\Gamma(x)}</math></p> <p>See <math>\Gamma_{XY}</math> below for <math>\Gamma_u(x, y)</math> and p. 91 for <math>\Gamma(x)</math>.</p>

See here for more:  
[https://en.wikipedia.org/wiki/Incomplete\\_gamma\\_function](https://en.wikipedia.org/wiki/Incomplete_gamma_function)

Name	Remarks (see pp. 12ff for general information)
$J_y(x)$	<p>Generally, the <i>Bessel functions</i> solve the differential equation</p> $x^2 f''(x) + xf'(x) + (x^2 - \nu^2)f(x) = 0 \quad \text{with } \nu \in \mathbb{C}.$ <p><math>J_y(x)</math> returns the <i>Bessel function of first kind</i> and order <math>y = \nu</math>. For arbitrary <math>\nu</math>, this is</p> $J_\nu(x) = \sum_{m=0}^{\infty} \frac{(-1)^m}{m! \Gamma(m+\nu+1)} \left(\frac{x}{2}\right)^{2m+\nu}$ <p>For integer <math>\nu</math>, this is also</p> $J_\nu(x) = \frac{1}{\pi} \int_0^\pi \cos[\nu t - x \sin(t)] dt$ <p>Start reading here for more information:  <a href="http://en.wikipedia.org/wiki/Bessel_function">http://en.wikipedia.org/wiki/Bessel_function</a>.</p>

Name	Remarks (see pp. 12ff for general information)
$W_p$ , $W_m$	<p>Returns <i>Lambert's W</i> with its principal branch (called <math>W_p</math> here) and its negative branch (called <math>W_m</math> for <u>minus</u>). The connecting point is <math>(-1/e, -1)</math>. The diagram shows the real values of both branches.</p> <p>Start reading here for more information:  <a href="http://en.wikipedia.org/wiki/Lambert_W_function">http://en.wikipedia.org/wiki/Lambert_W_function</a> . Learn more here:  <a href="http://mathworld.wolfram.com/LambertW-Function.html">http://mathworld.wolfram.com/LambertW-Function.html</a> .</p> 
$\gamma_{xy}$	<p>Returns the <i>lower incomplete Gamma function</i></p> $\gamma(x, y) = \int_0^y t^{x-1} e^{-t} dt .$ <p>Required for <math>\text{IG}_p</math> above.</p>
$\Gamma_{xy}$	<p>Returns the <i>upper incomplete Gamma function</i></p> $\Gamma_u(x, y) = \int_y^\infty t^{x-1} e^{-t} dt .$ <p>Required for <math>\text{IG}_q</math> above.</p>
$\zeta(x)$	<p>Returns <i>Riemann's Zeta</i> for real arguments, with</p> $\zeta(x) = \sum_{n=1}^{\infty} \frac{1}{n^x}$ <p>for <math>x &gt; 1</math> , and its analytical continuation for <math>x &lt; 1</math> :</p> $\zeta(x) = 2^x \pi^{x-1} \sin\left(\frac{\pi}{2} x\right) \cdot \Gamma(1-x) \cdot \zeta(1-x).$ <p>Note the different vertical scales for negative and positive <math>x</math> in the plot overleaf.</p>

See here for more:  
[https://en.wikipedia.org/wiki/Incomplete\\_gamma\\_function](https://en.wikipedia.org/wiki/Incomplete_gamma_function)

Name	Remarks (see pp. 12ff for general information)
	 <p>Look here for more:  <a href="http://mathworld.wolfram.com/RiemannZetaFunction.html">http://mathworld.wolfram.com/RiemannZetaFunction.html</a> .</p>

Note the *error function* as well as *Laguerre*, *Legendre*, and *Bessel functions* were already provided on the *Commodore M55* pocket calculator of 1976/77 (featuring 55 keys).

Beyond what is printed in this appendix, you will find lots of information about the special functions implemented in your *WP 43S* in the internet in addition. Generally speaking, *Wikipedia* is a good starter – we recommend checking the articles in different languages since they may well contain different material and use different approaches. For applied statistics, the *NIST Sematech* online handbook (quoted on pp. 203ff) is a competent source. And *Mathworld* (quoted on pp. 233ff) may contain more details than you ever want to know. Further references are found at these sites.

## APPENDIX I: INFORMATION FOR ADVANCED USERS

### Recursive Programming

Using local registers allows for creating a subroutine that calls itself recursively. Each invocation deals with its local data only. Of course, the *RPN stack* is global so be careful not to corrupt it.

Below is a recursive implementation of the factorial. It is an **example** for demonstration purposes only, since this routine will neither set the *stack* correctly nor will it work for input greater than some hundred:

```
LBL 'FACT'  
IP  
X> 1 ?  
GTO 00  
1  
RTN  
LBL 00  
LocR 01  
STO .00  
DEC X  
XEQ 'FACT'  
RCLx .00  
RTN
```

Assume  $x=4$  when you call FACT. Then it will allocate one local register (**R.00**) and store **4** therein. After decrementing  $x$ , FACT will call itself.

Then FACT<sub>2</sub> will allocate a local register (**R.00<sub>2</sub>**) and store **3** therein. After decrementing  $x$ , FACT will call itself again.

Then FACT<sub>3</sub> will allocate a local register (**R.00<sub>3</sub>**) and store **2** therein. After decrementing  $x$ , FACT will call itself once more.

Then FACT<sub>4</sub> will return to FACT<sub>3</sub> with  $x=1$ . This  $x$  will be multiplied by **r.00<sub>3</sub>** there, returning to FACT<sub>2</sub> with  $x=2$ . This  $x$  will be multiplied by **r.00<sub>2</sub>** there, returning to FACT with  $x=6$ , where it will be multiplied by **r.00** and will finally become 24.

Xxx

## APPENDIX J: RELEASE NOTES

	Date	Release notes
0	29.11.12	<b>Official project start with the first publication of a layout on the forum of the MoHPC</b> ( <a href="https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234685#234685">https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234685#234685</a> ). There are found, however, far older traces of a '43S' denoting a 'Super HP-42S', though in various more or less fictional cases – pure vapourware™.
0.1	2.2.14 23.5.15	Manual setup based on the one of WP 34S. Passed to <i>Jake Schwartz</i> , <i>Eric Smith</i> , and <i>Richard Ottosen</i> for first information.
0.2	3.10.15	Update based on Jake's feedback and further thoughts, distributed to <i>Eric</i> , <i>Jake</i> , <i>Marcus</i> , and <i>Pauli</i> .
0.3	21.3.16	Split the manual in three; moved LBL onto the keyboard, renamed STOM to STOCFG, RCLM to RCLCFG, SERR to $s_m$ , and SERR <sub>w</sub> to $s_{mw}$ ; refined the <i>Key Response Table</i> . Passed to <i>Michael Steinmann</i> for information.
0.4	28.3.16	Renamed LOGS to EXP and <b>EEX</b> to <b>E</b> . Added hardware information from 2 <sup>nd</sup> manufacturer.
0.5	29.10.16	Returned <b>EEX</b> . Changed the keyboard layout.
0.6	22.8.17	Merged the <i>Applications</i> and <i>Owner's Manual</i> . Changed the input order of complex number parts on <i>Pauli</i> 's request. Changed the keyboard layout introducing D.MS, SST, BST, and % while removing ÿ, RAN#, 'FRC, and 'CFIT. Put 'CFIT into 'STAT and 'FRC into 'MODE. Placed OFF below EXIT for easier customizing. Renamed cc to C5, <b>EEX</b> to <b>E</b> , STOPW to TIMER, SHOW to REGS, 'SOLVE to 'ADV, DLINES to DSTACK, 12h to CLK12, and 24h to CLK24. Replaced IND by →. Deleted %MG since covered by Δ%, added EIGVAL and EIGVEC. Swapped CNST and CONST. Defined the echo rows for alphanumeric and command input. Expanded and modified the character sets for better use of display space. Added the QRG.

Date	Release notes
0.7 2.4.18	Changed keyboard layout. Replaced the labels BST by <b>≡A</b> , SST by <b>≡V</b> , and UNDO by <b>↶</b> ; added some <i>alpha input mode</i> reminders on the keyboard. Added AGRAPH, CLLCD, EQ.xxx, <b>HYP</b> , J/G, M.GOTO, ORTHOF, PIXEL, POINT, TDISP, and <b>USER</b> . Moved the background considerations out of <i>ReM App. D</i> . Introduced <b>K</b> as <i>alpha register</i> for alphanumeric constants in programs. Removed <i>fraction data type</i> . Extended <i>items</i> from 6 to 7 characters to match <i>HP-42S</i> . Specified <i>data types</i> more precisely in <i>ReM App. D</i> . Reduced the maximum number of <i>local registers</i> from 888 to 100. Deleted JG1582 and JG1752. Renamed two commands for TVM. Replaced the heading apostrophe for <i>menu names</i> . Put <b>SUMS</b> in <b>STAT</b> . Renamed the trigonometric and hyperbolic functions according to mathematical standards, and <b>CHR</b> to <b>CHAR</b> . Redistributed the chapter about constants. Modified STATUS display. Refined the unit conversions to ensure <i>SI</i> on one side. Specified 0 SEED. Expanded <i>ReM App. A</i> . Added formula output for L.R. Modified CPX?, DBL?, and REAL?. Changed output of binary tests for compatibility with <i>HP-42S</i> .
0.8 7.5.18 20.9.18	Changed keyboard layout: introduced <b>TRG</b> containing trigonometric functions, removed <b>HYP</b> into <b>EXP</b> and <b>π</b> to g-shifted <b>7</b> , swapped some shifted labels. Refined the chapters about register arithmetic, <i>Command Parameter Input</i> , <i>Alphanumeric Input</i> , <i>Matrix Calculations</i> , and <i>Orthogonal Polynomials</i> . Introduced CLCVAR and more vintage examples. Rearranged <i>temporary information</i> on the screen. Renamed REGS to RBR and CLx to CLX. Deleted ANGLE.  Corrected errors and inconsistencies. Added one more example. Moved the key response table into an appendix.
0.9 3.1.19	Removed the <i>angle data type</i> . Added another industrial application and many more examples. Exchanged keyboard pictures due to changed bezel. Expanded <i>App. B</i> . Added SHOW for displaying full precision of DP numbers and FBR for browsing our two fonts. Split a chapter. Expanded some titles. Added the overlay drawing. Modified functionality of <b>EXIT</b> and <b>½</b> to match <i>HP-42S</i> . Added a chapter about curve fitting. Modified functionalities of <b>ENTER↑</b> and <b>↶</b> . Moved the printer character to <b>f R/S</b> . Expanded <i>App. K</i> . Renamed DOUBLE to →DP. Added →SP and conversions of <i>quarts</i> . Rearranged <b>X.FN</b> . Replaced <b>USR</b> by <b>UM</b> . Changed keyboard moving <b>UM</b> , <b>½</b> , and <b>TRI</b> . Added XIN and XOUT. Added a chapter in <i>App. E</i> and information about infinite integers. Extended the domain of GCD and LCM. Refined and corrected.

	Date	Release notes
0.10	3.3.19	Returned <i>angle data type</i> and $\alpha$ SR. Added IDIVR and VANGLE. Refined FP, IP, IMPFRC, PROFRC, SDIGS?, $\rightarrow$ DP, $\rightarrow$ HR, $\rightarrow$ INT, $\rightarrow$ REAL, $\rightarrow$ SP, explanation of ALL, the summary of integer functions, and handling of long alpha strings. Modified contents of <u>CPX</u> , <u>MATX</u> , and $\alpha$ . Added a summary of matrix functions. Removed the <u>ON</u> -key combinations. Modified MEM?. Rewrote the angular conversions. Renamed infinite and finite integers to <i>long</i> and <i>short integers</i> . Added a chapter about $\pm\infty$ and NaN. Modified RBR and the menu for STO and RCL. Removed $\blacksquare$ from the keyboard. Renamed $X_u$ to $X_e$ for the distributions. Corrected.
0.11	8.5.19	Changed keyboard making <u>CC</u> primary and user mode shifted, removing $x^2$ , $x\bar{x}$ , and DSP, adding $ x $ , DROP, and SHOW, and moving some shifted labels. Modified <u>BITS</u> , CLREGS, <u>CNST</u> , <u>CPX</u> , <u>DISP</u> , <u>EXP</u> , <u>INTS</u> , <u>MODE</u> , <u>PARTS</u> , SHOW, <u>STAT</u> , <u>U<math>\rightarrow</math></u> , <u><math>\alpha</math>MATH</u> , the division matrix, <i>data type</i> conversions, and the <i>Quick Reference Guide</i> . Added conversions of <i>barrels</i> , <i>carats</i> , and <i>fathoms</i> . Deleted DSP. – Separated predefined variables. Refined Sect. 6. Added $\bar{x}_H$ , $\bar{x}_{RMS}$ ; nine statistical sums and five curve fit models. Split <u>STAT</u> in <u>STAT</u> and <u>SUMS</u> ; renamed RMDR to RMD, $L_n$ to $L_m$ , $L_{na}$ to $L_{ma}$ , $\Pi$ to $\Pi_n$ , $\Sigma$ to $\Sigma_n$ , and some constants to avoid search ambiguities. Refined App. J, Sect. 3 and 4, $\rightarrow$ INT, CLR, and the functions of $\Delta$ and $\nabla$ . Put <u>SUMS</u> instead of RMD on the keyboard, moved <u>ADV</u> , <u>BITS</u> , <u>CATALOG</u> , <u>EQN</u> , <u>FILL</u> , <u>INTS</u> , <u>MATX</u> , <u>MODE</u> , <u>PROB</u> , RTN, SHOW, <u>STAT</u> , and $\alpha$ .FN. Rearranged <u>A...<math>\Omega</math></u> and Sect. 2 of the OM. Corrected.
0.12	9.9.19	Rearranged the appendices of the <i>ReM</i> from App. D on. Expanded App. A of the OM and App. K. Deleted the standardized normal distribution $\Phi$ and rearranged <u>PROB</u> . Updated <u>CNST</u> following CODATA 2018. Renamed the angular conversions. Changed the composing and cutting functionality of <u>CC</u> . Refined exiting <i>short integer</i> input. Expanded App. D. Specified maximum size of <i>long integers</i> . Changed keyboard adding $\sqrt[4]{}$ , moving <u>CPX</u> , <u>FIN</u> , RBR, R $\uparrow$ , and SHOW, removing %. Renamed VANGLE to V $\sqrt[4]{}$ . Modified <u>CPX</u> , <u>MATX</u> , <u>TRI</u> , and <u>X.FN</u> . Rearranged Section 1 of the OM. Added some internal <i>data types</i> to App. B. Corrected.



# WP 43S QUICK REFERENCE GUIDE

## USING MENUS

A *menu* defines the top row of keys by displaying up to three *softkeys* above each . If the current *menu* has more than three rows, its current view is limited by a dashed line indicating that it is a *multi-view menu* and or can be used to display the additional views of this *menu*.

## MEMORY

The **stack** is a workspace for calculations. Each **stack register** may contain any type of data. Choose a **stack** of four (**X**, **Y**, **Z**, and **T**) or eight **registers** (**X**, **Y**, **Z**, **T**, **A**, **B**, **C**, and **D**). Last  $x$  is saved in **register L**.

**General purpose registers:** There are 100 numbered global general purpose **registers** (00 ... 99). And there are **I**, **J**, and **K** serving special purposes in matrix handling (see p. vii), probability distributions (see p. viii), and programming but may be used globally otherwise. Also **A**, **B**, **C**, and **D** may be used this way unless being part of **stack**. Each **register** may contain any type of data. **STO nn** stores a copy of  $x$  into **Rnn**, **RCL nn** recalls a copy of the contents of **Rnn** into **X**, and **xz nn** swaps  $x$  and the contents of **Rnn**.

**Variables** are named storage locations that may contain any type of data. E.g. for storing  $x$  into a variable named **XYZ**, enter **STO** **@ XYZ ENTER↑**. Variable names shall be unique,  $\leq 7$  characters long, and contain  $\geq 1$  letter.

**Flags:** There are 112 global user *flags*. Of these, the following have a special meaning if set:

- 103 **T** sets print mode to Tracing
- 105 **B** Overflow
- 106 **C** Carry
- 107 **D** allows for infinite and non-numeric results ("Danger")
- 109 **I** allows for complex results

**Programs** consist of  $\geq 4$  program steps: LBL with a global label, at least one action step, RTN, and END. Each program may contain subroutines (up to 8 levels deep). See p. v for more.

**Available memory:** **INFO MEM?** (or **FLAGS STATUS**) displays the amount of free memory. Use CLP for clearing programs or clear variables to deallocate memory that is no longer needed.

## DATA TYPES

**Long integers** are the simplest type of data. Any number you enter without using **.  
E  
CC** is taken as a *long integer* of base 10.

**Real numbers:** Any number you enter using **.** and/or **E** is a real number.

**Complex numbers:** A complex number consists of two real numbers combined to represent its real and imaginary part like **1.23-i×4.56** in rectangular mode (set RECT and press **1.23 CC 4.56 +/- ENTER↑**) or its magnitude and phase like **-7.89 ∠ 120°** in polar mode (set POLAR and press **7.89 +/- CC 120 ENTER↑**).

**Angles:** Any real number input trailed by **d.ms** is interpreted as an *angle* in *sexagesimal degrees*. Alternatively, *angles* may be entered as well in *decimal degrees, radians, multiples of π, or radians*. Choose the appropriate angular display mode via **MODE** (see overleaf).

**Times:** Any real number input trailed by **h.ms** is interpreted as a sexagesimal *time*. It will be displayed like **23:45:43.210 9** with as many decimal *seconds* as needed.

**Dates:** Any real number input trailed by **.d** is interpreted as a *date* in the format selected (yyyy.mmdd for Y.MD or dd.mm-yyyy for D.MY or mm.dd-yyyy for M.DY).

**Matrices:** see p. vii.

**Short integers:** Any numeric input trailed by **#** and a legal base is interpreted as a *short integer* of the base specified. **D** and **H** are shortcuts for base 10 and 16, respectively. *Short integers* may occupy 1 ... 64 bits.

**Alphanumeric strings:** Enter *alpha input mode (AIM)* by pressing **α**. Data entered in AIM become an alphanumeric string when closed (unless they are function parameters). International (e.g. accented) letters are found in **g +**. Greek letters are accessed via **g** plus the corresponding Latin letter. Turn to lower case by **▼** and back to upper by **▲** for all letters.

**f** plus one of the keys **+**, **-**, **×**, **/**, **.**, and **0** – **9** will enter the corresponding character. Special characters are found in **g -** and **g .**

**f R↓** makes the subsequent character entered a subscript, **f E** makes it a superscript, if applicable.

## MODES

	SETSIG				LZOFF		
	1COMPL	2COMPL	UNSIGN	SIGNMT	LZON	WSIZE	
MODE	DENMAX	DENANY	DENFAC	DENFIX	SSIZE4	SSIZE8	
	FAST	SLOW	RM	QUIET	REALRE	CPXRES	
	DEG	RAD	GRAD	MUL $\pi$	RECT	POLAR	

- DEG      Selects *degrees*      as angular display mode (*ADM*).  
 RAD      Selects *radians*      as *ADM*.  
 GRAD     Selects *gradians*, a.k.a. *gon*, as *ADM*.  
 MULT $\pi$    Selects *multiples of  $\pi$*       as *ADM*.  
 RECT     Sets rectangular format    for displaying complex numbers.  
 POLAR    Sets polar format        for displaying complex numbers.  
 FAST     Sets processor to normal speed.  
 SLOW    Reduces processor speed (approx. two times slower than fast).  
 RM      Sets rounding mode.  
 QUIET   Disables or enables the beeper.  
 REALRE   Allows only real results.  
 CPXRES   Allows also complex results of real calculations (e.g.  $\sqrt{-1}$  ).  
 DENMAX   Sets the maximum denominator for calculating with fractions.  
 DENANY   Any denominator up to DENMAX is legal.  
 DENFAC   Any integer factor of the maximum denominator is legal  
 DENFIX   Sets DENMAX as fixed denominator.  
 SSIZE4, SSIZE8   Sets stack size to 4 (or 8) *registers*.  
 SETSIG      Sets calculator precision (1 ... 34 significant digits).

For the commands 1COMPL through WSIZE see *OPERATIONS ON SHORT INTEGERS* on p. xiii.

## DISPLAY FORMATS

	CHINA	EUROPE	INDIA	JAPAN	UK	USA	
	GAP				DSTACK		
	SCI0VR	ENG0VR	MULT $\times$	MULT $\cdot$	RDX.	RDX,	
DISP	SDL	SDR				RDP	RSD
	FIX	SCI	ENG	ALL	ROUND1	ROUND	

FIX	Fixed number of decimals.
SCI, ENG	Scientific (or engineering) notation.
ALL	Displays all digits required as far as possible.
ROUND	Rounds a <i>time</i> , real, or complex <i>x</i> to current display format.
ROUNDI	Rounds to next integer.
RDP	Rounds <i>x</i> to <i>n</i> decimal places (1 ... 99, think of FIX)
RSD	Rounds <i>x</i> to <i>n</i> significant digits (1 ... 34, think of SCI).
SDL, SDR	Shifts digits left (right) by <i>n</i> decimal positions.
SCIOVR, ENGOVR	Specify the display format if ALL is not viable anymore.
MULT $\times$ , MULT $\cdot$	Select the multiplication symbol.
RDX., RDX,	Select the radix mark.
GAP	Selects a digit group gap inserted after every <i>n</i> digits.
DSTACK	Sets the number of <i>stack registers</i> displayed (1 ... 4).
CHINA, EUROPE, INDIA, JAPAN, UK, USA	Set local display preferences.

## EXECUTING FUNCTIONS AND PROGRAMS

Any function or program can be executed via **[XEQ]  $\alpha$  name [ENTER↑]** where **name** is the function name or the program label. If **name** is not unique, the global label closest to the permanent end (.END.) has precedence. If **name** is a local label, WP 43S searches the current program only.

**Smart program menu:** **[XEQ] PROGS** displays all programs (actually: global labels) defined. Specify the required program by pressing the corresponding softkey.

**Single stepping:** To execute the current program step, press **≡V** (or **▼** if no multi-view menu is displayed).

**The Run/Stop key:** Pressing **R/S** runs the current program beginning with the current step or stops a running program after the current step is executed completely.

**The catalog of functions:** Browse **CATALOG FCNS** and execute the required function by pressing the corresponding softkey. This catalog can be searched alphabetically.

## Specifying Function Parameters

**Numeric parameters:** Functions accepting numeric parameters prompt you with a cursor for each digit expected. To key in a numeric parameter, just enter its digits. If you provide a digit for each underscore, the function will execute. You can also provide less digits and complete input with **ENTER↑**.

**Alphanumeric parameters:** Many functions accept alphanumeric parameters as well. The parameter you want will often be an object already existing, so your WP 43S will display a *menu* for quick entry. If it does not exist yet, type it. E.g. for creating a variable ABC just type **STO** **ABC** **ENTER↑**.

**Stack parameters:** Any function accepting a ‘usual’ *register* as parameter also accepts a *stack register*. Just press the corresponding *softkey* for X ... T or the keys in second row for A ... D, if applicable.

**Indirect addressing:** Rather than providing an actual parameter, you can specify the variable or *register* containing the parameter. Just press the *softkey* **→**. E.g. to display the contents of the variable or *register* specified in R12, key in **VIEW** **→** **12**. This works with *stack registers* as well.

## CLEARING AND DELETING

<b>CLR</b>	<b>CLall</b>					<b>RESET</b>	<b> </b>	
	<b>CLREGS</b>	<b>CLPall</b>	<b>CLFall</b>			<b>CLLCD</b>	<b>CLSTK</b>	
	<b>CLΣ</b>	<b>CLP</b>	<b>CF</b>	<b>CLMENU</b>	<b>CLCVAR</b>	<b>CLX</b>		

- CLΣ** Clears all statistical data.
- CLP** Clears (deletes) the *current program*.
- CF *n*** Clears *flag n*.
- CLMENU** Clears the *programmable menu*.
- CLCVAR** Clears all variables used in *current program*.
- CLX** Clears *stack register X*.
- CLREGS** Clears all *registers* (except the *stack* and statistical data).
- CLPALL** Clears (deletes) all programs in *RAM*.
- CLFall** Clears all user *flags*.
- CLLCD** Clears the *LCD* above and to the right of pixel *x, y*.
- CLSTK** Clears the entire *stack* (i.e. fills all its *registers* with zero).
- CLALL** Clears everything but the modes set.
- RESET** Resets the *WP 43S* to *startup default*.

- CATALOG VARS ...** allows for deleting the user variable selected.
- CATALOG MENUS ...** allows for deleting the user *menu* selected.
- CATALOG PROGS ...** allows for deleting the user program selected.

# PROGRAMMING

## Program Entry

- P/R** toggles *program entry mode*.
- GTO** [ ] moves the *program pointer* to a new program space.
- GTO** [ ] *nnnn* moves it to step number *nnnn*.
- ▲** moves it to previous step  
**▼** moves it to next step  
**[ ]** deletes the *current program step* entirely. (use **▲** or **▼** if no *multi-view menu* is displayed).

## Labels

A program label is a marker used to identify an entire program or a section within a program. Each program must begin with a global label.

**Global labels** can be accessed from anywhere in memory (thus, they should be unique). Global labels are alphanumeric and up to 7 characters long.

**Local labels** can be accessed only within the current program (thus, they should be unique within this program). Local labels are numeric (00 ... 99).

## Local registers

... are allocated via **LOCR n** with the amount of *registers* specified ( $\leq 100$ ). 16 *local flags* come with them. Local data are valid in the calling routine only.

## Tests (Do if True, Skip if False)

When a test step (a.k.a. a conditional function) is executed, the program step immediately following said conditional is executed if the condition is “true”; if the condition is “false”, the step following the conditional is skipped.

## Looping

ISE, ISG, ISZ, DSE, DSL, and DSZ (found in LOOP) control looping. Each accesses a variable or *register* containing a loop control number in the form cccccccc.ffffii with cccccccc being the current counter value, ffff the final counter value, and ii the increment (or decrement) size (default is 1). As long as the count is not complete, the step following the instruction is executed (usually a branch to the top of the loop). E.g. the program segment pictured here counts from 1 to 52 by threes (executing the loop 18 times) and then beeps.

```
...
1.05203
STO "Count"
LBL 01
...
ISG "Count"
GTO 01
BEEP
...
```

## Using a Variable Menu

A *variable menu* may be displayed by the *Solver* or the numeric integrator (see p. xif) or by VARMNU within a program. Each label in the *menu* represents a variable. While the *menu* is displayed, you can:

**Store a value into a variable:** Key in the value and then press the *softkey*.

**Recall the contents of a variable:** Press **RCL** and then the *softkey*.

**View the contents of a variable without recalling it:** Press **VIEW** and then the *softkey*.

**Select a variable:** Press the corresponding *softkey* without keying in a number first. (For the *Solver*, this is how you select the unknown variable; for the integrator, this is how you select the variable of integration.)

You can call and use any function *menu* without exiting from the *variable menu*.

## MATRIX OPERATIONS

A matrix is an array with **m** rows and **n** columns of real or complex elements.

**To create a new  $m \times n$  matrix,** enter its dimensions (**m** **ENTER↑** **n**) and press

**MATX NEW** for a matrix in X or

**MATX DIM** **α name** **ENTER↑** for a matrix in a variable. If the variable already exists, DIM re-dimensions it.

**For editing the matrix in X,** use **MATX EDIT** .

**For editing a named matrix,** use **MATX EDITN name**.

When a matrix is being edited it is said to be *indexed* (to index a named matrix without editing it, use INDEX). Whenever there is an indexed matrix, two pointers are used to indicate the row and column of the current element: they are stored in **I** and **J**, respectively. If **I** and **J** are pointing to the last element (bottom right) in a matrix and you press **→** then ...

- ...the pointers wrap around to the first element of the matrix (**Wrap mode**, automatically set whenever you enter or exit the *Matrix Editor*) or ...
- ...the matrix grows by one complete row and the pointers move to the new row (**Grow mode**).

WRAP and GROW are in the **f**-shifted row of the *Matrix Editor menu*.

**Matrix arithmetic:** **[+]**, **[-]**, **[×]**, and **[÷]** work for matrices just as for individual numbers. Advanced functions often operate on the individual matrix

elements. Any time a matrix is used in a mathematical operation with a complex object, the result will be a complex matrix.

**To solve a system of simultaneous linear equations** represented by the matrix equation  $(A)\vec{X} = \vec{B}$ :

1. Key in **MATX SIM EQ n** with **n** being the number of unknowns. Your WP 43S will automatically create or re-dimension the matrix variables **Mat\_A**, **Mat\_B**, and **Mat\_X**.
2. Press **Mat A**; fill the matrix; press **EXIT**.
3. Press **Mat B**; fill the matrix; press **EXIT**.
4. Press **Mat X** to compute the solution matrix.

## PROBABILITY

	RAN#	SEED					$\Gamma(x)$	
<b>PROB</b>		NBin:	Geom:	Hyper:	Binom:	Poiss:		
	LgNrm:	Cauch:		Expon:	Logis:	Weibl:		
	Norml:	t:	C <sub>yx</sub>	P <sub>yx</sub>	F:	$\chi^2$ :		
Binom:		Binom <sub>p</sub>	Binom			Binom <sub>e</sub>	Binom <sup>-1</sup>	

- C<sub>yx</sub> , P<sub>yx</sub> Returns the number of possible combinations (or permutations, a.k.a. arrangements) of  $x$  items taken out of a set of  $y$  items.  
 RAN# Returns a random real number between 0 and 1.  
 SEED Stores a seed for RAN#.  
 $\Gamma(x)$  Returns the *Gamma function* value of  $x$ .

These 14 continuous (c) and discrete (d) distributions (d.) are provided:

- |        |   |                                                        |                                                                                         |
|--------|---|--------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Geom:  | d | <i>Geometric distribution</i>                          | $(i = p_0 =$ gross probability of a success)                                            |
| Binom: | d | <i>Binomial d.</i>                                     | $(i = p_0, j = n =$ sample size)                                                        |
| Cauch: | c | <i>Cauchy-Lorentz</i> (a.k.a. <i>Breit-Wigner</i> ) d. | $(i =$ location, $j =$ shape)                                                           |
| Expon: | c | <i>Exponential d.</i>                                  | $(i =$ rate)                                                                            |
| F:     | c | <i>Fisher's F d.</i>                                   | $(i =$ degrees of freedom ( <i>dof</i> ) <sub>1</sub> , $j =$ <i>dof</i> <sub>2</sub> ) |
| Hyper: | d | <i>Hyperbolic d.</i>                                   | $(i = p_0, j = n, k =$ batch size)                                                      |
| LgNrm: | c | <i>Log-normal d.</i>                                   | $(i = \mu, j = \sigma)$                                                                 |
| Logis: | c | <i>Logistic d.</i>                                     | $(i = \mu, j =$ scale parameter)                                                        |
| NBin:  | d | <i>Negative Binomial d.</i>                            | $(i = p_0, j = n)$                                                                      |
| Norml: | c | (General) <i>normal d.</i>                             | $(i = \mu, j = \sigma)$                                                                 |

Poiss:	d	<i>Poisson d.</i>	$(i = n \ p_0 = \text{Poisson parameter})$
t:	c	<i>Student's t d.</i>	$(i = \text{dof})$
Weibl:	c	<i>Weibull d.</i>	$(i = \text{shape}, \ j = \text{characteristic lifetime})$
$\chi^2$ :	c	<i>Chi-square d.</i>	$(i = \text{dof})$

Following naming convention holds for most distributions, e.g. for the *normal d.*: **Norml<sub>p</sub>** denotes the *probability density function*, **Norml** the *cumulated d. function*, **Norml<sub>e</sub>** the *error probability*, and **Norml<sup>-1</sup>** the *quantile function*. Store the required parameters in **I**, **J**, and **K** as listed above; the remaining parameter must be given in **X** before calling the respective function – note the *quantile functions* require a probability given in **X** ( $0 \leq x \leq 1$ ).

## STATISTICS

Statistical data are accumulated in 23 dedicated summation *registers*, separate from all the other *registers* introduced above.

**Clear the statistical registers** before doing a new stat. analysis: **STAT CLΣ**.

**Then, accumulate the data:**

- For each individual data value: **x-value Σ+**.
- For each weighted data value: **weight-value [ENTER↑] x-value Σ+**.
- For each x-y data pair or point: **y-value [ENTER↑] x-value Σ+**.
- For x-y data pairs stored in a two-column matrix (x-values in column 1, y-values in column 2): place the complete matrix in **X** and then press **Σ+**.

**To undo input mistakes or remove erroneous data,**

- either press **⬅** (for the very last data point)
- or recall the (earlier) incorrect y and x data in the *stack* and press **Σ-**.

## Data Evaluation and Analysis

	OrthoF	GaussF	CauchF	ParabF	HypF	RootF	
	LinF	ExpF	LogF	PowerF		BestF	
		$\bar{x}_{\text{RMS}}$					
		$\bar{x}_H$	$\text{cov}$				
	L.R.	r	$s_{xy}$	$\hat{x}$	$\hat{y}$	$x^2$	
STAT	CLΣ	$\bar{x}_G$	$\varepsilon$	$\varepsilon_p$	$\varepsilon_m$	PLOT	
	$\Sigma^-$	$\bar{x}_w$	$s_w$	$g_w$	$s_{mw}$	SUM	
	$\Sigma^+$	$\bar{x}$	s	g	$s_m$	$x^2$	

$\bar{x}$ , $s$ , $\sigma$ , $s_m$	Arithmetic mean value, sample standard deviation ( <i>SD</i> ), population <i>SD</i> , standard error (a.k.a. <i>SD</i> of the mean).
$\bar{x}_w$ , $s_w$ , $\sigma_w$ , $s_{mw}$	Same for weighted data.
$\bar{x}_g$ , $\varepsilon$ , $\varepsilon_p$ , $\varepsilon_m$	Geometric mean value, sample scattering factor ( <i>SF</i> ), population <i>SF</i> , <i>SF</i> of the mean.
$\bar{x}_H$ , $\bar{x}_{RMS}$	Harmonic and quadratic mean values.
SUM	Returns $\Sigma x$ and $\Sigma y$ .
PLOT	See the <i>ReM, App. K.</i>
L.R.	Computes the parameters $a_0$ and $a_1$ (and $a_2$ , if applicable) of the fit model(s) selected (see below).
r	Returns the correlation coefficient.
$s_{xy}$ , cov	Return the sample or population covariance.
$\hat{x}$ , $\hat{y}$	Return the forecast for x or y following the fit model selected.
LinF	Linear fit model: $y = a_0 + a_1 x$ .
ExpF	Exponential fit model: $\ln(y) = \ln(a_0) + a_1 x$ or $y = a_0 e^{a_1 x}$ .
LogF	Logarithmic fit model: $y = a_0 + a_1 \ln(x)$ .
PowerF	Power fit model: $\ln(y) = \ln(a_0) + a_1 \ln(x)$ or $y = a_0 x^{a_1}$ .
RootF	Root fit model: $y = a_0 a_1^{1/x}$ .
HypF	Hyperbolic fit model: $y = 1/(a_0 + a_1 x)$ .
ParabF	Parabolic fit model: $y = a_0 + a_1 x + a_2 x^2$ .
CauchF	Cauchy peak fit model: $y = 1/[a_0 (x + a_1)^2 + a_2]$ .
GaussF	Gauss peak fit model: $y = a_0 e^{\frac{(x-a_1)^2}{a_2}}$ .
BestF	Blindly selects the model returning the best correlation coefficient.
OrthoF	Works like LINF but assumes equal errors in x and y. ORTHOF is not part of the pool BESTF investigates.

## ADVANCED OPERATIONS

**EQN** is for interactive editing, storing, recalling, solving, integrating, and deriving equations.

**ADV** is for programmed summing, multiplying, solving, integrating, and deriving.

### Interactive Operations on Equations

<b>EQN</b>	...						
	<b>DELETE</b>						
	<b>NEW</b>	<b>EDIT</b>	$f''$	$f'$	$\int f$	<b>Solver</b>	

For creating a new equation, press **NEW**. The *Equation Editor menu* will open, and the blue row will display the current equation. Press **EXIT** when finished.

For browsing existing equations, press **▲** or **▼**. The equation displayed in **g**-shifted row is called the *current equation*.

For editing (or deleting) the current equation, press **EDIT** (or **DELETE**).

For operating on the current equation, press the respective *softkey*. A menu will pop up displaying the names of all variables used and more.

### Using Advanced Operations in Programs

<b>ADV</b>	<b>PGMSLV</b>	$f''(x)$					
	<b>SOLVE</b>	<b>SLVQ</b>	$f'(x)$	$\Pi_n$	$\Sigma_n$	$\int f dx$	

**SLVQ** solves the quadratic equation  $ax^2 + bx + c = 0$  with its parameters on the input stack [**c**, **b**, **a**, ...]. It returns two real or complex solutions.

**$\Pi_n$  label** calculates the product of the terms given by the routine specified, using the loop control number given in **X** (cf. p. vi).

**$\Sigma_n$  label** calculates the sum of the terms given by the routine specified, using the loop control number given in **X** (cf. p. vi).

**SOLVE var** solves for an unknown variable in an expression, given values for all the other variables. The expression  $f(x_1, x_2, \dots)$  shall be written as a program (let's call it **AB**, for example):

- **AB** must begin with a global label.

- **The body of AB** shall evaluate the expression. For an expression to be solved, it must be coded that  $f(x_1, x_2, \dots) = 0$  is fulfilled. Recall the variables of the expression as they are required and calculate  $f$ .
- **AB must logically end with RTN.**

Then write a program calling the *Solver* (let's call it **CD**, for example). At the position where you need the expression solved, press **ADV**:

1. Press **PGMSLV** and specify **AB**.
2. Store a value into each known variable, e.g. using STO. Optionally store a guess into the unknown variable to direct the *Solver* to a solution.
3. Press **SOLVE** and specify the unknown variable.

When running **CD** later on, SOLVE will solve for the unknown.

**f'(x)** (or **f''(x)**) calculates the first (or second) derivative of  $f(x)$  at location  $x$ . The function  $f(x)$  shall be written as a program (e.g. called **EF**); it must begin with a global label, take care of all variables used, and evaluate  $f(x)$ .

Then write a program calling the derivator (let's call it **GH**, for example).

1. Store a value into each of the variables that shall remain constant under derivation.
2. At the position where you need the derivative, put the respective location into **X**, then press **ADV** **f'(x)** (or **f''(x)**) specifying **EF**.

When running **GH** later on, the derivative will be returned in **X**.

**ʃfd var** numerically computes a definite integral. The integrand  $f(x)$  shall be written as a program (e.g. called **IJ**); it must begin with a global label, recall all integration constants used, and evaluate  $f(x)$ .

Then write a program calling the integrator (let's call it **KL**, for example). At the position where you need the integral, press **ADV**:

1. Press **ʃfdx**. A submenu will open.
2. Press **PGMINT** and specify **IJ**.
3. Store a value into each of the variables that shall remain constant under integration, e.g. using STO.
4. Store the lower limit (**↓LIM**), the upper limit (**↑LIM**), and the accuracy factor (ACC).
5. Press **ʃ** and specify the variable of integration.

When running **KL** later on, the integral will be returned in **X** and the uncertainty of computation will be returned in **Y**.



FLOOR	R	Returns the greatest integer $\leq x$ .
CEIL	R	Returns the smallest integer $\geq x$ .
LCM	Z	Returns the least common multiple of $x$ and $y$ .
GCD	Z	Returns the greatest common divisor of $x$ and $y$ .
DBL /, DBLR, DBL $\times$		Double word length commands for division, remainder, and multiplication.

## OPERATIONS ON ALPHANUMERIC STRINGS

Connect strings by pressing . Then  $x$  will be appended to the string  $y$ . With numeric data in X, their current display format is taken into account.

	FBR						
					αLENG?	αPOS?	
	$x \rightarrow \alpha$	αRL	αRR	αSL	αSR	α $\rightarrow$ x	

$x \rightarrow \alpha$ s	Converts a code $x$ to the corresponding character and appends it to the string in $s$ .
αRL, αRR s	Rotates the string in $s$ by $x$ characters to the left (or right).
αSL, αSR s	Deletes the first (or last) $x$ characters of the string in $s$ .
$\alpha \rightarrow x$ s	Pushes the code of the first character in $s$ on the stack.
αLENG? s	Pushes the length of the string in $s$ on the stack.
αPOS? s	Returns the position where the substring $x$ begins in the string in $s$ .
FBR	Displays all characters defined in both fonts.

## **APPENDIX K: BACKGROUND CONSIDERATIONS AND FACTS**

This is for recording and explaining some of the boundary conditions considered and the settings chosen for the *WP 43S*.

### **Alpha Register**

For long I thought we could do without a dedicated *alpha register*. Some special programming functions like KEYG and KEYX, however, seem to require such a *register* – else handling these functions would become more complicated than it was on the *HP-42S*.

Especially direct entry of alphanumeric constants in programs is easier when the destination is automatically defined, and people became used to this method in decades since the *HP-42S* was launched. Thus, I introduced this *register* in v0.7, taking **K** for this task.

### **Angles**

Originally, a separate *data type* for *angles* was planned. It was removed in v0.9 since its scope is quite limited and the opinion rose that ‘*angles work like reals*’. It turned out, however, that D.MS data would need special treatment in calculations, so *data type 4* returned with v0.10 for sake of keeping algebraic operations simple and avoiding special purpose commands like D.MS+, D.MS–, etc.

Actually, *angles* are displayed in five ‘modes’ (*decimal and sexagesimal degrees, radians, multiples of  $\pi$ , and gon or grads*) but were represented internally in a fixed format of 1296 units per turn – similar to *short integers* where a fixed bit pattern may be displayed differently in various *integer sign modes* and bases. *Radians*, however, did not fit into this concept due to the necessity for high precision storage of  $\pi$  for modulo calculations and rounding errors.

Generally, trigonometric functions shall actually operate on *angles* within  $\pm 180^\circ$  only; thus, angular input beyond this range shall be

reduced modulo  $360^\circ$ , then minus  $180^\circ$  (or equivalents in the other *angular display modes* available) before executing the function. Again, the crucial mode are *radians*. WP 34S had demonstrated that 451 (!) digits for  $\pi$  are sufficient to warrant 16 digits accuracy of respective function results for the number range of *SP* reals.

## Character Sets

The browser FBR displays the characters of both fonts provided as designed and implemented for the WP 43S, sorted according to their hexadecimal codes (most of them following Unicode).

The so-called '**numeric**' font uses a matrix of up to  $16 \times 32$  px (variable width, fixed height). Therein, the punctuation space ( $2008_{16}$ , 8 px wide) is employed for separating groups of digits in longer numbers – so we follow ISO 80000-1 for an unambiguous numeric display.

In total, six blank characters are provided allowing for any spacing wanted (standard / em / figure, punctuation, four-per-em, and hair space being 16, 8, 4 and 1 px wide).

Most of the elevated characters are for exponents or numerators of fractions. The digits below are for denominators. Numeric indices are for indicating bases of short integers. Non-numeric indices are mainly provided for CNST.

Optionally, narrow digits can be used in complex numbers or in matrices or in *short integers* of small base where space may be scarce (see pp. xviiiff).

This font is also employed for echoing numeric input unless too long. It may be used for echoing command input as well.

All characters of the **standard** (a.k.a. small) font of alphanumeric characters as designed and implemented live in a matrix of up to  $14 \times 20$  px (variable width, fixed height again). Herein, characters usually start at column one and feature two empty columns at their right side. There are exceptions, however: see e.g. the multiplication dot at  $B7_{16}$  and the root symbols in row  $2210_{16}$ .

Characters with codes < 20<sub>16</sub> are for control purposes; some of them (4, 10<sub>10</sub>, 27<sub>10</sub>) may be useful for printer control (e.g. of *HP 82240 A/B*).

Many characters are 8 px wide as digits – they will help where a constant character spacing is wanted.

There is a number of super- and subscripts provided. They allow for displaying all the *items* featured on the *WP 43S*. Arbitrary numeric indices or exponents are possible as well.

Eight blank characters are provided (listed with their hexadecimal addresses and their widths in the table at right). Using them, any spacing is feasible.

This small character set allows for correctly spelling the languages of more than  $3.5 \times 10^9$  people using either Greek or Latin alphabets:

Afrikaans, Aymara, Bahasa Indonesia, Bahasa Melayu, Basa Jawa, Basa Sunda, Bosanski, Català, Cebuano, Česky, Cymraeg, Dansk, Deutsch, Eesti, Ελληνικά, English, Español, Euskara, Français, Gaeilge, Galego, Hrvatski, Italiano, Kiswahili, Kreyòl, Kurdî, Lietuvių, Magyar, Malagasy, Nāhuatl, Nederlands, Nihongo (Rōmanji), Norsk, Özbek tili, Polski, Português, Quechua, Română, Shqip, Slovenščina, Slovensky, Srpski, Suomi, Svenska, Tagalog, Tatarça, Türkçe, Türkmençe, and Zhōngwén (hànyǔ pīnyīn).

This makes the *WP 43S* the most versatile calculator available worldwide. If you know of further living languages covered (with one million speakers or more) beyond the ones listed, please tell us.

	Character code	px
Standard space	20 <sub>16</sub>	10
m space	2003 <sub>16</sub>	12
m/3 space	2004 <sub>16</sub>	4
m/4 space	2005 <sub>16</sub>	3
m/6 space	2006 <sub>16</sub>	2
Figure space	2007 <sub>16</sub>	8
Punctuation sp.	2008 <sub>16</sub>	4
Hair space	200A <sub>16</sub>	1

Turn to the OM for examples where these characters are used.<sup>64</sup> See here some sample strings in either font, approximately to a common realistic scale:

-1.602 22 $\times 10^{-19}$  C -1,602 22 $\cdot 10^{-19}$  C

-1.602 22 $\times 10^{-19}$  As

-1,602 22 $\cdot 10^{-19}$  As

## Display Limits

Due to the character sizes and their design mentioned on pp. xvif, the screen could take inputs of up to 23 digits, a sign, and an 8-px radix mark:

-4.2345678901234567890123 ,

occupying  $15 + 23 \times 16 + 8 = 391$  px. Numeric output would allow for the same 23 digits. Without digit group separators, however, this would be hardly readable. With 3-digit separators (*startup default* mode), 20 digits are displayable in one row instead:

-4.234 567 890 123 456 789 0 ,

taking  $15 + 20 \times 16 + 7 \times 8 = 391$  px again. This maximum precision is independent of the position of the radix mark. Scientific or engineering notation allows for a 16-digit mantissa

-4.234 567 890 123 456 $\times 10^{-925}$  ,

taking 395 px ( $= 15 + 16 \times 16 + 5 \times 8 + 15 + 16 + 4 \times 13 + 1$ ) for displaying this number this way.<sup>65</sup>

For double precision numbers, a 34-digit mantissa plus exponent can be shown using the small font:

-8.123 456 789 012 345 678 901 234 567 890 123 $\times 10^{-925}$  .

---

<sup>64</sup> Some characters displayed by FBR are not found in any other *menu* of your WP 43S. They are not required for any *item* provided so far and may be for future use.

<sup>65</sup> One blank pixel column had to be added at right since exponential digits are right adjusted (since used for numerators as well) and the screen is framed in black.

Some *temporary information* may limit output precision. E.g. for linear regression, up to 8 digits are viable allowing for 2-digit exponents in SCI or ENG and up to 12 digits in FIX:

$$\begin{array}{l} \text{Logarithmic* } a_1: -5.234\ 567\ 8 \times 10^{-92} \\ y = a_0 + a_1 \ln(x) \quad a_0: -1.234\ 567\ 890\ 12 \end{array}$$

**Complex numbers** in Cartesian notation require  $1 + 15 + 12 + 15 + 1 = 44$  px for  $+i\bar{x}$  in addition to the space for two reals. Only the real part may need extra space for a 15-px sign. This allows for 8 decimals per part in worst case

$$-4.234\ 567\ 89 + j \times 4.234\ 567\ 89,$$

since  $44 + 15 + 2 \times (16 + 8 + 48 + 8 + 48 + 8 + 32) = 397$  px in total. It applies if both real and imaginary parts are in the same order of magnitude and the multiplication cross is chosen.

With SCI or ENG, a minimum of 3 decimals can be shown ( $15 + 2 \times (4 \times 16 + 8 + 15 + 16 + 4 \times 13) + 44 + 1 = 370$  px, but another digit would need  $2 \times 16$  px at least):

$$-4.234 \times 10^{-925} + i \times 4.234 \times 10^{-925}.$$

Using 8 px wide multiplication dots instead, only  $1 + 15 + 12 + 8 + 1 = 37$  px are necessary for  $+i\cdot$ . Thus, we can show one decimal more since  $15 + 2 \times (5 \times 16 + 3 \times 8 + 16 + 4 \times 13) + 37 + 1 = 397$  px:

$$-4,234\ 5 \cdot 10^{-925} + i \cdot 4,234\ 5 \cdot 10^{-925}.$$

Alternatively, 13 px wide narrow digits allow for 4 decimals even with multiplication crosses, while 5 decimals are viable with multiplication dots:

$$\begin{array}{l} -6.234\ 5 \times 10^{-925} + i \times 6.234\ 5 \times 10^{-925}, \\ -6.234\ 56 \cdot 10^{-925} + i \cdot 6.234\ 56 \cdot 10^{-925} \end{array}$$

Complex numbers in polar notation need  $4 + 16 + 4 = 24$  px for  $\angle$  plus 16 px for the angular unit in addition to the space for two signed reals. Both magnitude and angle may require a 15 px sign. 7 decimals

in FIX occupy  $40 + 2 \times (15 + 8 \times 16 + 3 \times 8) = 374$  px, so we can display them this way:

-4.234 567 8 ↵ -0.234 567 8π .

With SCI or ENG, the minimum number of decimals depends on the angular display mode since output is confined to the interval  $-180^\circ$  to  $+180^\circ$  or its equivalents, e.g.  $-\pi$  to  $+\pi$  in *radians* or  $-200^g$  to  $+200^g$  in *gon* (see Sect. 2 of the OM). Hence, the angular parts can be displayed without exponents always. This allows for a minimum of 4 decimals for *degrees* and *gon*:

-4.234 5 $\times 10^{-925}$  ↵ -120.234 5° .

For *radians* or *multiples of π*, however, 5 decimals at least are displayable always:

-4.234 56 $\times 10^{-925}$  ↵ -0.234 56π .

Digits in **fractions** are 13 px wide like in exponents. Thus, a 4-digit numerator and denominator take  $4 \times 13 + 8 = 60$  px each; the fraction bar takes another 16 px and the trailer 29 ( $= 16 + 12 + 1$ ). The remaining 235 px would suffice for the optional sign, an 11-digit number, and the 16 px gap between integer and fraction ( $15 + 12 \times 16 + 3 \times 8 = 231$  px) in a proper fraction:

-67 890 234 567 2 289/4 567 > .

For **long integers**, up to 21 digits and a sign may be displayed using large digits:

-123 456 789 012 345 678 901 .

Larger *long integers* may employ the small font, allowing for 42 digits and a sign:

-123 456 789 012 345 678 901 234 567 890 123 456 789 012 .

Even larger *long integers* are displayed with an exponent replacing as many of their least significant digits as necessary:

-123 456 789 012 345 678 901 234 567 890 123 456 $\times 10^{21}$  .

For unsigned ***short integers***, up to 21 *bits* may be shown in large digits in binary representation:

0 1100 0010 1101 0110 0000<sub>2</sub> .

Base 3 (with narrow blanks every three digits) allows for displaying 20 digits and a sign:

-22 211 200 201 120 001 212<sub>3</sub> .

In base 4 (with narrow blanks every two digits), 19 digits representing 38 *bits* are displayable:

3 21 23 30 22 11 21 20 32 12<sub>4</sub> .

Also bases 5, 6, and 7 allow for showing 20 digits and a sign like base 3, base 8 for 19 digits like base 4 (but representing 57 *bits* in base 8).

Using the narrow digits provided, up to 25 *bits* are displayable in binary representation:

0 1110 1100 0010 1101 0110 0000<sub>2</sub> .

Then 24 digits and a sign can be shown for bases 3, 5, 6, and 7, as well as 22 digits for bases 4 and 8.

Longer integers in bases 2 through 6 must be displayed using the small font. This allows for showing up to 44 *bits* in binary notation:

1110 1100 0101 1101 0110 1110 1100 0010 1101 0110 0000<sub>2</sub> .

41 digits and a sign can be displayed for base 3 being already sufficient for 64 *bits*, as well as the 39 digits theoretically displayable for base 4.

For showing the maximum of 64 *bits* in base 2, two special 5 px wide characters were created:

1110 1100 0010 1101 0110 1110 1100 0010 1101 0110 0000<sub>2</sub> .

Summing up, for given base and word size, the following fonts will do for ***short integers***:

Base ▼	Allowable size of digits for display			
	large	narrow	small	special
2	$\leq 21 \text{ bits}$	$\leq 25 \text{ bits}$	$\leq 44 \text{ bits}$	$\leq 64 \text{ bits}$
3	$\leq 31 \text{ bits}$	$\leq 38 \text{ bits}$		
4	$\leq 38 \text{ bits}$	$\leq 44 \text{ bits}$	$\leq 64 \text{ bits}$	
5	$\leq 46 \text{ bits}$	$\leq 55 \text{ bits}$		
6	$\leq 51 \text{ bits}$	$\leq 62 \text{ bits}$		
7	$\leq 56 \text{ bits}$		$\leq 64 \text{ bits}$	
8	$\leq 57 \text{ bits}$		$\leq 64 \text{ bits}$	
$> 8$	$\leq 64 \text{ bits}$			

One row of four arbitrary **real matrix elements** (with absolute values  $< 10^{100}$ ) takes 399 px in small font, SCI 3:

$$\begin{bmatrix} -6,609 \cdot 10^{-19} & -6,609 \cdot 10^{-19} & -1,609 \cdot 10^{-19} & -1,609 \cdot 10^{-19} \end{bmatrix}$$

using multiplication dots. Else you will lose one decimal. A slightly different notation allows for SCI 4:

$$\begin{bmatrix} -6.609 \cdot 2 \cdot 10^{-19} & -6.609 \cdot 2 \cdot 10^{-19} & -1.609 \cdot 2 \cdot 10^{-19} & -1.609 \cdot 2 \cdot 10^{-19} \end{bmatrix}$$

Matrices with more than four columns will need ellipses added on one or both sides:

$$\begin{bmatrix} \dots & -6,609 \cdot 2 \cdot 10^{-19} & -6,609 \cdot 2 \cdot 10^{-19} & -1,609 \cdot 2 \cdot 10^{-19} & \dots \end{bmatrix}.$$

allowing to display a section of three elements in SCI 4 format. Using multiplication crosses will cost one decimal.

Vertically, each such matrix row requires 20 px as other small font strings do. Within the space of 3 standard numeric output rows,  $3 \times 32 + 2 \times 5 = 106$  px are available, allowing for 5 matrix rows ( $5 \times 20 + 4$ ). Thus, a  $5 \times 4$  real matrix can be displayed entirely always, using SCI 3 in worst case.

In consequence, any chosen  $3 \times 3$  section out of a real matrix of arbitrary size can be shown in SCI 3 minimum with surrounding ellipses. In FIX format, 8 decimals can be displayed always.

In analogy, for a **complex matrix** of arbitrary size any chosen  $3 \times 2$  section can be displayed in FIX 6 format maximum with surrounding ellipses like

[... -6.609 226+i·6.609 226 -1.609 226+i·1.609 226 ...]

while displaying complex matrix elements featuring large exponents may become inconvenient very soon, regardless of the symbols used:

[... -6.60E-199+i·6.60E-199 -1.60E-199+i·1.60E-199 ...].

Also displaying an arbitrary  $3 \times 3$  section out of a larger complex matrix is viable up to FIX 3 as long as the numbers stay in a reasonable range:

[... -6,609+i·6,609 -6,609+i·1,609 -1,609+i·1,609 ...].

One row of **alphanumeric text** will typically take some 40 characters. The actual number will vary depending on their individual widths as mentioned above.

The *status bar* is a good example for such an alphanumeric row: Loaded to maximum, it might look like

2017-05-08 23:49 RL<sub>E</sub>π /3 546f 64:U<sub>C</sub> A ☰ ⓘ ⓘ ⓘ ⓘ ⓘ ⓘ ⓘ

containing 45 characters.

Putting the alphabet in a row allows for

abcdefghijklmnopqrstuvwxyz ABCDEFGHIJKLMNOP

i.e. 41 characters.

Echoing command input requires up to 16 characters (the 17<sup>th</sup> will close input) for a 7-character command indirectly addressing a 7-character variable entered in A/M. This can be done in either font.

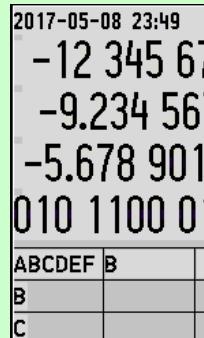
Command and variable names in menus are discussed in the last paragraph of next chapter. Although seven characters are allowed for such names, six may well fill the screen space available there. Thus, it

is recommended to keep such names as short as possible, though meaningful.

## Display Segmentation

The *LCD* of your *WP 43S* is full dot matrix: 400 px wide and 240 high. Each pixel is 0.147 mm square. Going top down, you will find

- 20 px for the status bar,
- 4 blank rows for separation,
- 147 px for either
  - a) the contents of up to 4 *stack registers*, or
  - b) 7 program steps in *PEM*, and
- 69 px maximum for the menu section.



The reasons for these figures are as follows:

- Each regular alphanumeric row (e.g. labels or status or program steps) requires 20 px vertically (cf. pp. xvif). There shall be at least one pixel separating it from the next row.
- Hence, each *menu* row takes (counting bottom-up)  $1 + 20 + 1 + 1 = 23$  px (the first pixel is for the distance to the black frame, the last for its upper frame line). Thus, three *menu* rows require 69 px. In U<sub>2</sub>, extra-large labels may appear (cf. p. 128): they will require  $1 + 20 + 1 + 20 + 1 + 1 = 44$  px for double height or  $1 + 20 + 1 + 20 + 1 + 20 + 1 + 1 = 65$  px for triple height then.
- At top of the *LCD*, the *status bar* takes another 20 px plus 4 for separation. Thus,  $240 - 69 - 24 = 147$  px minimum remain.
- Each regular numeric output requires 32 px vertically (cf. pp. xvif) plus 5 px separating it from the next such row. Thus, for 4 rows we need  $4 \times 32 + 3 \times 5 = 143$  px. We put the remaining 4 px below this output block.
- If there is a short alpha string in any *stack register*, its ground line is positioned where the ground line of the respective numeric output would have been.

- With an alpha string needing two rows,  $20 + 1 + 20 + 5 = 46$  px are required vertically where 37 px are available for one numeric row. So a second numeric row has to go here – up to three stack registers can be displayed only now.

Two subsequent alpha strings of this kind, e.g. after **ENTER↑**, require 92 px. Three regular numeric rows cover 111 px, so here is no further loss. The ground line of the lowest alpha string is positioned where the ground line of the respective numeric output would have been. The other string is positioned in the center of the free space remaining.

- An alpha string needing three rows requires 67 px which are still covered by two regular numeric rows. Two such strings, however, push any other stack register out of the screen. Then string **y** shall have its ground line where the second numeric row would have it.
- In *PEM*, on the other hand,  $147 = 7 \times 21$  corresponds to a block of 7 alphanumeric program rows.
- If there will be more space left, we will put it below the numeric block. This is for clear separation from the *menu section* and avoiding vertical output jitter. (gibt's diesen Fall überhaupt noch?)

In the *menu section*, we also have a horizontal structure for the six *softkeys*. We start one pixel off the black frame at left display edge. On the right edge, the characters themselves contain at least one blank column. A minimum of 2 px separate *softkey* labels from each other (one black and one blank). This way we lose a total of  $1 + 5 \times 2$  px. The remaining 389 px mean a width of 65 available for 6 *softkey* labels, corresponding to six standard width letters (though letters may extend from 4 to 14 px in small font) which should be centered as good as possible. Note that labels in *menu views* may be not fully displayed if they are wider than 64 px, so labels deviating only in their very last characters may become visually indistinguishable.

## Equations

Equations are entered in **EQN** as written (i.e. following algebraic notation and rules). While editing them, punctuation spaces are automatically inserted after each constant or variable (you know a variable name ends when the next operator is entered) as well as after **=** and each operator like **+**, **-**, **\***, **/**, **!**, except **^**; a standard space is inserted after **:**. There is no implicit multiplication.

Other functions like absolute values, roots, or trigs shall be written using the parentheses softkey, e.g. pressing **( )**, then stepping back into the parentheses for specifying the argument. The same applies to dyadic (like **C<sub>xy</sub>**) and triadic operations in analogy – their arguments shall be separated by blank spaces inserted via **R/S**.

Closing the *Equation Editor*, numeric exponents are automatically converted from e.g. **xy ^23** to **xy<sup>23</sup>**. For easier handling, this will be reverted when editing such an equation again.

## Menus

*Menu* size corresponds to keystroke efficiency; optimum is a *menu* encompassing three *views* containing up to 54 functions in total: the top view, one *view* going up via **▲**, and one going down via **▼**. Larger *menus* lack efficiency, smaller *menus* lack functions. Besides function visibility, an operation presented in the unshifted row of top *menu view* is more efficient than a shifted function presented on the keyboard – if used more than just once.

Generally, I separated status setting from “acting” operations in different *views* or rows at least.

## Plotting?

It is mentioned elsewhere we are not out for creating a graphing calculator. There is, however, a very useful application where a basic scatter plot of measured data points would support decision making significantly (see the third industrial statistics application example in

Section 2 of the OM). This would require the statistical data (e.g. max. 100 data points, i.e. 100 pairs of  $x$  and  $y$  values) to be stored point by point in a matrix, not just summed up as in the *WP 34S* and earlier *RPN* calculators.

Plotting could be called by a command **PLOT** stored in **STAT** displaying the data points collected in a quadratic diagram. Both axes shall reach from minimum value measured to maximum value measured (plus a little extension which can be calculated based on the data points). Axis scales are not required for analysis so I omitted them. Drawing area has to be quadratic ( $240 \times 240$  px for data,  $242 \times 240$  px incl. the vertical axis). Hence softkeys can be positioned on one side of the diagram (max.  $3 \times 2$  labels) still. The *status bar* would be partially overwritten by the diagram. See the following sketch (to scale) for general screen layout and various data point symbols for checking visibility.

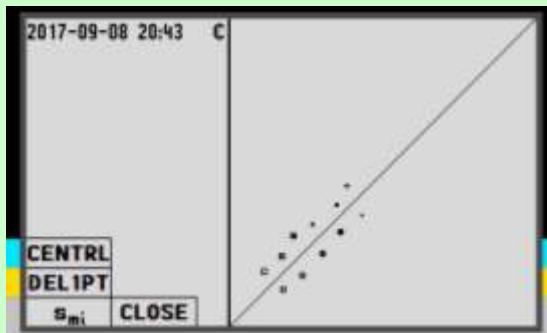
CLLCD is modified for clearing just the screen section required for the diagram.

Four characters are provided in small font for ‘drawing’ the vertical axis and the  $45^\circ$  line:



But both lines can be created using **AGRAPH** and **PIXEL** as well.

Data points can then be plotted using **POINT** (containing  $3 \times 3$  px) – positioning them properly in the diagram, however, will require some background calculations best performed by a program. For **POINT**, also some of the control modes of *HP-42S* shall be implemented in analogy (the picture below is copied from the *HP-42S OM*, p. 137; settings 1 and 3 should do for our plotting):



<b>Flag 34</b>	<b>Flag 35</b>	<b>How the AGRAPH Image is Displayed</b>
Clear*	Clear*	The image is merged with the existing display (logical OR).
Clear	Set	The image overwrites all pixels in that portion of the display.
Set	Clear	Duplicate "on" pixels get turned "off."
Set	Set	All pixels are reversed (logical XOR).

\* Default setting.

Softkey functions could be ...

- CENTRL for fitting the center line to the data points and plotting it for checking deviations from the 45° line (some background calculations in L.R. using ORTHOF for orthogonal regression are required for the plot, setting 1 in the picture above will do while plotting);
- DEL1PT turned obsolete;
- $s_{mi}$  for calculating the minimum experimental standard deviation of the measuring instrument (some background calculations required again); and
- CLOSE for closing the plot screen, returning to normal display.

It may be beneficial to define a general origin for graphics at a location deviating from 0, 0 (i.e. the bottom left corner of the *LCD*) – the point 158, 0 may be a useful origin. This would allow for creating also other graphics than just the correlation diagrams mentioned above, while reserving a ‘protected screen space’ for up to six *softkeys*. Any user may do his own thing in this almost quadratic drawing area then, employing the provided commands AGRAPH, CLLCD, CLOSE, PIXEL, and POINT.

## Precision and Accuracy

As mentioned more than once, there are inevitable errors in each calculation step, frequently caused by rounding to the internal finite precision the calculator features. Already a simple fraction like  $1/3$  stored as an SP real number deviates from the truth by more than  $3 \times 10^{-17}$ . During calculations, such errors accumulate as seen e.g. in footnote 55.

In real-world problems, usually the least accurate of all input (real) parameters determines the accuracy of the result. In the standard test mentioned in said footnote starting with  $9^\circ$  SP, you can nevertheless get 10 digits precision in the result since the input of  $9^\circ$  is exact (but note you lose one digit precision with each trigonometric function calculated here).

Internally, for instance, the *WP 34S* computes with 39 digits and rounds the results to 34 or 16 digits, respectively (seems *Free42* works alike since the standard test results match). Following these, this is implemented for the *WP 43S* as well.

Luckily, real-world problems are usually far less precisely defined than the internal precision of the *WP 43S*. Compare the set of constants provided.

## Prefixes

Prefixes  and  passed without any discussions for six years until 2019-06. Alternatively, prefixes  and  could have been chosen but their typography leaves less freedom for label placing.

## Stack Depth

At a very early stage of this project (2013), *stack depth* was discussed. At the bottom line, eight *stack registers* turn out being sufficient for solving any real-world mathematical, scientific, or engineering problem (cf. also the *WP 34S*).

An *RPL*-like ‘infinite’ stack would allow for saving (pushing) everything thereon before calling a (sub-) routine and popping it after RTN but makes traditional R↓, R↑, and top level repetition obsolete (and FILL as well); I suggested two new commands called CLOSES and OPENS for closing the bottom section (4 or 8 registers) of an infinite stack for the time when R↓, R↑, FILL, and top level repetition were required, and opening it thereafter.

After all, we decided sticking to *RPN* as implemented on the *WP 34S* and *WP 31S*. It covers everything needed with minimum complexity. For special action support, the commands STOS and RCLS are provided.

## Stack Lift Disabling Functions

Also these functions were subject of discussion. For sake of backward compatibility, we decided to keep them as they were on the vintage *HP RPN* pocket calculators up to the *HP-42S* (and *WP 34S* and *WP 31S*):

Only ENTER↑, CLX, Σ+, and Σ- disable *automatic stack lift*, all other functions enable it.

## Structured Programming

In 2013, I suggested the following control structures:

- IF – THEN – ELSE – END,
- FOR – FROM – TO – END,
- REPEAT – UNTIL,
- WHILE – END.

Traditional END would need to be called ENDPGM then.

Later, we discussed some *PASCAL*-like structures:

- IF – THEN BEGIN – END ELSE BEGIN – END;

- FOR – DO BEGIN – END;
- WHILE – DO BEGIN – END;

We refrained from implementing such commands since we had doubts about mixing keystroke programming and structured programming features.

## UNDO

In 2013, UNDO was planned as it works in *HP-48*, recalling the *stack* as it was before executing last command. The *WP 31S*, on the other hand, features an UNDO recalling the entire calculator status as it was. It turned out that such a complete UNDO was viable here, too, so we implemented it.