



## 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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*HP* is a registered trade mark of *Hewlett-Packard*.

The pictures on p. 161 and bottom of p. 162 were kindly supplied by *SwissMicros* as well as the drawing on p. 213, the picture on p. 209 by *Martin Lorang*. The plots in Appendix H are based on material found in *Wikipedia*. The other 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 over a third 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, MENUS, PREDEFINED VARIABLES and SYSTEM FLAGS 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 .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, binary and hexadecimal codes, and describing numeric formats.
- Times New Roman regular letters are for unit symbols and for mathematical functions. Italics 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 decimal 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*).

*BCD* = binary coded decimal.

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

*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*).

*SRS* = subroutine return stack (see *App. B* on pp. 165ff).

*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 (I/O)

All the *items* provided on your *WP 43S* (more than 850) are listed below with their *names* (as they are printed in routines) in column 1 and the keystrokes necessary to call them. Most *items* shall be picked from *menus* (see pp. 120ff).<sup>1</sup>

There is an important difference between the *names* of *items* and their labels as printed on the keyboard or displayed in *menus*: **Each item provided is identified by its unique reserved name of up to 7 characters – it may be accessible under one or more different labels**, featuring less or more characters than its *name* (see some unit conversions, for example).<sup>2</sup>

On your *WP 43S*, sorting (e.g. of *names*) works in the following order:<sup>3</sup>



Accented letters follow their parents, as do superscripts and subscripts.

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.

<sup>1</sup> For commands stored in *menus*, we list the keys calling the respective *menu*, the prefix 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 *names* only, however, since they are sorted alphabetically and will be explained in detail in a separate chapter below.

<sup>2</sup> These labels are not required to be unique, be they printed or displayed.

<sup>3</sup> Characters printed on grey background are inaccessible for users for the time being. The entire sorting table is printed in an appendix.

Operations working with the accumulated statistical data are marked light blue. Those operating also 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*.

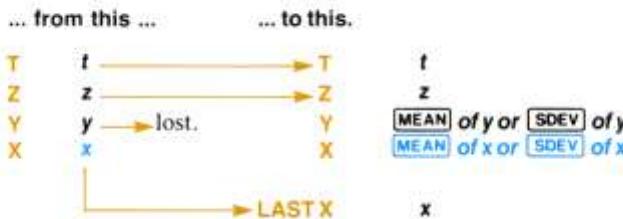
For the vast majority of operations, remarks start with a number:

- (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>4</sup>

<sup>4</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 addressing 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 program 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 input parameter, you can enter XYZ → ST.X and it will take its parameter from X instead – like a good old traditional RPN command.

*Automatic stack lift* is enabled after each command – except after CLX, ENTER↑, Σ+, and Σ- (cf. Section 1 of the OM); thus, numeric input immediately following one of these four operations will overwrite x instead of pushing it on the stack as usual.<sup>5</sup>

Some 300 functions featured in your WP 43S are new compared to HP's RPN pocket calculators.<sup>6</sup> Operations carrying familiar names but deviating in their functionality from previous HP RPN calculators or the WP 34S are marked light red.

The *data types* a particular function operates on are listed in { } under “remarks” if there are restrictions – cf. App. B on pp. 165ff. 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>7</sup>

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<sup>5</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>6</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>7</sup> This applies for °C→°F, for instance: For *real* number input, output will stay *real*. For integer input, however, output will be *real*.

Some functions operating on *long* integers will return either such integers or *reals*, depending on the input value. See the OM, Section 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 will return a *real* for an input of 28 although this is a *long integer* as well. The same function operating on a *short integer* will return 3 for both cases, in whatever base applicable.

Below, the functions checked already are highlighted green, those which didn't work yet (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*.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$		(1) {2}; {1} → {2}
$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	etc.	Convert temperatures. See pp. 146ff.
$10^x$		(1) {1, 2, 3, 8*, 9*, 10} Returns $10^x$ , the inverse of $\lg(x)$ .
1COMPL		(0) Sets 1's complement mode for operations on <i>short integers</i> . Indicated in the <i>status bar</i> . See Sect. 2 of the OM.
$\frac{1}{2}$		(-1) {} → {2} Trivial but helpful constant for iterations.
$1/x$		(1) {2, 3, 8*, 9*}; {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> . Indicated in the <i>status bar</i> . See Sect. 2 of the OM.
$2^x$		(1) {1, 2, 3, 8*, 9*, 10} Returns $2^x$ .
$\sqrt[3]{x}$		(1) {1, 2, 3, 8*, 9*, 10}; ({1} → {2}) Returns the cube root of $x$ . Roots of non-cube <i>long integers</i> will return <i>reals</i> .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
a	<b>g CNST a</b>	(-1) {} → {2} Gregorian year in <i>days</i> and Bohr radius in <i>meter</i> .
a <sub>0</sub>	<b>g CNST a<sub>0</sub></b>	
ABS	<b>f CATALOG FCNS ABS</b>	Points to  x  on p. 99. Maintained for backward compatibility only.
ACOS	<b>f CATALOG FCNS ACOS</b>	Points to arccos on p. 18.
ac→m <sup>2</sup>	<b>f U→ f A: acre → m<sup>2</sup></b>	
ac <sub>us</sub> →m <sup>2</sup>	<b>f U→ f A: acre<sub>us</sub> → m<sup>2</sup></b>	(1) {2}; {1} → {2} Convert areas. See pp. 146ff.
ADV	<b>f ADV</b>	Menu. See p. 127.
AGM	<b>g X.FN AGM</b>	(2) {2, 3}; {1} → {2} Returns the <i>arithmetic-geometric mean</i> of x and y. Will throw an error for x or y being negative. See p. 247 for more.
AGRAPH	<b>g P.FN PFN2 g AGRAPH s</b>	(0) Alpha graphics. Displays a graphics image. Each character in the source <i>s</i> 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 valid (but see pp. xxxii ff). 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	<b>g DSP ALL n</b>	(0) Sets the numeric display format to show all decimals of <i>real</i> or <i>complex</i> numbers whenever displayable (trailing decimal zeros will not be shown). ALL 0 works like ALL in <i>HP-42S</i> 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 necessary decimals displayable using the large font (see ALLSCI). The same will happen if $x < 10^{-n}$ and more than 16 digits are required to show $x$ entirely (see examples in Section 2 of the OM). The limits differ in RBR – see p. 63.
a <sub>Moon</sub>	<b>g [CNST] a<sub>Moon</sub></b>	(-1) { } → {2} Semi-major axis of the Moon's orbit around the earth in <i>meter</i> .
AND	<b>f [BITS] AND</b>	(2) {10} Works bitwise as in HP-16C (see the OM, Section 2).
		(2) {1, 2} → {1} Works like AND in HP-28S, i.e. $x$ and $y$ are interpreted before executing this operation. Zero is 'false'; any other <i>real</i> number is 'true'.
ANGLES	<b>f [CAT.] VARS ANGLES</b>	Submenu of tagged angular variables defined at execution time. See pp. 121f.
arccos	<b>TRI arccos</b>	(1) {3, 8*, 9*}; {1, 2} → {4}; Returns the tagged angle $\text{arccos}(x)$ . <sup>8</sup>
arcosh	<b>g [EXP] g arcosh</b>	(1) {2, 3, 8*, 9*}
	<b>TRI g arcosh</b>	Returns $\text{arcosh}(x)$ .
arcsin	<b>TRI arcsin</b>	(1) {3, 8*, 9*}; {1, 2} → {4}; Returns the tagged angle $\text{arcsin}(x)$ . <sup>9</sup>

<sup>8</sup> Precisely, ARCCOS returns the principal value of  $\text{arccos}(x)$ , i.e. a *real* part  $\in [0, \pi]$  in  $\frac{\pi}{4}^r$ , or  $\in [0^\circ, 180^\circ]$  in  $\frac{\pi}{4}^\circ$  or  $\frac{\pi}{4}''$ , or  $\in [0^g, 200^g]$  in  $\frac{\pi}{4}^g$ , or  $\in [0, 1]$  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*}; {1, 2} → {4}; Returns the tagged angle $\text{arctan}(x)$ . <sup>10</sup>
arsinh	<b>g EXP g arsinh</b>	(1) {2, 3, 8*, 9*}
	<b>TRI g arsinh</b>	Returns $\text{arsinh}(x)$ .
artanh	<b>g EXP g artanh</b>	(1) {2, 3, 8*, 9*}
	<b>TRI g artanh</b>	Returns $\text{artanh}(x)$ .
ASIN	<b>f CATALOG FCNS ASIN</b>	Points to arcsin above. 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 <i>menu</i> , 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>	Points to arctan above. Maintained for backward compatibility only.

<sup>9</sup> Precisely, ARCSIN returns the principal value of  $\text{arcsin}(x)$ , i.e. a *real* part  $\in [-\pi/2, \pi/2]$  in  $\text{\#r}$ , or  $\in [-90^\circ, 90^\circ]$  in  $\text{\#^\circ}$  or  $\text{\#''}$ , or  $\in [-100^\circ, 100^\circ]$  in  $\text{\#^\circ}$ , or  $\in [-0.5, 0.5]$  in  $\text{\#pi}$ . Cf. ISO/IEC 9899.

<sup>10</sup> Precisely, ARCTAN returns the principal value of  $\text{arctan}(x)$ , i.e. a *real* part  $\in [-\pi/2, \pi/2]$  in  $\text{\#r}$ , for example (cf. ASIN), if SPCRES is set. Else the result interval for ATAN becomes  $(-\pi/2, \pi/2)$  in  $\text{\#r}$ , for example. Cf. ISO/IEC 9899.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
atm→Pa	f [U→] F&p: ▶ atm→Pa	(1) {2}; {1} → {2}
au→m	f [U→] x: au→m	Convert pressures and distances. See pp. 146ff.
A:	f [U→] f A:	Submenu. See p. 146.
a <sub>⊕</sub>	g [CNST] a <sub>⊕</sub>	(-1) {} → {2} Semi-major axis of the Earth's orbit around the sun in <i>meter</i> .
BACK	g [P.FN] P.FN2 g BACK n	(0) Jumps <i>n</i> 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 manually maintain all those statements individually.
bar→Pa	f [U→] F&p: bar→Pa	(1) {2}; {1} → {2} Converts pressures. See pp. 146ff.
BATT?	g [INFO] f BATT?	(-1) {} → {2} Measures the battery voltage in the range between 1.9V and 3.4 V and returns this value. Measurement resolution is 1mV
bbl→m <sup>3</sup>	f [U→] f v: f barrel → m <sup>3</sup>	(1) {2}; {1} → {2} Converts volumes. See pp. 146ff.
BC?	f [BITS] g BC? n	(-1) {10} Tests if the specified bit in <i>x</i> is clear.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
BEEP	<b>f I/O BEEP</b>	(0) Sounds a sequence of four tones. See also TONE.
BeginP	<b>g FIN TVM</b> <b>f Begin</b>	(0) Sets “Begin” mode in TVM: payments occur at the beginning of each period. Typical for savings plans and leasing. Cf. ENDP.
BestF	<b>f STAT ▼</b> <b>BestF n</b>	<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_{XY}</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 <b>n</b> 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 <b>n</b>.</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>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		Note ORTHOF is <u>not</u> part of the set of models under investigation. See pp. 217ff for more.
<b>Binom</b>	<b>g PROB</b> <b>g Binom:</b> <b>Binom</b> etc.	(1) {2} <i>Binomial distribution</i> with the number of successes <b>g</b> in <b>X</b> , the probability of a success <b>p<sub>o</sub></b> in <b>I</b> , and the sample size <b>n</b> in <b>J</b> . See p. 217 for more.
<b>Binom<sub>e</sub></b>		
<b>Binom<sub>p</sub></b>		
<b>Binom<sup>-1</sup></b>		<b>Binom<sup>-1</sup></b> returns the maximum number of successes <b>m</b> for a given probability <b>p</b> in <b>X</b> , <b>p<sub>o</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. 130.
<b>BITS</b>	<b>f BITS</b>	<b>Menu</b> . See p. 124.
<b>B<sub>n</sub></b>	<b>g X.FN</b> <b>B<sub>n</sub></b>	(1) {1, 2} B <sub>n</sub> and B <sub>n</sub> <sup>*</sup> 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. 215).
<b>B<sub>n</sub><sup>*</sup></b>	<b>g X.FN</b> <b>B<sub>n</sub><sup>*</sup></b>	
<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>f U→ E: Btu→J</b>	(1) {2}; {1} → {2} Converts energies. See pp. 146ff.
<b>c</b>	<b>g CNST</b> <b>c</b> etc.	(-1) {} → {2}
<b>c<sub>1</sub></b>		Speed of light in vacuum in <i>meter / second</i> ;
<b>c<sub>2</sub></b>		first and second radiation constants in <i>Planck's Law</i> (see p. 137).
<b>cal→J</b>	<b>f U→ E: cal→J</b>	(1) {2}; {1} → {2} Converts energies. See pp. 146ff.

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 s.</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, <math>r12</math> 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. 121ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>Cauch</b>	<b>g PROB f Cauch: Cauch</b>	(1) {2} Cauchy-Lorentz (a.k.a. Lorentz or Breit-Wigner) distribution with the location $x_0$ specified in <b>I</b> and the shape $\gamma$ in <b>J</b> . See p. 220 for more.
<b>Cauch<sub>e</sub></b>	etc.	
<b>Cauch<sub>p</sub></b>		
<b>Cauch<sup>-1</sup></b>		Cauch <sup>-1</sup> returns $x$ for a given probability $p$ in <b>X</b> , with $x_0$ in <b>I</b> and $\gamma$ in <b>J</b> .
<b>Cauch:</b>	<b>g PROB f Cauch:</b>	Submenu. See p. 130.
<b>CauchF</b>	<b>f STAT ▶ 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. 226ff for more.
<b>CB</b>	<b>f BITS g CB n</b>	(1) {10} Clears the specified bit in $x$ , i.e. sets it to <b>0</b> .
<b>CEIL</b>	<b>g INTS g CEIL</b>	(1) {8*} {1, 2} → {1} Returns the smallest integer $\geq x$ . Cf. FLOOR.
<b>CF</b>	<b>g FLAGS CF n</b>	(0) Clears the flag specified, i.e. sets it to <b>0</b> .
	<b>g MODE CF n</b>	
	<b>g CLR CF n</b>	
<b>CHARS</b>	<b>f CATALOG CHARS</b>	Submenu of characters. See pp. 121ff.
<b>CLALL</b>	<b>g CLR 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.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CLCVAR	<b>g CLR CLCVAR</b>	(0) Clears all variables used in the <i>current program</i> , i.e. sets all such <i>real</i> and <i>complex</i> variables to <b>0.</b> , all integer ones to <b>0</b> , all <i>time</i> variables to <b>0:00:00</b> , all <i>date</i> variables to <b>January 1<sup>st</sup></b> of year <b>0</b> , all character strings to zero length, and all the elements of all matrix variables used to <b>0</b> .
CLFALL	<b>g FLAGS g CLFall</b>	(0) Clears all global and local <i>user flags</i> . Compare CF.
	<b>g CLR f CLFall</b>	
CLK	<b>g CLK</b>	<b>Menu.</b> See p. 120.
CLLCD	<b>g CLR f CLLCD</b>	(0) Clears the <i>LCD</i> in the rectangular window north and west of the point <i>x, y</i> . I.e. all pixels $\geq x$ and $\geq y$ are cleared.
CLMENU	<b>g CLR CLMENU</b>	(0) Clears all <i>menu</i> key definitions for the programmable <i>menu</i> . See MENU.
	<b>g P.FN P.FN2 ...</b>	
CLP	<b>g CLR CLP</b>	(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 CLR f CLPall</b>	(0) Clears all programs in <i>RAM</i> . Cf. CLP.
CLR	<b>g CLR</b>	<b>Menu.</b> See p. 127.
CLREGS	<b>g CLR f CLREGS</b>	(0) Clears all global and local general purpose <i>registers</i> allocated (see also LOCR), i.e. sets all these registers to <b>0</b> . The contents of the stack and <b>L</b> are kept.
CLSTK	<b>g CLR f CLSTK</b>	Clears all <i>stack registers</i> currently allocated (i.e. either <b>X ... T</b> or <b>X ... D</b> ). All other <i>register</i> contents are kept. Cf. CLREGS.
	<b>0 f FILL</b>	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CLX	<b>g CLR CLX</b>	(1) Clears register <b>X</b> , disabling <i>automatic stack lift</i> . The shortcut works for closed $x$ only. Cf. CLREGS.
	<b>⬅</b>	
CLΣ	<b>f STAT g CLΣ</b>	(0) Clears the statistical summation <i>registers</i> and releases the memory allocated for them (see p. 168).
	<b>g CLR CLΣ</b>	
CNST	<b>g CNST</b>	<b>Menu</b> . See CONST below and pp. 135ff.
COMB	<b>g PROB C<sub>yx</sub></b>	(2) (1) Returns the number of possible <u>subsets</u> of $x$ items taken out of a set of $y$ items (i.e. choose $x$ out of $y$ ). No item occurs more than once in a subset, and <u>different orders</u> of the same $x$ items are <u>not counted</u> separately. Cf. PERM.
		(2) (2, 3) See pp. 215f for the formula.
CONJ	<b>g CPX conj</b>	(1) [3, 9*] Returns the <i>complex conjugate</i> of $x$ .
CONST	<b>g P.FN f CONST n</b>	(-1) {} → {2} Returns the constant stored at position $n$ in <u>CONST</u> (see pp. 135ff). Allows for indirectly addressing these constants.
CONVG?	<b>g TEST</b> <b>g CONVG? r</b>	(0) {2} Checks for convergence by comparing $x$ and $y$ as determined by the lowest five bits of $r$ . a) The very lowest 2 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:</p> <p>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 treated:</p> <p>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	<b>f</b> <b>STAT</b> <b>▲</b> <b>r</b>	$(-1) \{ \} \rightarrow \{2\}$ <p>Returns the coefficient of correlation for the current statistical data and curve fit model. See pp. 226ff for more.</p>
cos	<b>TRI</b> <b>cos</b>	$(1) \{2, 3, 8^*, 9^*\}; \{1, 4\} \rightarrow \{2\}$ <p>Returns the cosine of the angle in <b>X</b> (see Section 2 of the OM for details).</p>
cosh	<b>g</b> <b>EXP</b> <b>g</b> <b>cosh</b>	$(1) \{2, 3, 8^*, 9^*\}$
	<b>TRI</b> <b>g</b> <b>cosh</b>	<p>Returns the hyperbolic cosine of <math>x</math>.</p>
COV	<b>f</b> <b>STAT</b> <b>▲</b> <b>cov</b>	$(-1) \{ \} \rightarrow \{2\}$ <p>Returns the population covariance for the two data sets entered via <b>(Σ+)</b>, depending on the curve fit model selected. See <math>s_{XY}</math> for the sample covariance and pp. 217ff for more.</p>
CPX	<b>g</b> <b>CPX</b>	<p><b>Menu.</b> See p. 127.</p>
CPXS	<b>f</b> <b>CATALOG</b> <b>VARS</b> <b>CPXS</b>	<p><b>Submenu</b> of complex variables defined at execution time. See pp. 121f.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CPX?	<b>g TEST ▲ CPX?</b>	(0) Checks if $x$ is <i>complex</i> . Returns <b>true</b> if $X$ contains data of type 3 or 9 with nonzero <i>imaginary part</i> .
CROSS	<b>f MATX f cross</b>	(2) {8} Requires two <i>real</i> 2D or 3D vectors in <b>X</b> and <b>Y</b> and returns their cross product. Crossing of 2D vectors works as for <i>complex numbers</i> .
	<b>g CPX cross</b>	(2) {3} → {2} When two <i>complex numbers</i> are crossed, your WP 43S simply returns a <i>real</i> number that is equal to the signed <i>magnitude</i> of the resulting moment vector.
ct→kg	<b>f U→ m: f carat → kg</b>	(1) {2}; {1} → {2}
cwt→kg	<b>f U→ m: cwt→kg</b>	Convert masses. See pp. 146ff.
CX→RE	<b>CC</b> (works in run mode only)	(-1) {3} → {2}; {9} → {8} Cuts a closed <i>complex object</i> $x$ , putting either
	<b>g CPX f CX→RE</b>	• (for <b>L</b> ) its <i>real</i> part in <b>Y</b> and its <i>imaginary</i> part in <b>X</b> or • (for <b>⊕</b> ) <i>magnitude</i> in <b>Y</b> and <i>phase</i> in <b>X</b> .
DATE	<b>g CLK DATE</b>	(-1) {} → {6} Recalls the date 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 VARS f DATES</b>	<b>Submenu</b> of <i>date variables</i> defined at execution time. See pp. 121f.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DATE→	<b>g CLK DATE→</b>	(-2) {2, 6} → {1} Assumes $x$ containing a date 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} → {1} Assumes $x$ containing a date in the format selected (or a real number in corresponding format) and extracts the day.
DBLR	<b>g INTS g DBLR</b> etc.	(10) Double word length commands for remainder, multiplication and division. <sup>11</sup>
DBLx		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/		DBLx takes $x$ and $y$ as factors as usual but returns the product in <b>X</b> and <b>Y</b> (most significant bits in <b>X</b> ).
dB→fr	<b>f U→ ▲ dB → field ratio</b>	(1) {2}; {1} → {2}
dB→pr	<b>f U→ ▲ dB → power ratio</b>	Convert ratios. See pp. 146ff.
DEC	<b>f LOOP f DEC r</b>	(0) {1, 2, 10} Decrements $r$ by 1. Does not load <b>L</b> even for target address <b>X</b> .

<sup>11</sup> See the HP-16C Owner's Handbook, Section 4 (pp. 52ff).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DECOMP	f PARTS DECOMP	(-1) {1, 2} → {1} Decomposes $x$ (after converting it to an <i>improper fraction</i> , if applicable), returning a stack [ <i>denominator</i> ( $x$ ), <i>numerator</i> ( $x$ ), ...]. Reversible by division. <b>Example:</b> If $X$ contains 2.25 then DECOMP will return $x = 4$ and $y = 9$ .
DEG	g MODE DEG	(0) Sets the <i>ADM</i> to <i>decimal degrees</i> . Indicated in the <i>status bar</i> .
DEG→	g L→ f DEG→	(1) {1, 2} → {4} Converts angles as described on p. 152.
DENMAX	g MODE f DENMAX	(1) Works like /c on <i>HP-35S</i> , but the maximum legal denominator is 9 999. For $x < 1$ or $x > 9\,999$ , DENMAX will be set to 9 999. Indicated in the <i>status bar</i> . For $x = 1$ , the current DENMAX setting is recalled, replacing $x$ .
DET	f CATALOG FCNS DET	Points to  M  explained on p. 99. Maintained for backward compatibility only.
DIGITS	f CAT. f DIGITS	<i>Submenu</i> of digits defined. See pp. 121ff.
DOT	g CPX dot	(2) {3} → {2} Returns $Re(x) \cdot Re(y) + Im(x) \cdot Im(y)$
	f MATX f dot	(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 the OM, Sect. 2.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DROP	<b>g</b> <b>DROP</b> <b>↓</b>	<b>Drops x</b> ... from the stack. See <i>Section 1</i> of the OM for details.
DROPy	<b>g</b> <b>STK</b> <b>DROPy</b>	<b>Drops y</b>
DSE	<b>f</b> <b>LOOP</b> <b>DSE</b> <b>r</b>	(0) {1, 2, 10} Given <code>cccccc.ffffii</code> in the source, DSE decrements <b>r</b> by <b>ii</b> , skipping next program step if then <code>cccccc ≤ ffff</code> . If <b>r</b> features no fractional part then <code>ffff</code> is 0. If <code>ii = 0</code> , <code>cccccc</code> will be decremented by 1. DSE does not load <b>L</b> even for destination address <b>X</b> . Note that neither <code>ffff</code> nor <code>ii</code> can be negative, and DSE is only sensible with <code>cccccc &gt; 0</code> .
DSL	<b>f</b> <b>LOOP</b> <b>DSL</b> <b>r</b>	(0) {1, 2, 10} Works like DSE but skips if <code>cccccc &lt; ffff</code> .
DSP	<b>g</b> <b>DSP</b>	<b>Menu.</b> See p. 127.
DSTACK	<b>g</b> <b>DSP</b> <b>▲</b> <b>f</b> <b>DSTACK</b> <b>n</b>	(0) Sets the maximum number of <i>stack registers</i> displayed. For an input of 1, only <b>x</b> will be shown directly above the <i>menu section</i> ; for 2, <b>x</b> and <b>y</b> will be displayed; maximum input is 4. 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> . This command is for old-school calculator users who may feel distracted by a multitude of <i>stack registers</i> displayed changing simultaneously.
DSZ	<b>f</b> <b>LOOP</b> <b>DSZ</b> <b>r</b>	(0) {1, 2, 10} Decrement <b>r</b> by 1 and skips the next step if $ r  < 1$ thereafter. Does not load <b>L</b> even for target address <b>X</b> . Cf. HP-29C, HP-67, HP-16C.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
D.MS	f [d.ms] (for closed input)	(0) Sets the <i>ADM</i> to <i>sexagesimal degrees</i> . Indicated in the <i>status bar</i> .
D.MS→	g [L→] f D.MS→	(1) {1, 2} → {4}
D.MS→D	g [L→] g D.MS→D	Convert angles as described on pp. 152f.
D.MY	g [CLK] ▲ D.MY	(0) Sets the format dd.mm.yyyy for <i>dates</i> .
D→D.MS	g [L→] g D→D.MS	(1) {1, 2} → {4}
		Converts angles as described on p. 152.
D→J	g [CLK] f D→J	(1) {2, 6} → {1} Assumes <i>x</i> containing a <i>date</i> in the format selected (or a <i>real number</i> in corresponding format) and converts it to a <i>Julian day number</i> <sup>12</sup> according to J/G setting.
D→R	g [L→] g D→R	(1) {1, 2} → {4}
		Converts angles as described on p. 152.
e	g [CNST] e	(-1) {} → {2}
e <sub>E</sub>	g [CNST] e <sub>E</sub>	Elementary charge in <i>coulomb</i> and <i>Euler's e</i> .
EIGVAL	f [MATX] ▲ g EIGVAL	(-1) {8, 9} Evaluates the matrix <i>x</i> and pushes a diagonal matrix containing its eigenvalues on the stack.
EIGVEC	f [MATX] ▲ g EIGVEC	(-1) {8, 9} Evaluates the matrix <i>x</i> and pushes a matrix containing its eigenvectors on the stack.

<sup>12</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)
END	<b>g P.FN END</b>	(0) Last command in a program and terminal for searching local labels as described in the OM, Section 3. Works like RTN in all other aspects.
ENDP	<b>g FIN TVM f End</b>	(0) Sets “End” mode in TVM: payments occur at the end of each period. Typical for loans and investments. Cf. BEGINP.
ENG	<b>g DSP ENG n</b>	(0) Sets engineer’s display format (see Section 2 of the OM).
ENORM	<b>f MATX g ENORM</b>	(1) {8, 9} → {2}  Calculates the Euclidean norm of the matrix in <b>X</b> . 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. 99.
ENTER↑	<b>ENTER↑</b>	(-1) Separates two entries in input. Copies $x$ into <b>Y</b> , disabling <i>automatic stack lift</i> . See p. 117 and the OM (Section 1) 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 AIM, 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. 128.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
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}; {1} → {2}  Returns the error function or its complement. See pp. 247ff for more.
erfc		
ERR	<b>g P.FN ERR 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. 178ff for the respective error codes. Cf. MSG.
EVEN?	<b>g TEST f EVEN?</b>	(0) Checks if $x$ is integer and even.
$e^x$	<b>e<sup>x</sup></b>	(1) {2, 3, 8*, 9}; {1, 10} → {2}  Returns $e^x$ .
EXITALL	<b>g P.FN P.FN2 EXITall</b>	(0) Exits all menus.
EXP	<b>g EXP</b>	Menu. See p. 128.
ExpF	<b>f STAT ▾ ExpF</b>	(0) Selects the exponential curve fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 217ff for more.
Expon	<b>g PROB</b>	(1) {2}
Expon <sub>e</sub>	<b>f Expon: Expon</b> etc.	<i>Exponential distribution</i> with the rate $\lambda$ in <b>J</b> . See pp. 217ff for more.
Expon <sub>p</sub>		
Expon <sup>-1</sup>		Expon <sup>-1</sup> returns the survival time $t_s$ for a given probability $p$ in <b>X</b> , with $\lambda$ in <b>J</b> .

See Section 4 of  
the OM.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Expon:	<b>g PROB f Expon:</b>	<b>_submenu.</b> See p. 130.
EXPT	<b>f PARTS EXPT</b>	(1) {1, 2} → {1} Returns the exponent $h$ of the number $x = m \cdot 10^h$ displayed. Cf. MANT.
$e^x - 1$	<b>g EXP f <math>e^x - 1</math></b>	(1) {2, 8*} For $x \approx 0$ , this returns a more accurate result for the fractional part than $e^x$ does.
E:	<b>f U→ E:</b>	<b>_submenu.</b> See p. 145.
F	<b>g CNST F</b>	(-1) {} → {2} <i>Faraday constant in coulomb per mol.</i>
FB	<b>f BITS g FB n</b>	(1) {10} Inverts ('flips') the specified bit in $x$ .
FBR	<b>g a.FN g FBR</b>	(0) Font browser. Shows all characters implemented in the fonts designed for your WP 43S.
FCNS	<b>f CATALOG FCNS</b>	<b>_submenu</b> of provided functions. See pp. 121ff.
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		
$F_e(x)$	<b>g PROB F: <math>F_e(x)</math></b>	(1) {2} <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. 217ff for more. etc.
$F_p(x)$		
$F(x)$		
$F^{-1}(p)$		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
FF	<b>g</b> FLAGS FF <b>n</b>	(0) Flips the flag specified.
FIB	<b>g</b> X.FN <b>f</b> FIB	(1) {1} Returns the Fibonacci number (see pp. 215f).
		(1) {2, 3} Returns the extended Fibonacci number.
FILL	<b>f</b> FILL	Copies $x$ to all stack registers.
FIN	<b>g</b> FIN	Menu. See p. 128.
FIX	<b>g</b> DSP FIX <b>n</b>	(0) Sets fixed point display format (see the OM, Sect. 2).
FLAGS	<b>g</b> FLAGS	Menu. See p. 128.
FLASH	<b>f</b> CATALOG PROGS FLASH	Submenu of global labels defined at execution time. See pp. 121f.
FLASH?	<b>g</b> INFO <b>f</b> FLASH?	(-1) {} → {1} Returns the number of free words in FM (1 word = 2 bytes).
FLOOR	<b>g</b> INTS <b>g</b> FLOOR	(1) {8*} {1, 2} → {1} Returns the greatest integer $\leq x$ . Cf. CEIL.
fm.→m	<b>f</b> U→ <b>x:</b> ▲ fathom → m	(1) {2, 11; {1} → {2}} Converts distances. See pp. 146ff.
FP	<b>f</b> PARTS FP	(1) {1, 2, 8*, 10} Returns the fractional part of $x$ . Cf. IP.
FP?	<b>g</b> TEST <b>f</b> FP?	(0) Tests $x$ for having a fractional part $\neq 0$ .
fr→dB	<b>f</b> U→ ▲ field ratio→dB	(1) {2}; {1} → {2} Converts ratios. See pp. 146ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
FS?	<b>g FLAGS FS? <i>n</i></b>	(0) Tests if the specified <i>flag</i> is set.
FS?C	<b>g FLAGS f FS?C <i>n</i></b>	
FS?F	<b>f FS?C <i>n</i></b> 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>f U<math>\rightarrow</math> x: f ft.<math>\rightarrow</math>m</b>	
ft <sub>US</sub> $\rightarrow$ m	<b>f U<math>\rightarrow</math> x: ▲ survey foot<sub>US</sub> <math>\rightarrow</math> m</b>	(1) {2}; {1} $\rightarrow$ {2}
ft <sub>UK</sub> $\rightarrow$ m <sup>3</sup>	<b>f U<math>\rightarrow</math> f V: f floz<sub>UK</sub> <math>\rightarrow</math> m<sup>3</sup></b>	Convert distances and volumes, respectively. See pp. 146ff.
ft <sub>US</sub> $\rightarrow$ m <sup>3</sup>	<b>f U<math>\rightarrow</math> f V: f floz<sub>US</sub> <math>\rightarrow</math> m<sup>3</sup></b>	
F <sub><math>\alpha</math></sub>	<b>g CNST F<sub><math>\alpha</math></sub></b> etc.	(-1) {} $\rightarrow$ {2}
F <sub><math>\delta</math></sub>		Feigenbaum's $\alpha$ and $\delta$ .
F:	<b>g PROB F:</b>	_submenu_. See p. 130.
f'	<b>g EQN f'</b>	Submenus for calculating the first or second derivative of a given equation. See the OM (Sect. 4) for more.
f''	<b>g EQN f''</b>	
f'(x)	<b>f ADV f'(x) <i>labl</i></b>	[1, 2] $\rightarrow$ {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 <i>labl</i> . 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 ADV f f''(x) <i>labl</i></b>	<b>ATTENTION:</b> f(x) and f'(x) fill all stack registers with x before calling the routine specified.
F&p:	<b>f U<math>\rightarrow</math> F&amp;p:</b>	_submenu_. See p. 146.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
G		(-1) {} → {2} Newtonian constant of gravitation in $m^3/kg\ s^2$ ; also called $\gamma$ by other authors.
$G_0$		Conductance quantum in <i>siemens</i> .
GAP		(0) Defines the interval for inserting digit group separators in <i>reals</i> . 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 <i>reals</i> .  After GAP 2, 1, or GAP 0, <u>no</u> group separators will be displayed in any numbers at all.  See Sect. 2 of the OM.
GaussF		(0) Selects the Gauß peak fit model. Relevant for CORR, COV, L.R., $s_{xy}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 226ff for more.
$G_c$		(-1) {} → {2} <i>Catalan's</i> (mathematical) constant.
GCD		(2) {1; 10}  Returns the Greatest Common Divisor of $x$ and $y$ . <sup>13</sup> This will always be positive.
$g_d$	 etc.	(1) {2, 3}; {1} → {2}  Returns the Gudermannian function or its inverse. See p. 248 for details.
$g_d^{-1}$		
$g_e$		(-1) {} → {2} <i>Landé's</i> electron g-factor.

<sup>13</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)
Geom	<b>g PROB</b> <b>g Geom:</b> <b>Geom</b> etc.	(1) {2}  <i>Geometric distribution:</i> 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. 217ff for more.
Geom <sub>e</sub>		
Geom <sub>p</sub>		
Geom <sup>-1</sup>		Geom <sup>-1</sup> returns the number of failures <b>f</b> before 1 <sup>st</sup> success for given probabilities <b>p</b> in <b>X</b> , <b>p<sub>0</sub></b> in <b>J</b> .
Geom:	<b>g PROB</b> <b>f Geom:</b>	Submenu. See p. 130.
gl <sub>uk</sub> →m <sup>3</sup>	<b>f U→</b> <b>f V:</b> gl <sub>uk</sub> →m <sup>3</sup> etc.	(1) {2}; {1} → {2}
gl <sub>us</sub> →m <sup>3</sup>		Convert volumes. See pp. 146ff.
GM <sub>⊕</sub>	<b>g CNST</b> GM <sub>⊕</sub>	(-1) {} → {2}  Newtonian constant of gravitation times the Earth's mass with its atmosphere included according to WGS84. <sup>14</sup> Displayed in $m^3/s^2$ .
GRAD	<b>g MODE</b> GRAD	(0) Sets the ADM to grad/gon. <sup>15</sup> Indicated in the status bar.
GRAD→	<b>g L→</b> <b>f GRAD→</b>	(1) {1, 2} → {4}  Converts angles as described on pp. 152f.
GTO	<b>f GTO</b> <b>labl</b>	(0) In PEM, inserts an unconditional branch to <b>labl</b> .  Else positions the program pointer to <b>labl</b> .

<sup>14</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>15</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</b> [GTO] . <i>n</i>	to step <i>n</i> (specify up to four digits until becoming unambiguous in used program memory).
	<b>f</b> [GTO] . <i>label</i>	to the global label specified.
	<b>f</b> [GTO] . ▲	(0) Puts the program pointer ... directly after previous END, going to the top of <i>current program</i> (see Sect. 3 of the OM).
	<b>f</b> [GTO] . ▼	directly after <u>next</u> END, going to the top of next program.
	<b>f</b> [GTO] . .	to the end of used program memory in RAM (i.e. to the final END statement).
g <sub>⊕</sub>	<b>g</b> [CNST] g <sub>⊕</sub>	(-1) {} → {2} Standard earth acceleration in $m/s^2$ .
h	<b>g</b> [CNST] h	(-1) {} → {2} Planck constant in joule-second.
ha→m <sup>2</sup>	<b>f</b> [U↔] <b>f</b> A: ha → m <sup>2</sup>	(1) {2}; {1} → {2} Converts areas. See pp. 146ff.
H <sub>n</sub>	<b>g</b> [X.FN] Orthog H <sub>n</sub>	(2) {2}; {1} → {2}
H <sub>np</sub>	... Orthog <b>f</b> H <sub>np</sub>	<i>Hermite polynomials</i> for probability (H <sub>n</sub> ) and physics (H <sub>np</sub> ). See p. 242 for details.
hp <sub>E</sub> →W	<b>f</b> [U↔] P: hp <sub>E</sub> →W etc.	(1) {2}; {1} → {2}
hp <sub>M</sub> →W		Convert powers. See pp. 146ff.
hp <sub>UK</sub> →W		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Hyper	<b>g PROB</b> <b>g Hyper:</b> Hyper etc.	(1) {2} <i>Hypergeometric distribution</i> 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. 217ff 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. 130.
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. 226ff for more.
$\hbar$	<b>g CNST</b> $\hbar$	(-1) {} → {2} $= \frac{h}{2\pi}$ , reduced Planck constant (a.k.a. so-called Dirac constant) in joule-second.
IDIV	<b>g INTS</b> <b>f IDIV</b>	(2) {1, 10}; {2} → {1} Integer division, working like <b>Z IP</b> . See the OM, Sect. 2, for the data type of the quotient.
IDIVR	<b>f CATALOG</b> FCNS IDIVR	{1, 2, 10} Like IDIV but also returns the remainder in $Y$ . See the OM, Section 2, for the resulting data types of quotient and remainder.
iHg→Pa	<b>f U→</b> F&p: <b>f in.Hg</b> → Pa	(1) {2}; {1} → {2} Converts pressures. See pp. 146ff.
Im	<b>g CPX</b> <b>f Im</b> <b>f PARTS</b> <b>g Im</b>	(1) {3} → {2}; {9} → {8};
		Returns the imaginary part of $x$ . Cf. RE.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
INC	f [LOOP] f INC r	(0) {1, 2, 10} Increments r by 1. Does not load L even for target address X.
INDEX	f [MATX] f INDEX name	(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	g [INFO]	Menu. See p. 128.
INPUT	g [P.FN] INPUT r	Works in programs only: Recalls the content of the source specified into X, displays the name of the source along with r, and halts program execution, allowing you to enter or calculate a value; pressing R/S then stores x 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	g [INTS]	Menu. See p. 128.
INT?	g [TEST] f INT?	(0) Tests x for being an integer, i.e. having a fractional part equal to zero. Cf. FP?.
INVRT	f [CATALOG] FCNS INVRT	Works like [M] <sup>-1</sup> on p. 99. Maintained for backward compatibility only.
in.→m	f [U→] x: g in.→m	(1) {2}; {1} → {2} Converts distances. See pp. 146ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
IP	<b>f PARTS IP</b>	(1) {1, 8*, 10}; {2} → {1} Returns the integer part of $x$ . Cf. FP.
ISE	<b>f LOOP ISE s</b>	(0) {1, 2, 10} Given $cccccc.f ffi i i$ in the source $s$ , ISE increments $s$ by $ii$ , skipping next program step if $cccccc \geq ffff$ then. If $s$ has no fractional part then $fff = 0$ and $ii = 0$ . If $ii = 0$ , $cccccc$ will be incremented by 1. ISE does not load <b>L</b> even for target address <b>X</b> . Note that neither $fff$ nor $ii$ can be negative, but $cccccc$ can.
ISG	<b>f LOOP ISG s</b>	(0) {1, 2, 10} Works like ISE but skips if $cccccc > ffff$ .
ISZ	<b>f LOOP ISZ s</b>	(0) {1, 2, 10} Increments $s$ by 1, skipping next program step if then $ s  < 1$ . ISZ does not load <b>L</b> even for target address <b>X</b> . Cf. HP-29C, HP-67, and HP-16C.
$I_{xyz}$	<b>g X.FN f I<sub>xyz</sub></b>	(3) {1, 2} Returns the <i>regularized Beta function</i> . <span style="float: right;">See p. 248 for more.</span>
$I\Gamma_p$	<b>g X.FN f I<sub>\Gamma_p</sub></b> etc.	(2) {1, 2} Returns the <i>regularized Gamma function</i> (one of two kinds).
I+	<b>f MATX ▲ I+</b>	(1) Increments or decrements the row index of the indexed matrix. See INDEX and also J+, J-, RCLEL, STOEL, RCLIJ, and STOIJ.
I-	<b>f MATX ▲ I-</b>	
I/O	<b>f I/O</b>	<b>Menu.</b> See p. 128.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$J_y(x)$		(2) {2}; {1} → {2} $J_y(x)$ returns the <i>Bessel function of first kind</i> and order $y$ . See p. 249 for details.
$J+$		(1) Increments or decrements the column index of the indexed matrix. If 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 $I+$ , $I-$ , RCLEL, STOEL, RCLIJ, and STOIJ.
$J-$		
$J/G$		(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.
$J \rightarrow Btu$		(1) {2}; {1} → {2}
$J \rightarrow cal$	etc.	Convert energies. See pp. 146ff.
$J \rightarrow D$		(1) {1} → {6} Takes $x$ as a <i>Julian day number</i> <sup>16</sup> and converts it to a common <i>date</i> according to J/G (see above) and the date format selected.
$J \rightarrow Wh$		(1) {2}; {1} → {2} Converts energies. See pp. 146ff.
$k$		(-1) {} → {2} <i>Boltzmann constant</i> in <i>joule per kelvin</i> .
KEY		See KEYG and KEYX below.

<sup>16</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</b> P.FN2 <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</b> P.FN2 <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 no 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 <b>r</b> . Key codes reflect the rows and columns on the keyboard (see the OM, Sect. 3; cf. GETKEY on HP-42S).
kg→ct	<b>f U→ m: f kg → carat</b>	(1) {2}; {1} → {2} Convert masses. See pp. 146ff.
kg→cwt	<b>f U→ m: kg→cwt</b> etc.	
kg→lb.		
kg→oz		
kg→scw	<b>f U→ m: f kg → sh.cwt</b>	
kg→sto	<b>f U→ m: f kg → stone</b>	
kg→s.t	<b>f U→ m: ▲ kg → short ton</b>	
kg→ton	<b>f U→ m: ▲ kg→ton</b>	
kg→trz	<b>f U→ m: f kg → tr.oz</b>	
K <sub>J</sub>	<b>g CNST K<sub>J</sub></b>	(-1) {} → {2} Josephson constant in hertz per volt.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
KTYP?	<b>g INFO KTYP? <i>r</i></b>	<p>(-1) <math>\{ \} \rightarrow \{ 1 \}</math></p> <p>Assumes a key code in the address specified (see KEY?), checks it, and returns its 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 Sect. 1 of the OM. Actually, this command will be recorded as RCL L in routines.
lbf→N	<b>f U→ F&amp;p: lbf→N</b>	(1) {2}; {1} → {2} Converts forces. See pp. 146ff.
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 Section 3 of the OM.
LBL?	<b>g TEST g LBL? <i>label</i></b>	(0) Tests for existence of the label specified, anywhere in program memory. See LBL for more.
lb.→kg	<b>f U→ m: lb.→kg</b>	(1) {2}; {1} → {2} Converts masses. See pp. 146ff.
LCM	<b>g INTS f LCM</b>	(2) {1; 10} Returns the Least Common Multiple of x and y. <sup>17</sup> This will always be positive.

<sup>17</sup> See also GCD. Remember school?

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LEAP?	[g] TEST [f] LEAP?	(0) {2, 6} Assumes $x$ containing a <i>date</i> in the format selected (or a <i>real</i> number in corresponding format), extracts the year, and tests for a leap year.
LgNrm	[g] PROB [f] LgNrm: LgNrm etc.	(1) {2B} <i>Log-normal distribution</i> with $\mu = \ln \bar{x}_g$ specified in I and $\sigma = \ln \varepsilon$ in J. See $\bar{x}_g$ and $\varepsilon$ below and pp. 217ff for more.
LgNrm <sub>e</sub>		
LgNrm <sub>p</sub>		
LgNrm <sup>-1</sup>		LgNrm <sup>-1</sup> returns $x$ for a given probability $p$ in X, with $\mu$ in I and $\sigma$ in J.
LgNrm:	[g] PROB [f] LgNrm:	Submenu. See p. 130.
LinF	[f] STAT ▾ LinF	(0) Selects the linear fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 217ff for more.
LJ	[f] BITS [g] LJ	{10} Left justifies a bit pattern within its <i>word size</i> as in HP-16C: The stack will lift, placing the left-justified word in Y and the count of bit-shifts necessary to left justify the word in X.  Example for word size 8: 1 0110 <sub>2</sub> LJ returns $x = 3$ and $y = 1011\ 0000_2$
L <sub>m</sub>	[g] X.FN Orthog L <sub>m</sub> etc.	(2) {2}; {1} → {2} Laguerre polynomials and Laguerre's generalized polynomials. See pp. 232f for more.
L <sub>ma</sub>		
LN	[In]	(1) {2, 3, 8*, 9}; {1, 10} → {2} Returns the natural logarithm of $x$ .

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)
$\text{LN}\beta$	<b>g X.FN g</b> $\text{ln}\beta$	(2) {2, 3}; {1} → {2} Returns the natural logarithm of <i>Euler's Beta function</i> (see p. 90).
$\text{LN}\Gamma$	<b>g X.FN g</b> $\text{ln}\Gamma$	(1) {2, 3}; {1} → {2}
	<b>g PROB ▲</b> $\text{ln}\Gamma$	Returns the natural logarithm of $\Gamma(x)$ (see p. 91). Allows also for calculating really great factorials (see an example in the OM).
$\text{LN}(1+x)$	<b>g EXP f</b> $\text{ln } 1+x$	(1) {2, 8*} For $x \approx 0$ , this returns a more accurate result for the fractional part than $\text{ln}(x)$ does.
LOAD	<b>f I/O LOAD</b>	Restores the entire backup from <i>FM</i> and returns <b>Backup restored</b> . Thus, $\text{LOAD} = \text{LOADP} + \text{LOADR} + \text{LOADSS} + \text{LOAD}\Sigma$ . <sup>18</sup>
LOADP	<b>f I/O LOADP</b>	(0) Loads the entire program memory from backup and appends it to the programs already in <i>RAM</i> (if there is sufficient space – else an error will be thrown). <sup>18</sup>
LOADR	<b>f I/O LOADR</b>	(0) Recovers the numbered general purpose <i>registers</i> from backup. Lettered <i>registers</i> will not be recalled. <sup>18</sup>
LOADSS	<b>f I/O LOADSS</b>	(0) Recovers the system state from backup. <sup>18</sup>
LOADΣ	<b>f I/O LOADΣ</b>	(0) Recovers the statistical summation <i>registers</i> from backup. Throws an error if there are none. <sup>18</sup>
LocR	<b>g P.FN g</b> <b>LocR n</b>	(0) Allocates <i>n local registers</i> ( $\leq 100$ ) and 16 <i>local flags</i> for the <i>current routine</i> . See the OM, Sect. 3.

<sup>18</sup> See *SAVE* on p. 73 and *App. A* on pp. 143f for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LocR?	[g] [INFO] [f] LocR?	(-1) {} → {1} Returns the number of <i>local registers</i> currently allocated.
LOG <sub>10</sub>	[g] [lg]	(1) {1, 2, 3, 8*, 9*, 10} ({1} → {2}) Returns the logarithm of $x$ for base 10.
LOG <sub>2</sub>	[g] [EXP] lb x	(1) {1, 2, 3, 8*, 9*, 10} ({1} → {2}) Returns the logarithm of $x$ for base 2.
LogF	[f] [STAT] ▾ 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. 217ff for more.
Logis	[g] [PROB]	(1) {2} <i>Logistic distribution with <math>\mu</math> given in I and <math>s</math> in J.</i> See pp. 217ff for details.
Logis <sub>e</sub>	[f] Logis: Logis etc.	
Logis <sub>p</sub>		
Logis <sup>-1</sup>		
Logis:	[g] [PROB] [f] Logis:	Submenu. See p. 130.
LOG <sub>x</sub> y	[g] [EXP] log <sub>x</sub> y	(2) {1, 2, 3, 8*, 9*, 10}; ({1} → {2}) Returns the logarithm of $y$ for the base $x$ .
LOOP	[f] [LOOP]	Menu. See p. 129.
l <sub>PL</sub>	[g] [CNST] l <sub>PL</sub>	(-1) {} → {2} <i>Planck length in meter.</i>
ly→m	[f] [U→] x: ly→m	(1) {2}; {1} → {2} Converts distances. See pp. 146ff.
L.INTS	[f] [CATALOG] VARS L.INTS	Submenu of <i>long integer variables defined at execution time</i> . See pp. 121ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
L.R.	f [STAT] ▲ L.R.	(-2) or (-3) { } → {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 registers on the stack, 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. 217ff for more.
$m^2 \rightarrow ac$	f [U→] f A: $m^2 \rightarrow acre$	
$m^2 \rightarrow ac_{us}$	f [U→] f A: $m^2 \rightarrow acre_{us}$	(1) {2}; {1} → {2} Convert areas. See pp. 145ff.
$m^2 \rightarrow ha$	f [U→] f A: $m^2 \rightarrow ha$	
$m^3 \rightarrow bbl$	f [U→] f V: f $m^3 \rightarrow barrel$	
$m^3 \rightarrow fz_{uk}$	f [U→] f V: f $m^3 \rightarrow floz_{uk}$	(1) {2}; {1} → {2}
$m^3 \rightarrow fz_{us}$	etc.	Convert volumes. See pp. 145ff.
$m^3 \rightarrow gl_{uk}$	f [U→] f V: $m^3 \rightarrow gl_{uk}$	
$m^3 \rightarrow gl_{us}$	etc.	
MANT	f [PARTS] MANT	(1) {2}; {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 <i>n</i>	(-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 <i>n</i>	<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	<b>Submenu</b> of matrix variables defined at execution time. See pp. 121f.
MATR?	g TEST ▲ MATR?	(0) Checks if <i>x</i> is a <i>real</i> or <i>complex</i> matrix.
MATX	f MATX	<b>Menu.</b> See p. 129.
Mat_X	f MATX SIM EQ Mat X	(-1) Returns the solution vector of a system of linear equations (see the OM, Sect. 2).
max	g X.FN g max	(2) {1, 2, 4, 5, 6, 7, 10} Returns the maximum of <i>x</i> and <i>y</i> .
m_e	g CNST m_e	(-1) {} → {2} Electron mass in <i>kilogram</i> .
MEM?	g INFO MEM?	(-1) {} → {1} Returns the number of free <i>bytes</i> in program memory, also taking into account the local <i>registers</i> allocated.
MENU	g P.FN P.FN2 MENU	Displays the programmable <i>menu</i> . See the HP-42S OM, Part 2, Section 10, p. 146.
MENUS	f CAT. MENUS	<b>Submenu</b> of all <i>menus</i> defined at execution time. See pp. 121ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>min</b>	<b>g X.FN g min</b>	(2) {1, 2, 4, 5, 6, 7, 10} Returns the minimum of $x$ and $y$ .
<b>MIRROR</b>	<b>f BITS f MIRROR</b>	(1) {10} Reflects the bit pattern in $x$ (e.g. $0001\ 0111_2$ would become $1110\ 1000_2$ for word size 8).
<b>mi.<math>\rightarrow</math>m</b>	<b>f U<math>\rightarrow</math> x: f mi.<math>\rightarrow</math>m</b>	(1) {2}; {1} $\rightarrow$ {2} Converts distances. See pp. 145ff.
<b>M<sub>Moon</sub></b>	<b>g CNST M<sub>Moon</sub></b> etc.	(-1) {} $\rightarrow$ {2}
<b>m<sub>n</sub></b>		Mass of the Moon in <i>kilogram</i> ;
<b>m<sub>n</sub>/m<sub>p</sub></b>		neutron mass in <i>kilogram</i> ; neutron to proton mass ratio.
<b>MOD</b>	<b>g INTS f MOD</b>	(2) {1, 2, 10} Returns $y \bmod x$ (modulo, see Section 2 of the OM for examples). Cf. RMD.
<b>MODE</b>	<b>g MODE</b>	<i>Menu</i> . See p. 129.
<b>MONTH</b>	<b>g CLK f MONTH</b>	(1) {2, 6} $\rightarrow$ {1} Assumes $x$ containing a <i>date</i> in the format selected (or a <i>real</i> number in corresponding format) and extracts the month.
<b>m<sub>p</sub></b>	<b>g CNST m<sub>p</sub></b> etc.	(-1) {} $\rightarrow$ {2}
<b>m<sub>PL</sub></b>		Proton mass and <i>Planck</i> mass in <i>kilogram</i> ;
<b>m<sub>p</sub>/m<sub>e</sub></b>		proton to electron mass ratio.
<b>MSG</b>	<b>g P.FN P.FN2</b> <b>f MSG</b>	(0) {1, 2} Throws the ( <i>temporary</i> ) error message specified by the integer part of $x$ . Cf. ERR. See App. C on pp. 178ff 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> .
MULπ	<b>g</b> [MODE] MULπ	(0) Sets the <i>ADM</i> to <i>multiples of π</i> . Indicated in the <i>status bar</i> .
MULπ→	<b>g</b> [L→] <b>f</b> MULπ→	(1) {1, 2} → {4} Converts angles as described on pp. 152f.
MVAR	<b>g</b> [P.FN] <b>f</b> MVAR name	(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 <i>OM</i> , Section 6.
Myα	<b>f</b> [CAT.] CHARS Myα	User menu in <i>AIM</i> .
$m_\mu$	<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 name	(0) {1, 2} Creates a new named matrix or re-dimensions an existing matrix to IP(y) rows and IP(x) columns. See <i>DIM</i> 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 <b>Y</b> , columns to <b>X</b> ). Note the matrix is saved in <b>L</b> . Previous <i>y</i> goes into <b>Z</b> , previous <i>z</i> into <b>T</b> , etc.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
M.DY	<b>g CLK ▲ M.DY</b>	(0) Selects the format mm/dd/yyyy for dates.
M.EDI	<b>f MATX EDIT</b>	(2) {8, 9} Opens $x$ using the <i>Matrix Editor</i> (like MATRIX EDIT in HP-42S). <sup>19</sup> See Section 2 of the OM.
M.EDIN	<b>f MATX</b> <b>f EDITN name</b>	(2) Opens a named matrix using the <i>Matrix Editor</i> (like MATRIX EDITN in HP-42S). See Section 2 of the OM.
M.EDIT		<b>Submenu</b> for matrix editing, called by M.EDI or M.EDIN. See p. 129.
M.GET	<b>f MATX g GETM</b>	(0) {1, 2} → {8, 9} Gets a sub-matrix with IP(y) rows and IP(x) columns out of the indexed matrix into $X$ (like GETM in HP-42S). Cf. M.PUT.
M.GOTO	<b>f GOTO</b>	(0) Asks for target row and column and moves to this matrix element.
M.GROW	<b>f GROW</b>	(0) Allows the indexed matrix to grow automatically (see J+ above and Section 2 of the OM; see also GROW in the HP-42S Owner's Manual, p. 213.). Cf. M.WRAP.
M.INSR	<b>f INSR</b>	(0) Inserts a new row of elements containing zero, left of the current cursor position in the matrix.

with M.EDIT displayed

<sup>19</sup> In the real HP-42S, EDIT and EDITN don't actually disable *automatic stack lift*; they preserve the *stack lift* state – you can observe this if you do ENTER vs. a *stack-lift*-enabling operation (e.g.  $x\gtrless y$ ) just before invoking them. This behavior is not really useful, but it needs to be emulated anyway, since not doing so risks breaking HP-42S programs.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
M.LU	<b>f</b> MATX ▲ <b>f</b> M.LU	(1) WP 34S: Takes a <i>descriptor</i> of a square matrix in <b>X</b> . Transforms ( <i>X</i> ) into its LU decomposition in-situ. The value in <b>X</b> 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.
M.NEW	<b>f</b> MATX NEW	(2) {1, 2} → {8}  Creates a new matrix (like NEW in HP-42S). Its number of rows shall be supplied in <b>Y</b> and its number of columns in <b>X</b> . M.NEW returns a matrix <i>x</i> with all its elements set to zero.
M.OLD	OLD with M.EDIT displayed	(0) Recalls the old element content (like OLD in HP-42S). See the OM, Sect. 2.
M.PUT	<b>f</b> MATX <b>g</b> PUTM	(0) {8, 9}  Puts the matrix <i>x</i> as is into the indexed matrix (like PUTM in HP-42S). Cf. M.GET.
M.R>R	<b>f</b> MATX ▲ <b>f</b> R>R	(0) {8, 9}  Swaps row <i>x</i> and row <i>y</i> of the indexed matrix (like R>R in HP-42S).
M.SIMQ		Submenu of MATX, called by SIM_EQ.
M.SQR?	<b>g</b> TEST ▲ <b>f</b> M.SQR?	(0) Returns true if <i>x</i> is a square matrix.
M.WRAP	<b>f</b> WRAP with M.EDIT displayed	(0) Controls the index pointers (see Section 2 of the OM). Cf. M.GROW.
m:	<b>f</b> U→ m:	Submenu. See p. 145.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$m \rightarrow au$	f [U] $\rightarrow$ x: m → au	(1) {2}; {1} → {2} Convert distances or heights. See pp. 145ff.
$m \rightarrow fm.$	f [U] $\rightarrow$ x: ▲ m → fathom	
$m \rightarrow ft.$	f [U] $\rightarrow$ x: f m → ft.	
$m \rightarrow ft_{us}$	f [U] $\rightarrow$ x: ▲ m → survey foot <sub>us</sub>	
$m \rightarrow in.$	f [U] $\rightarrow$ x: g m → in.	
$m \rightarrow ly$	f [U] $\rightarrow$ x: m → ly	
$m \rightarrow mi.$	f [U] $\rightarrow$ x: f m → mi.	
$m \rightarrow nmi.$	f [U] $\rightarrow$ x: f m → nmi.	
$m \rightarrow pc$	f [U] $\rightarrow$ x: m → pc	
$m \rightarrow pt.$	f [U] $\rightarrow$ x: g m → point	
$m \rightarrow yd.$	f [U] $\rightarrow$ x: g m → yd.	
$m_{\oplus}$	g [CNST] m <sub>⊕</sub> etc.	(-1) {} → {2}
$m_{\odot}$		Masses of the Earth and Sun in kilogram.
$N_A$	g [CNST] N <sub>A</sub>	(-1) {} → {2} Avogadro's number in particles per mol.
NAND	f [BITS] f NAND	(2) Works in analogy to AND. See p. 18.
NaN	g [CNST] NaN	(-1) Not a Number.
NaN?	g [TEST] ▲ f NaN?	(0) Returns true if x is Not a Number.
NBin	g [PROB]	(1) {2}
NBin <sub>e</sub>	g NBin: NBin etc.	Negative binomial distribution with the total number of failures f in X, the probability of a success p <sub>0</sub> in I, and the number of draws n in J. See pp. 217ff for more information.
NBin <sub>p</sub>		
NBin <sup>-1</sup>		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
NBin:	[g] PROB [g] NBin:	Submenu. See p. 130.
NEIGHB	[g] INFO [f] NEIGHB	<p>(2) {1}</p> <p>Returns ...</p> <ul style="list-style-type: none"> <li>• <math>x + 1</math> for <math>x &lt; y</math> ;</li> <li>• <math>x</math> for <math>x = y</math> ;</li> <li>• <math>x - 1</math> for <math>x &gt; y</math> .</li> </ul> <p>(2) {2}</p> <p>Returns the nearest machine-representable number to <math>x</math> in the direction towards <math>y</math> in the mode set. For</p> <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> <p>NEIGHB may be useful investigating numeric stability (see NEIGHBOR in the HP-71 Math Pac).</p>
NEXTP	[g] X.FN [g] NEXTP	<p>(1) {1, 2} → {1}</p> <p>Returns the next prime number greater than <math>x</math>.</p>
nmi.→m	[f] U→ [x:] [f] nmi.→m	(1) {2}; {1} → {2}
		Converts distances. See pp. 145ff.
NOP	[g] P.FN P.FN2 [f] NOP	'Empty' program step (for historical reasons only).
NOR	[f] BITS [f] NOR	(2) Works in analogy to AND. See p. 18.
Norml	[g] PROB	(1) {2}
Normle	Norml: Norml etc.	Normal distribution with an arbitrary mean $\mu$ given in <b>I</b> and a standard deviation $\sigma$ in <b>J</b> . See Sect. 2 of the OM for an application example and pp. 217ff for more.
Normlp		
Norml <sup>-1</sup>		Norml <sup>-1</sup> returns $x$ for a given probability $p$ in <b>X</b> , with $\mu$ in <b>I</b> and $\sigma$ in <b>J</b> .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Norml:	<b>g PROB Norml:</b>	<i>Submenu.</i> See p. 130.
NOT	<b>f BITS NOT</b>	(1) {10} Inverts $x$ bit-wise as on <i>HP-16C</i> .  (1) {1, 2} → {1} Returns 1 for $x = 0$ , and 0 for $x \neq 0$ .
nΣ	<b>g Σ n</b>	(-1) {} → {1} Recalls the number of accumulated data points.
N→lbf	<b>f U→ F&amp;p: N→lbf</b>	(1) {2}; {1} → {2} Converts forces. See pp. 145ff.
ODD?	<b>g TEST f ODD?</b>	(0) Checks if $x$ is integer and odd.
OFF	<b>g OFF</b>	(0) In <i>PEM</i> , inserts a step to turn your <i>WP 43S</i> off under program control. Else turns your <i>WP 43S</i> off.
OR	<b>f BITS OR</b>	(2) Works in analogy to AND. See p. 18.
OrthoF	<b>f STAT ▾</b> <b>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. 226ff for more.
ORTHOG	<b>g X.FN Orthog</b>	<i>Submenu.</i> See p. 132.
oz→kg	<b>f U→ m: oz→kg</b>	(1) {2}; {1} → {2} Converts masses. See pp. 145ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
P <sub>0</sub>	[g] [CNST] P <sub>0</sub>	(-1) { } → {2} Standard atmospheric pressure in pascal.
ParabF	[f] [STAT] ▼ [f] ParabF	(0) Selects the parabolic fit model. Relevant for COV, CORR, L.R., s <sub>XY</sub> , $\hat{x}$ , and $\hat{y}$ . See pp. 226ff for more.
PARTS	[f] [PARTS]	Menu. See p. 129.
PAUSE	[g] [P.FN] PAUSE n	(0) Within a routine running, refreshes the display and pauses program execution for n ticks (s. TICKS), with $0 \leq n \leq 99$ . The pause will terminate early when you press a key.
Pa→atm	[f] [U→] F&p: ▼ Pa→atm	
Pa→bar	[f] [U→] F&p: Pa→bar	
Pa→iHg	[f] [U→] F&p: [f] Pa → in.Hg	(1) {2}; {1} → {2} Convert pressures. See pp. 146ff.
Pa→psi	[f] [U→] F&p: Pa→psi	
Pa→tor	[f] [U→] F&p: [f] Pa → torr	
pc→m	[f] [U→] x: pc→m	(1) {2}; {1} → {2} Converts distances. See pp. 146ff.
PERM	[g] [PROB] P <sub>yx</sub>	(2) {1} Returns the number of possible <u>arrangements</u> (a.k.a. <u>permutations</u> ) of $x$ <u>items</u> taken out of a set of $y$ <u>items</u> . No <u>item</u> occurs more than once in an arrangement, and <u>different orders</u> of the same $x$ <u>items</u> <u>are counted</u> separately. Cf. COMB.  (2) {2, 3} See pp. 215f for the formula.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
PGMINT	f ADV f PGMINT <i>label</i>	Specifies the address of the expression to be integrated or solved, respectively.
PGMSLV	f ADV f PGMSLV <i>label</i>	See Section 4 of the OM.
PIXEL	g P.FN P.FN2 g PIXEL	(0) Turns on a single pixel (dot) on the screen. The location of the pixel is given by the numbers in the <b>X</b> - and <b>Y</b> -registers. See AGRAPH on p. 17 for more.
PLOT	f STAT g PLOT	(0) Plots the <i>n</i> data points given by the <i>nx2</i> matrix <i>x</i> . See p. xxxii for more.
P <sub>n</sub>	g X.FN Orthog P <sub>n</sub>	(1) {2}; {1} → {2} <i>Legendre polynomials.</i> See pp. 232f for more.
POINT	g P.FN P.FN2 g POINT	(1) {1, 2} Turns on a square point (3x3 px □) on the screen. The location of its center is given by the integer parts of the numbers in <b>X</b> and <b>Y</b> . See AGRAPH on p. 17 for more.
Poiss	g PROB	(1) {2}; {1} → {2}
Poiss <sub>e</sub>	g Poiss: Poiss etc.	Poisson distribution with the number of successes <i>g</i> in <b>X</b> and the Poisson parameter <i>λ</i> in <b>I</b> . See pp. 217ff for details.
Poiss <sub>p</sub>		Poiss <sup>-1</sup> returns the maximum number of successes <i>m</i> for a given probability <i>p</i> in <b>X</b> and <i>λ</i> in <b>I</b> .
Poiss <sup>-1</sup>		
Poiss:	g PROB g Poiss:	Submenu. See p. 130.
PopLR	g P.FN g PopLR	(0) Pops the local registers allocated to the <i>current routine</i> (see Section 3 of the OM) <u>without returning to the calling routine</u> . See LOCRI and RTN.
Power F	f STAT ▶ PowerF	(0) Selects the power curve fit model. Relevant for CORR, COV, L.R., s <sub>XY</sub> , ū, and ŷ (see pp. 217ff for more).

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 <i>OM</i> ). 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} Checks if the absolute value of IP( $x$ ) is a prime. The method works up to $3.3 \times 10^{24}$ .
PRINT	<b>[g PRINT]</b>	<i>Menus</i> . See p. 130.
PROB	<b>[g PROB]</b>	
PROG		<i>Submenu</i> of global labels defined when calling XEQ etc. See Section 3 of the <i>OM</i> .
PROGS	<b>[f CATALOG] PROGS</b>	<i>Submenu</i> of global labels defined at execution time. See pp. 121f.
pr→dB	<b>[f U→] ▲ power ratio → dB</b>	(1) {2}; {1} → {2}
psi→Pa	<b>[f U→] F&amp;p: psi→Pa</b>	Convert ratios or pressures. See pp. 145ff.
PSTO	<b>[g P.FN] [f PSTO]</b>	(0) Copies the <i>current program</i> (see the <i>OM</i> ) 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	f U $\rightarrow$ x: g point $\rightarrow$ m	(1) {2}; {1} $\rightarrow$ {2} Converts print heights. See pp. 145ff.
PUTK	g P.FN f PUTK r	(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. (R/S) is required to resume program execution then. May help in user interaction with routines (see the OM, Section 3).
P.FN	g P.FN	Menu. See p. 130.
P.FN2	g P.FN P.FN2	_submenu. See p. 130.
P:	f U $\rightarrow$ P:	_submenu. See p. 145.
R	g CNST R	(-1) {} $\rightarrow$ {2} Molar gas constant in <i>joule per mol and kelvin</i> .
RAD	g MODE RAD	(0) Sets the ADM to <i>radians</i> . Indicated in the <i>status bar</i> .
RAD $\rightarrow$	g L $\rightarrow$ f RAD $\rightarrow$	(1) {1, 2} $\rightarrow$ {4} Converts angles as described on pp. 152f.
RAM	f CAT. PROGS RAM	_submenu of global labels defined at execution time. See pp. 121f.
RANI#	g PROB ▲ RANI#	(-1) {} $\rightarrow$ {1} Returns an integer random number $n$ with $IP[min(x, y)] \leq n \leq IP[max(x, y)]$ . After execution of RANI#, the stack looks like [n, x, y, ...], so you can drop or roll down $n$ and call RANI# again to get another random integer with the same parameters. Use RANI# e.g. for throwing dices.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RAN#	[g] PROB [▲] RAN#	(-1) {} → {2} Returns a random number between 0 and 1 like RAN does in HP-42S. See also SEED.
RBR	[f] RBR	Calls the <i>register browser</i> – see the OM, Section 5. You may call RBR also in PEM but it is not programmable.  Within RBR, <i>real</i> and <i>complex</i> numbers are generally displayed in the format chosen within the screen space available. Since RBR uses the small font all the way, more digits are displayable here in ALL 0 than in a numeric row using the large font. For <i>reals</i> and ALL 0, RBR display will turn over to SCI or ENG at 33 instead of 16 digits in worst case. Extended display precision may be observed for <i>complex</i> numbers as well.
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 Sect. 2 and 6 of the OM).
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.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RCL+	<b>RCL</b> <b>+</b> <i>r</i>	(1) Recalls a content of a <i>register</i> or variable, executes the operation specified, and puts the result on the stack like a <i>monadic</i> function. <sup>20</sup>
RCL-	<b>RCL</b> <b>-</b> <i>r</i>	
RCL×	<b>RCL</b> <b>×</b> <i>r</i>	
RCL /	<b>RCL</b> <b>/</b> <i>r</i>	
RCL↑	<b>RCL</b> <b>f</b> <b>Max</b> <i>r</i>	(1) {1, 2, 4, 5, 6, 10} Replaces <i>x</i> with the maximum of <i>r</i> and <i>x</i> . <sup>20</sup>
	<b>RCL</b> <b>▲</b> <i>r</i>	
RCL↓	<b>RCL</b> <b>f</b> <b>Min</b> <i>r</i>	(1) {1, 2, 4, 5, 6, 10} Replaces <i>x</i> with the minimum of <i>r</i> and <i>x</i> . <sup>20</sup>
	<b>RCL</b> <b>▼</b> <i>r</i>	
RDP	<b>g</b> <b>DSP</b> <b>f</b> <b>RDP</b> <i>n</i>	(1) {2, 3, 5, 8*, 9*} Rounds <i>x</i> to <i>n</i> decimal places ( $0 \leq n \leq 99$ , think of FIX format), taking the RM setting into account. See RM and compare RSD.
Re	<b>g</b> <b>CPX</b> <b>Re</b> <b>f</b> <b>PARTS</b> <b>g</b> <b>Re</b>	(1) {3} → {2}, {9} → {8} Returns the <i>real</i> part of <i>x</i> . Cf. IM.
r <sub>e</sub>	<b>g</b> <b>CNST</b> <b>r<sub>e</sub></b>	(-1) {} → {2} Classical electron radius in <i>meter</i> .
REALS	<b>f</b> <b>CAT.</b> <b>VARS</b> <b>REALS</b>	Submenu of <i>real</i> variables defined at execution time. See pp. 121f.
REAL?	<b>g</b> <b>TEST</b> <b>▲</b> <b>REAL?</b>	(0) Checks if <i>x</i> is a <i>real</i> number or matrix.
RECV	<b>f</b> <b>I/O</b> <b>f</b> <b>RECV</b>	(0) Prepares your WP 43S for receiving data via serial I/O. See SEND and Sect. 3 in the OM for more.

<sup>20</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)
RESET	<b>g CLR g RESET</b>	Executes CLALL and resets all modes to <i>startup default</i> , i.e. 2COMPL, ALL <b>0</b> , DEG, DENMAX <b>0</b> , DSTACK 4, GAP 3, J/G <b>1752-01-01</b> , LinF, LocR <b>0</b> , RM <b>0</b> , TDISP <b>-1</b> , WSIZE <b>64</b> , and Y.MD.  RESET sets ALLSCI, DECIM., DENANY, MULTx, PROPFR, RECTN, and TDM. It clears all others.  See these commands and flags for more.
RE→CX	<b>CC</b> (works in run mode only)  <b>g CPX f RE→CX</b>	(2) {2} → {3}  Composes a <i>complex number</i> out of two <i>reals</i> or integers <i>x</i> and <i>y</i> , setting <b>C</b> and taking either <ul style="list-style-type: none"><li>• (for <b>L</b>) the <i>real</i> part from <b>Y</b> and <i>imaginary</i> part from <b>X</b>, or</li><li>• (for <b>G</b>) the <i>magnitude</i> from <b>Y</b> and <i>phase</i> from <b>X</b>.</li></ul> (2) {8} → {9}  Works in analogy for two <i>real</i> matrices <i>x</i> and <i>y</i> .
Re↔Im	<b>g CPX Re↔Im</b>	(1) {3, 9*}  Swaps <i>real</i> and <i>imaginary</i> parts of <i>complex</i> objects.
RJ	<b>f BITS ▲ f RJ</b>	{10}  Right justifies a bit pattern within its word size, in analogy to LJ (see there). The <i>stack</i> will lift, placing the right-justified <i>word</i> in <b>Y</b> and the count of bit-shifts necessary to right justify the <i>word</i> in <b>X</b> .  <b>Example:</b> 10 1100 <sub>2</sub> RJ results in <i>y</i> = 1011 <sub>2</sub> and <i>x</i> = 2.
R <sub>K</sub>	<b>g CNST R<sub>K</sub></b>	(-1) {} → {2}  Von Klitzing constant in <i>ohm</i> .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RL	<b>RL</b> <b>n</b>	(1) {10}  Works like <b>n</b> consecutive RLs on HP-16C, similar to RLn there ( $0 \leq n \leq 63$ ). RL <b>0</b> executes as NOP, but loads L. See the OM, Sect. 2, for more.
RLC	<b>RLC</b> <b>n</b>	(1) {10}  Works like <b>n</b> consecutive RLCs on HP-16C, similar to RLCn there ( $0 \leq n \leq 64$ ). RLC <b>0</b> executes as NOP, but loads L. See the OM, Sect. 2, for more.
RM	<b>RM</b> <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 seven modes are supported:  0: round half even: $\frac{1}{2}\uparrow$ 0.5 rounds to next even number (default). <sup>21</sup> 1: round half up: $\frac{1}{2}\uparrow$ 0.5 rounds up ('businessman's rounding'). <sup>22</sup> 2: round half down: $\frac{1}{2}\downarrow$ 0.5 rounds down. 3: round up: $\leftarrow\uparrow\rightarrow$ rounds away from 0. 4: round down: $\rightarrow\uparrow\leftarrow$ rounds towards 0. 5: ceiling: $\lceil x \rceil$ rounds towards $+\infty$ . 6: floor: $\lfloor x \rfloor$ rounds towards $-\infty$ .  The abbreviations printed on grey are used in STATUS for indicating the respective rounding modes (see Section 5 of the OM).

<sup>21</sup> This is the way of rounding used in science.

<sup>22</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)
RMD	<b>f RMD</b>	(2) {1, 2, 10} Returns the remainder of a division. Equals RMD on HP-16C but works for <i>reals</i> as well. See the OM, Sect. 2, for examples. Cf. MOD.
	<b>g INTS f RMD</b>	
R <sub>Moon</sub>	<b>g CNST R<sub>Moon</sub></b>	(-1) {} → {2} Mean radius of the Moon in <i>meter</i> .
RM?	<b>g INFO RM?</b>	(-1) {} → {1} Returns the floating point rounding mode set. See RM for more.
RNORM	<b>f MATX ▲ f RNORM</b>	(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	<b>f STAT ▼ f RootF</b>	(0) Selects the root fit model. Relevant for CORR, COV, L.R., s <sub>XY</sub> , $\hat{x}$ , and $\hat{y}$ . See pp. 226ff for more.
ROUND	<b>g DSP ROUND</b>	(1) {2, 3, 4, 5, 6, 8*, 9*} Rounds $x$ using the current display format like RND on HP-42S.
ROUNDI	<b>g DSP ROUNDI</b>	(1) {8*}; {2} → {1} Rounds $x$ to next integer. $\frac{1}{2}$ rounds to 1.
RR	<b>f BITS ▲ RR n</b>	(1) {10}  Works like $n$ consecutive RRs on HP-16C, similar to RRn there ( $0 \leq n \leq 63$ ). RR 0 executes as NOP, but loads L. See the OM, Sect. 2, for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RRC	 	(1) {10}  Works like $n$ consecutive RRCs on HP-16C, similar to RRCn there ( $0 \leq n \leq 64$ ). RRC 0 executes as NOP, but loads L. See the OM, Sect. 2, for more.
RSD		(1) {2, 3, 4, 8*, 9*} Rounds $x$ to $n$ significant digits ( $1 \leq n \leq 34$ ), taking the RM setting into account. See RM, cf. RDP.
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 PEM, RTN is the logically last command in a routine (see Section 3 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  is lit.  If pressed in run mode with no routine executing, RTN resets the program pointer to the start of current program (see the OM, Sec. 3). If the program is in FM, the pointer is set to step 0000 in RAM, and  is lit.
RTN+1		(0) Works like RTN, but moves the program pointer two steps behind the XEQ instruction that called said routine.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
R-CLR	<b>[g] [P.FN] [g] R-CLR</b>	<p>(0) {2}</p> <p>Interprets <math>x</math> in the form <math>sss.nn</math>. Clears <math>nn</math> registers starting with address <math>sss</math>.</p> <p><b>Example:</b> For <math>x = 34.567</math>, R-CLR will clear <b>R34</b> through <b>R89</b>.</p> <p><b>ATTENTION:</b> For <math>nn = 0</math>, clearing will cover the maximum available:</p> <ul style="list-style-type: none"> <li>• For <math>sss \in [0; 99]</math>, it will stop at <b>R99</b>.</li> <li>• For <math>sss \in [100; 111]</math>, it will stop at <b>K</b>.</li> <li>• For <math>sss \geq 112</math>, it will stop at the highest currently allocated local register.</li> </ul>
R-COPY	<b>[g] [P.FN] [g] R-COPY</b>	<p>(0) {2}</p> <p>Interprets <math>x</math> in the form <math>sss.nnnnn</math>. Takes <math>nn</math> registers starting with address <math>sss</math> and copies their contents to <math>ddd</math> etc.</p> <p><b>Example:</b> For <math>x = 7.0304567</math>, <math>r07</math>, <math>r08</math>, <math>r09</math> will be copied into <b>R45</b>, <b>R46</b>, <b>R47</b>, respectively.</p> <p>For <math>x &lt; 0</math>, R-COPY will take <math>nn</math> registers from FM instead, starting with register number <math> sss </math>. Destination will be in RAM always.</p> <p><b>ATTENTION:</b> For <math>nn = 0</math>, copying will cover the maximum available as explained with R-CLR. Then <math>x</math> must be negative.</p>
R-SORT	<b>[g] [P.FN] [g] R-SORT</b>	<p>(0) {2}</p> <p>Interprets <math>x</math> in the form <math>sss.nn</math>. Sorts the contents of <math>nn</math> registers starting with address <math>sss</math>.</p> <p><b>Example:</b> Assume <math>x = 49.036\ 9</math>, <math>r49 = 1.2</math>, <math>r50 = -3.4</math>, and <math>r51 = 0</math>; then R-SORT will return <math>r49 = -3.4</math>, <math>r50 = 0</math>, and <math>r51 = 1.2</math>.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		<b>ATTENTION:</b> For $nn = 0$ , sorting will cover the maximum available as explained with R-CLR.
R-SWAP	<b>g P.FN g R-SWAP</b>	(0) {2} Works like R-COPY but <u>swaps</u> the contents of source and destination <i>registers</i> .
R→D	<b>g L→ g R→D</b>	(1) {1, 2} → {4} Converts angles as described on pp. 152f.
R↑	<b>g R↑</b>	Rotates the stack contents one level up or down, respectively. See Section 1 of the OM for details.
R↓	<b>R↓</b>	
R <sub>∞</sub>	<b>g CNST R<sub>∞</sub></b>	(-1) {} → {2}
R <sub>⊕</sub>	etc.	Rydberg constant (see p. 140);
R <sub>⊖</sub>		mean radii of the Earth and Sun in <i>meter</i> .
s	<b>f STAT s</b>	(-2) {} → {2} Takes the statistical sums accumulated, calculates the <i>sample standard deviations</i> <b>s<sub>y</sub></b> and <b>s<sub>x</sub></b> and pushes them on the stack. See Sect. 2 of the OM for the output format and pp. 217ff for the formula.
Sa	<b>g CNST Sa</b>	(-1) {} → {2} Semi-major axis in <i>meter</i> of the Earth model WGS84. <sup>23</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.

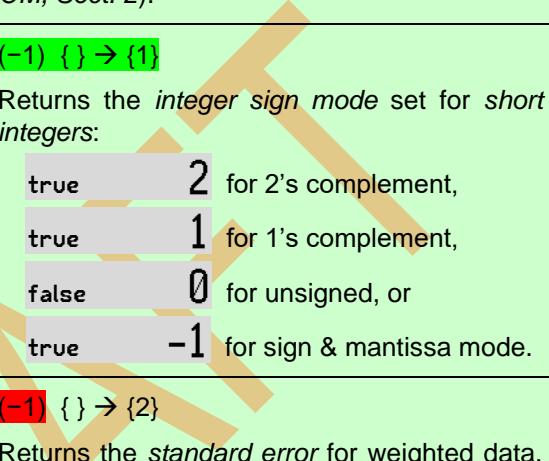
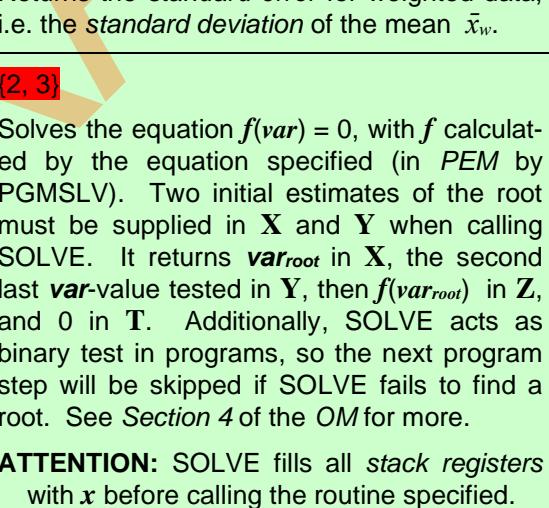
<sup>23</sup> This model is used to define the Earth's surface for surveying and GPS. See [http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350\\_2.html](http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html)

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SB	<b>f</b> BITS <b>g</b> SB <b>n</b>	(1) {10} Sets the specified bit in $x$ .
Sb	<b>g</b> CNST Sb	(-1) {} → {2} Semi-minor axis in <i>meter</i> of WGS84. <sup>23</sup>
SCI	<b>g</b> DSP SCI <b>n</b>	(0) Sets scientific display format (see Section 2 of the OM).
scw→kg	<b>f</b> U→ m: <b>f</b> short cwt → kg	(1) {2}; {1} → {2} Converts masses. See pp. 145ff.
SDIGS?	<b>g</b> INFO <b>f</b> SDIGS?	(-1) {} → {1} Returns the number of significant digits set by SETSIG. Also returned by STATUS.
SDL	<b>g</b> P.FN P.FN2 <b>f</b> SDL <b>n</b> etc.	(1) {2} Shifts digits left (right) by $n$ decimal positions, equivalent to multiplying (dividing) $x$ by $10^n$ . Cf. SL and SR for binary integers.
Se <sup>2</sup>	<b>g</b> CNST Se <sup>2</sup>	(-1) {} → {2} First eccentricity squared of the Earth model WGS84 (see footnote 23 on p. 70).
SEED	<b>g</b> PROB ▲ SEED	(0) {2} Stores a seed for random number generation. If $x = 0$ , the seed is taken from the real-time clock.
SEND	<b>f</b> I/O <b>f</b> 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	<b>g</b> DSP ▲ CHINA	(0) Sets regional format preferences (see Section 2 of the OM).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SETDAT	<b>g CLK ▲ SETDAT</b>	(0) Sets the date for the real-time clock (the emulator takes this information from the PC clock).
SETEUR	<b>g DSP ▲ EUROPE</b>	
SETIND	<b>g DSP ▲ INDIA</b>	(0) Set regional format preferences (see Section 2 of the OM).
SETJPN	<b>g DSP ▲ JAPAN</b>	
SETSIG	<b>g MODE 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 ▲ SETTIM</b>	(0) Sets the time for the real-time clock (the emulator takes this information from the PC clock).
SETUK	<b>g DSP ▲ UK</b>	(0) Set regional format preferences (see Section 2 of the OM).
SETUSA	etc.	
$Se'^2$	<b>g CNST Se'^2</b>	(-1) {} → {2} Second eccentricity squared of the Earth model WGS84 (see footnote 23 on p. 70).
SF	<b>g FLAGS SF n</b>	(0) Sets the flag specified.
	<b>g MODE SF n</b>	
$Sf^{-1}$	<b>g CNST Sf^{-1}</b>	(-1) {} → {2} Flattening parameter of the Earth model WGS84 (see footnote 23 on p. 70).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SHOW	f SHOW	(0) {1, 2, 3, 4} Shows all digits stored in X until next keystroke in top numeric row. Small font will be used. For <i>complex</i> numbers, either part will take one display row. Up to 294 digits of <i>long integers</i> will be shown using up to 7 display rows; for <i>long integers</i> exceeding 294 digits, the most significant 288 will be shown with a trailing power of 10.
SIGN	f PARTS sign	(1) {8} {1, 2, 10} → {1} Returns 1 for $x > 0$ , -1 for $x < 0$ , and 0 for $x = 0$ or non-numeric data. Corresponds to the mathematical function $\text{signum}(x)$ .  (1) {3} Returns the unit vector of the <i>complex</i> number $x$ (cf. UNITV). Maintained for backward compatibility only.
SIGNMT	f BITS ▼ SIGNMT g INTS ▲ ...	(0) Sets sign-and-mantissa mode for operations on <i>short integers</i> . See the OM, Section 2. Indicated in the status bar.
SIM_EQ	f MATX SIM EQ n	(0) Solves a system of $n$ linear equations $(MATA) \cdot \overline{MATX} = \overline{MATB}$ . 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*}; {1, 4} → {2} Returns the sine of the angle in X.
sinc	g X.FN ▲ sinc	(1) {2, 3, 8*, 9*} Returns $\sin(x)/x$ for $x \neq 0$ and 1 for $x = 0$ . Note input has to be supplied in radians.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
sinh	<b>g EXP g sinh</b>	(1) {2, 3, 8*, 9*}
	<b>TRI g sinh</b>	Returns the hyperbolic sine of $x$ .
SKIP	<b>g P.FN P.FN2</b> <b>g SKIP n</b>	(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 manually maintain all those statements individually.
SL	<b>f BITS ▲ SL n</b>	(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.
SLVQ	<b>f ADV SLVQ</b>	{1, 2, 3} → {1 or 2 or 3}  Solves the quadratic equation $ax^2 + bx + c = 0$ with its parameters on the input stack [ $c, b, a, \dots$ ], and tests the result. The following holds for <i>real</i> parameters: <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 Y and X. In a routine, the step after SLVQ will be executed.</li><li>• Else, SLVQ returns the first <i>complex</i> root in X and the second in Y (the <i>complex conjugate</i> of the first). In a routine, the step after SLVQ will be skipped.</li></ul> In either case and also for <i>complex</i> parameters, SLVQ returns r in Z. Higher stack registers are kept unchanged. L will contain equation parameter c.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$s_m$	<b>f</b> <b>STAT</b> <b>s<sub>m</sub></b>	(-2) {} → {2} Takes the statistical data accumulated and pushes the <i>standard errors</i> (i.e. <i>std. deviations</i> of the means $\bar{y}$ and $\bar{x}$ ) on the <i>stack</i> . Output format will be like the one of s (see the OM, Sect. 2).
S MODE?	<b>g</b> <b>INFO</b> <b>S MODE?</b>	(-1) {} → {1} Returns the <i>integer sign mode</i> set for <i>short integers</i> :   <p style="margin-left: 20px;"> <b>true</b>      2      for 2's complement,  <b>true</b>      1      for 1's complement,  <b>false</b>      0      for unsigned, or  <b>true</b>      -1     for sign &amp; mantissa mode.     </p>
$s_{mw}$	<b>f</b> <b>STAT</b> <b>f</b> <b>s<sub>mw</sub></b>	(-1) {} → {2} Returns the <i>standard error</i> for weighted data, i.e. the <i>standard deviation</i> of the mean $\bar{x}_w$ .
SOLVE	<b>f</b> <b>ADV</b> <b>SOLVE</b> <b>var</b>	{2, 3}   <p>Solves the equation <math>f(var) = 0</math>, with <math>f</math> calculated by the equation specified (in PEM by PGMSLV). Two initial estimates of the root must be supplied in <b>X</b> and <b>Y</b> when calling SOLVE. It returns <math>var_{root}</math> in <b>X</b>, the second last <b>var</b>-value tested in <b>Y</b>, then <math>f(var_{root})</math> in <b>Z</b>, and 0 in <b>T</b>. Additionally, SOLVE acts as binary 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.</p> <p><b>ATTENTION:</b> SOLVE fills all <i>stack registers</i> with <math>x</math> before calling the routine specified.</p>
Solver	<b>g</b> <b>EQN</b> <b>Solver</b>	<b>Submenu</b> for solving a given equation. See the OM, Sect. 4, for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SPEC?	<b>g TEST</b> ▲ <b>f SPEC?</b>	(0) True if $x$ is ‘special’ (i.e. $\pm\infty$ or NaN).
SR	<b>f BITS</b> ▲ <b>SR n</b>	(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.
SSIZE?	<b>g INFO SSIZE?</b>	(-1) {} → {1} Returns the number of stack registers currently allocated, 4 or 8.
STAT	<b>f STAT</b>	Menu. See p. 131.
STATUS	<b>g FLAGS STATUS</b> <b>f STATUS</b>	Flag browser. See Section 5 of the OM.
STK	<b>g STK</b>	Menu. See p. 131.
STO	<b>STO r</b>	(0) Stores $x$ into destination.
STOCFG	<b>STO f Config r</b>	(0) Stores the current configuration for later use as described in Section 2 of the OM. RCLCFG recalls such data.
STOEL	<b>f MATX</b> <b>g STOEL</b> <b>STO g ...EL</b>	(1) {1, 2, 3} Stores a copy of $x$ into the indexed matrix at the current element, $a_{ij}$ . Cf. RCLEL.
STOIJ	<b>f MATX</b> ▲ <b>STOIJ</b> <b>STO g ...IJ</b>	(1) {1} Sets the index pointers to $IP(x)$ (= column number) and $IP(y)$ (= row number). Cf. RCLIJ.
STOP	<b>R/S</b>	(0) Stops program execution. May be inserted in programs to wait for input, for example.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
STOS	[STO] f Stack r	(0) Stores the entire stack in a set of 4 or 8 registers, starting at the destination address specified. See RCLS.
STO+	[STO] + r	
STO-	[STO] - r	
STOx	[STO] x r	
STO/	[STO] / r	
sto→kg	f U m: f stone → kg	(1) {2}; {1} → {2} Converts masses. See pp. 145ff.
STO↑	[STO] f Max r	(0) {1, 2, 4, 5, 6, 10}
	[STO] ▲ r	Stores the maximum of r and x in the address specified. <sup>24</sup>
STO↓	[STO] f Min r	(0) {1, 2, 4, 5, 6, 10}
	[STO] ▼ r	Stores the minimum of r and x in the address specified. <sup>24</sup>
STRI?	g TEST g STRI?	(0) True if x is an alphanumeric string (like STR? in HP-42S).
STRING	f CATALOG VARS STRING	Submenu of alpha string variables defined at execution time. See pp. 121f.
SUM	f STAT 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.

<sup>24</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)
$s_w$		(-1) {} → {2} Calculates the <i>standard deviation</i> for weighted data (where the weight $y$ of each data point $x$ was entered via $\Sigma+$ ). See pp. 217ff for the formula.
$s_{xy}$		(-1) {} → {2} Calculates the <i>sample covariance</i> for the two data sets entered via $\Sigma+$ , depending on the curve fit model selected. See pp. 217ff for the formula and COV for the <i>population covariance</i> .
SYSTEM		(0) Returns to DMCP. Works on the calculator only (not the simulator). See App F.
SYS.FL		<i>Submenu</i> of system flags defined. See pp. 121f.
S.INTS		<i>Submenu</i> of short integer variables defined at execution time. See pp. 121f.
$s.t \rightarrow kg$		(1) {2}; {1} → {2}
$s \rightarrow year$		Convert masses and times. See pp. 145ff.
$T_0$		(-1) {} → {2} Standard temperature (0°C) in <i>kelvin</i> .
$\tan$		(1) {2, 3, 8*, 9*}; {1, 4} → {2} Returns the tangent of the angle in <b>X</b> . Returns “Not a Number” for $x = \pm 90^\circ$ or equivalents if SPCRES is set.
$\tanh$		(1) {2, 3, 8*, 9*}
		Returns the hyperbolic tangent of $x$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
TDISP	<b>g CLK ▲ TDISP <i>n</i></b>	(0) Sets time display format. TDISP <b>0</b> and <b>1</b> allow for displaying just <i>hours</i> and <i>minutes</i> , TDISP <b>2</b> for <i>seconds</i> , too, and $n \geq 3$ also for $n - 2$ digits showing decimal fractions of <i>seconds</i> . TDISP <b>-1</b> allows for displaying all digits.
TEST	<b>g TEST</b>	<b>Menu.</b> See p. 131.
$t_e(x)$	<b>g PROB t: <i>t<sub>e</sub>(x)</i></b>	(1) {2}
$t_p(x)$	etc.	<i>Student's t distribution.</i> The degrees of freedom are stored in <b>J</b> . $t_e(x)$ equals $Q(t)$ on HP-21S. See Section 2 of the OM for an application example and pp. 217ff for more mathematical details.
$t(x)$		
$t^{-1}(p)$		
TICKS	<b>g P.FN TICKS</b>	(-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	<b>g CLK TIME</b>	(-1) {} → {5} Recalls the time from the real-time clock at execution (see Sect. 2 of the OM for the output format).
TIMER	<b>f TIMER</b>	<b>Starts</b> the timer application based on the real-time clock and following the timer of HP-55. See the OM, Sect. 5 for a detailed description.
TIMES	<b>f CATALOG VARS f TIMES</b>	<b>Submenu</b> of time variables defined at execution time. See pp. 121f.
$T_n$	<b>g X.FN Orthog <i>T<sub>n</sub></i></b>	(2) {2}; {1} → {2} <i>Chebyshev polynomials of first kind.</i> See pp. 232f for details.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
TONE	f I/O f TONE n	(0) Sounds a tone according to <b>n</b> (= 1 ... 9).
ton→kg	f U→ m: ▲ ton→kg	(1) {2}; {1} → {2} Converts masses. See pp. 145ff.
TOP?	g TEST g TOP?	(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	f U→ F&p: f torr → Pa	(1) {2}; {1} → {2} Converts pressures. See pp. 145ff.
T <sub>p</sub>	g CNST T <sub>p</sub>	(-1) {} → {2}
t <sub>PL</sub>	g CNST t <sub>PL</sub>	Planck temperature in <i>Kelvin</i> ; Planck time in <i>seconds</i> .
TRANS	f CATALOG FCNS TRANS	Works like [M] <sup>T</sup> on p. 99. Maintained for backward compatibility only.
TRI	TRI	Menu. See p. 131.
trz→kg	f U→ m: f tr.oz → kg	(1) {2}; {1} → {2} Converts masses. See pp. 145ff.
TVM	g FIN TVM	Application. See Section 5 of the OM.
t:	g PROB t:	_submenu_. See p. 130.
t↔	g STK t↔ r	Swaps <i>t</i> and <i>r</i> , in analogy to <i>x↔</i>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
ULP?	<b>g</b> [INFO] <b>f</b> ULP?	(1) {1, 2} 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. Indicated in STATUS.
$U_n$	<b>g</b> [X.FN] Orthog <b>U<sub>n</sub></b>	(2) {2}; {1} → {2} <i>Chebyshev polynomials of second kind.</i> See pp. 232f for details.
UNITY	<b>f</b> [MATX] <b>f</b> UNITY	(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 <i>magnitude</i> will become 1.
	<b>g</b> [CPX] UNITY	(1) {3} Returns a <i>complex</i> number with <i>magnitude</i> $ r  = 1$ in direction of $x$ .
UNSIGN	<b>f</b> [BITS] ▾ UNSIGN	(0) Sets unsigned mode for mode for operations on <i>short integers</i> . Indicated in the <i>status bar</i> . Cf. UNSGN on HP-16C. See Section 2 of the OM.
	<b>g</b> [INTS] ▲ ...	
U→	<b>f</b> [U→]	Menu. See p. 131.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
VAR		<b>Submenu</b> of variables defined at execution time when calling STO, RCL, etc.
VARMNU	<b>g P.FN</b> <b>f VARMNU</b> <i>label</i>	Creates a variable <i>menu</i> using the MVAR instructions following the global label specified. Cf. the <i>HP-42S Owner's Manual</i> .
VARS	<b>f CATALOG</b> <b>VARS</b>	<b>Submenu</b> of variables defined at execution time. See pp. 121f.
VERS?	<b>g INFO</b> <b>g VERS?</b>	(0) Shows your firmware version and build number (see Section 2 of the OM).
VIEW	<b>f VIEW</b> <i>r</i>	(0) Shows <i>r</i> until the next key is pressed.  <b>Example:</b> If <i>r</i> is a variable called <b>Test12</b> containing <b>-123.45</b> , <b>VIEW</b> <b>α</b> <b>Test12</b> <b>ENTER↑</b> will display  <i>Test12 = -123.45</i>
<i>V<sub>m</sub></i>	<b>g CNST</b> <i>V<sub>m</sub></i>	(-1) {} → {2} Molar volume of an ideal gas at standard conditions in <i>cubic meter per mol</i> .
<i>V<sub>:</sub></i>	<b>f U→</b> <b>f V<sub>:</sub></b>	<b>Submenu</b> . See p. 145.
<i>V<sub>4</sub></i>	<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} → {1} Assumes $x$ containing a date 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>25</sup>
Weibl	<b>g PROB</b>	(1) {2}
Weibl <sub>e</sub>	<b>f Weibl: Weibl</b> etc.	Weibull distribution with its shape parameter $b$ in <b>I</b> and its characteristic lifetime $T$ in <b>J</b> . See pp. 217ff for details.
Weibl <sub>p</sub>		
Weibl <sup>-1</sup>		Weibl <sup>-1</sup> returns the survival time $t_s$ for a given probability $p$ in <b>X</b> , with $b$ in <b>I</b> and $T$ in <b>J</b> .
Weibl:	<b>g PROB f Weibl:</b>	Submenu. See p. 130.
WHO?	<b>g INFO g WHO?</b>	(0) Displays credits to the brave men who made this project work.
Wh→J	<b>f U→ E: Wh→J</b>	(1) {2}; {1} → {2} Converts energies. See pp. 145ff.
W <sub>m</sub>	<b>g X.FN</b>	(1) {2, 3}; {1} → {2}
W <sub>p</sub>	etc.	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. 247ff for more.
W <sup>-1</sup>		

<sup>25</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	<b>f</b> BITS ▼ WSIZE <b>n</b>  <b>g</b> INTS ▲ ...	(0) Works almost like on HP-16C, but with the parameter $1 \leq n \leq 64$ trailing the command instead of taken from X.  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. 165ff).  Increasing the word size will add empty bits to each stack register. WSIZE 0 sets the word size to maximum, i.e. 64 bits.  WSIZE is indicated in the status bar.
WSIZE?	<b>g</b> INFO <b>g</b> WSIZE?	(-1) {} → {1} Recalls the word size set.
W→hp <sub>E</sub>	<b>f</b> U→ P: W→hp <sub>E</sub>	
W→hp <sub>M</sub>	etc.	
W→hp <sub>UK</sub>		(1) {} → {2}; {1} → {2} Convert powers. See pp. 145ff.
$\hat{x}$	<b>f</b> STAT ▲ $\hat{x}$	(1) {} → {2}; {1} → {2} Returns a forecast $\hat{x}$ for a given $y$ (in X) according to the curve fit model chosen. See L.R. for more.
$\bar{x}$	<b>f</b> STAT $\bar{x}$	(-2) {} → {2} Calculates the arithmetic means of the $y$ - and $x$ -data accumulated and pushes them on the stack. See also s, s <sub>m</sub> , and σ.
$x^2$	$x^2$	(1) {1, 2, 3, 8*, 9*, 10} Return the square of $x$ .
$x^3$	<b>g</b> EXP $x^3$	(1) {1, 2, 3, 8*, 9*, 10} Returns the cube of $x$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
XEQ	[XEQ] <i>label</i>	(0) Executes the function or routine with the label specified. – In PEM, inserts a call to the subroutine with the label specified.
$\bar{x}_G$	[f] [STAT] [g] $\bar{x}_G$	(-2) {} → {2} Calculates the <i>geometric means</i> of the y- and x-data accumulated and pushes them on the stack. See pp. 226ff for the formula. Output format will be similar to the one of $\bar{x}$ . See also $\varepsilon$ , $\varepsilon_m$ , and $\varepsilon_p$ .
$\bar{x}_H$	[f] [STAT] [▲] [f] $\bar{x}_H$	(-2) {} → {2} Calculates the <i>harmonic means</i> of the y- and x-data accumulated and pushes them on the stack.
xIN	[XEQ] <i>type</i>	with <i>type</i> = NILADIC, MONADIC, DYADIC, TRIADIC, or ..._COMPLEX defines how many stack levels are used for parameter input to the function under consideration. Furthermore it does some initialization work (e.g. set SSIZE).  xIN is the recommended way to start an XROM routine. Thereafter, SSIZE is clear. Note xIN cannot nest and XROM routines using xIN cannot call user code.
XNOR	[f] [BITS] [f] XNOR	(2) Work in analogy to AND. See p. 18.
XOR	[f] [BITS] XOR	
xOUT	[XEQ] <i>way</i>	Cleans and reverts the settings of xIN, taking care of a proper return including the correct setting of <i>I</i> and the stack. Typically, <i>way</i> = xOUT_NORMAL. Generally, xOUT shall be the last command of an XROM routine.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\bar{x}_{\text{RMS}}$	f STAT ▲ g $\bar{x}_{\text{RMS}}$	(-2) {} → {2} Calculates the <i>quadratic means</i> of the $y$ - and $x$ -data accumulated and pushes them on the stack.
$\bar{x}_w$	f STAT f $\bar{x}_w$	(-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. 226ff for the formula. See also $s_w$ and $s_{mw}$ .
$\sqrt[x]{y}$	g EXP $\sqrt[x]{y}$	(2) Returns the $x^{\text{th}}$ root of $y$ . Roots of negative integers or <i>reals</i> will return <i>complex</i> numbers if CPXRES is set.
X.FN	g X.FN	Menu. See p. 132.
$x!$	f $x!$	(1) {1, 10} Returns the <i>factorial</i> $n!$ . Note this is only defined for positive integers. $20!$ is the biggest factorial $< 2^{64}$ . $450!$ is the biggest factorial allowed for <i>long integers</i> .
		(1) {2, 3} Returns $\Gamma(x + 1)$ . $2\ 123.549\ 956\ 662\ 463\ 236\ 31$ is the maximum $x$ for <i>reals</i> .
x:	f U→ x:	Submenu. See p. 145.
$x \rightarrow \text{DATE}$	g CLK $x \rightarrow \text{DATE}$	(1) {2} → {6} Interprets the <i>real</i> number $x$ as a date coded in the date format selected (Y.MD, D.MY, or M.DY) and converts it to a proper <i>date</i> .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$x \rightarrow \alpha$	<b>g a.FN</b> $x \rightarrow \alpha$	(1) {1, 2, 10} → {7} Interprets the integer part of $x$ as a character code and converts it to the respective character $x$ , similar to XTOA in the HP-42S.
$x \leftrightarrow r$	<b>g 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 TEST</b> $x = ? r$	(0)
$x \neq ?$	<b>g TEST</b> $x \neq ? r$	Compare $x$ with $r$ . See $x < ?$ for more.
$x = +0?$	<b>g TEST</b> $\Delta x = +0?$ etc.	(0) {1, 2, 3, 10} These tests are for comparing <i>short integers</i> in modes 1COMPL and SIGNMT, and for <i>long integers</i> , <i>real</i> or <i>complex</i> numbers if SPCRES is set. Then e.g. $0/(-7)$ will display $-0$ .
$x = -0?$		
$x \approx ?$	<b>g TEST</b> $\Delta x \approx ? r$	(0) {2, 3, 4, 5, 8, 9} Will be true if the <u>rounded</u> values of $x$ and $r$ are equal (see ROUND). See $x < ?$ for more.
$x < ?$	<b>g TEST</b> $x < ? r$ etc.	(0) {1, 2, 4, 5, 6, 7, 10} Compare $x$ with $r$ . Strings are compared according to their sorting order.
$x \leq ?$		
$x \geq ?$		
$x > ?$		<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.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\hat{y}$	<b>f</b> <b>STAT</b> <b>▲</b> $\hat{y}$	(1) {2}; {1} $\rightarrow$ {2} Returns a forecast $y$ (in $X$ ) for a given $x$ according to the curve fit model chosen. See L.R. for more.
$yd.\rightarrow m$	<b>f</b> <b>U→</b> <b>x:</b> <b>g</b> <b>yd.→m</b>	(1) {2}; {1} $\rightarrow$ {2} Converts distances. See pp. 145ff.
YEAR	<b>g</b> <b>CLK</b> <b>f</b> <b>YEAR</b>	(1) {2, 6} $\rightarrow$ {1} Assumes $x$ containing a <i>date</i> in the format selected (or a <i>real</i> number in corresponding format) and extracts the year.
year $\rightarrow$ s	<b>f</b> <b>U→</b> <b>f</b> <b>year<math>\rightarrow</math>s</b>	(1) {2}; {1} $\rightarrow$ {2} Converts times. See pp. 145ff.
$y^x$	<b>y<sup>x</sup></b>	(2) {1, 2, 3, 10} Returns the $x^{\text{th}}$ power of $y$ . It allows for raising any positive <i>real</i> number to an arbitrary <i>real</i> power, as well as any negative <i>real</i> number to an arbitrary integer power, all returning <i>reals</i> . Exceeding these boundaries may produce <i>complex</i> results if CPXRES is set.
Y.MD	<b>g</b> <b>CLK</b> <b>▲</b> <b>Y.MD</b>	(0) Sets the format yyyy-mm-dd for <i>dates</i> .
$y \rightleftharpoons r$	<b>g</b> <b>STK</b> <b>y</b> <b>↔</b> <b>r</b>	Swaps $y$ and $r$ , in analogy to $x \leftarrow$ .
$Z_0$	<b>g</b> <b>CNST</b> <b>Z<sub>0</sub></b>	(-1) {} $\rightarrow$ {2} Characteristic impedance of vacuum in <i>ohm</i> .
$z \rightleftharpoons r$	<b>g</b> <b>STK</b> <b>z</b> <b>↔</b> <b>r</b>	Swaps $z$ and $r$ , in analogy to $x \leftarrow$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\alpha$		(-1) {} → {2} Fine-structure constant.
$\alpha\text{INTL}$		_submenu. See pp. 121ff.
		Menu in AIM (see p. 133).
$\alpha\text{LENG?}$		(-1) {} → {1}
		Returns the number of characters found in $r$ , similar to ALENG in HP-42S. <sup>26</sup>
$\alpha\text{MATH}$		submenu. See pp. 121ff.
		Menu in AIM. See p. 134.
$\alpha\text{POS?}$		(-1) {} → {1}  Looks in $r$ for the <b>target</b> given in <b>X</b> . 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>26</sup>
		The <b>target</b> may be an individual character code or an <i>alpha string</i> . $\alpha\text{POS}$ saves a copy of the <b>target</b> in <b>L</b> . It works similar to POSA in HP-42S.
$\alpha\text{RL}$		(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 <b>L</b> . <sup>26</sup>
$\alpha\text{RR}$		(0) Works like $\alpha\text{RL}$ but rotates to the right.
$\alpha\text{SL}$		(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. $\alpha\text{SL } 0$ executes as NOP, but loads <b>L</b> . <sup>26</sup>

<sup>26</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)
$\alpha\text{SR}$	<b>g</b> <b>a.FN</b> $\alpha\text{SR}$ <b>r</b>	(0) Works like $\alpha\text{SL}$ but for the $x$ rightmost characters out of $r$ , deleting the last $x$ characters in the string. <sup>26</sup>
$\alpha.\text{FN}$	<b>g</b> <b>a.FN</b>	<b>Menu.</b> See p. 134.
$\text{A}....\Omega$	<b>f</b> <b>CAT.</b> <b>CHARS</b> $\text{A}....\Omega$	<b>Submenu</b> of Greek letters, see pp. 121ff.
$\alpha\cdot$	<b>f</b> <b>CAT.</b> <b>CHARS</b> $\alpha\cdot$	<b>Submenu.</b> See pp. 121ff.
	<b>g</b> <b>.</b>	<b>Menu</b> in A/M. See p. 134.
$\alpha\rightarrow x$	<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>26</sup>
$\beta(x,y)$	<b>g</b> <b>X.FN</b> <b>▲</b> $\beta(x,y)$	(2) {2, 3}; {1} → {2} Returns <i>Euler's Beta</i> $B(x,y) = \frac{\Gamma(x)\Gamma(y)}{\Gamma(x+y)}$ 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 $m^3/kg\ s^2$ ;
$\gamma_{\text{EM}}$	<b>g</b> <b>CNST</b> <b>γ<sub>EM</sub></b>	<i>Euler-Mascheroni constant</i> (for mathematics);
$\gamma_p$	<b>g</b> <b>CNST</b> <b>γ<sub>p</sub></b>	proton gyromagnetic ratio (see p. 141).
$\Gamma_{xy}$	<b>g</b> <b>X.FN</b> <b>▲</b> $\Gamma_{xy}$	(2) {2}; {1} → {2} Returns the <i>lower incomplete Gamma function</i> . See pp. 247ff for more.
$\gamma_{xy}$	<b>g</b> <b>X.FN</b> <b>▲</b> <b>f</b> $\gamma_{xy}$	(2) {2}; {1} → {2} Returns the <i>upper incomplete Gamma function</i> . See pp. 247ff for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Gamma(x)$	<b>g PROB</b> □ $\Gamma(x)$	(1) {2, 3}; {1} → {2} Returns $\Gamma(x)$ . Note <b>x</b> calls $\Gamma(x + 1)$ . See also LNF.
$\delta x$	<b>f CAT. PROGS</b> $\delta x$	Predefined global label for $f'(x)$ and $f''(x)$ – see Section 4 of the OM.
$\Delta\nu_{Cs}$	<b>g CNST</b> $\Delta\nu_{Cs}$	(-1) {} → {2} Hyperfine transition frequency of $^{133}\text{Cs}$ in hertz.
$\Delta\%$	<b>f Δ%</b>	(1) {2}; {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 g ε</b>	(-2) {} → {2} Calculates the scattering factors $\varepsilon_y$ and $\varepsilon_x$ for log-normally distributed sample data and pushes them on the stack. This $\varepsilon_x$ works for the geometric mean $\bar{x}_g$ in analogy to the standard deviation $s$ for the arithmetic mean $\bar{x}$ but multiplicative instead of additive. See pp. 217ff for more information.
$\varepsilon_0$	<b>g CNST</b> $\varepsilon_0$	(-1) {} → {2} Electric constant or vacuum permittivity in ampere-second per volt-meter.
$\varepsilon_m$	<b>f STAT g ε_m</b>	(-2) {} → {2} Works like $\varepsilon$ above but returns the scattering factors of the two geometric means (in analogy to the standard error for arithmetic means).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\varepsilon_p$	<b>f</b> <b>STAT</b> <b>g</b> <b><math>\varepsilon_p</math></b>	(-2) {} → {2} Works like $\varepsilon$ but returns the <i>scattering factors</i> of the two populations.
$\zeta(x)$	<b>g</b> <b>X.FN</b> <b>▲</b> <b>f</b> <b><math>\zeta(x)</math></b>	(1) {2, 3} Returns <i>Riemann's Zeta</i> . See p. 250 for more.
$\lambda_c$	<b>g</b> <b>CNST</b> <b><math>\lambda_c</math></b>	(-1) {} → {2}
$\lambda_{cn}$	etc.	<i>Compton wavelength of the electron, neutron, and proton in meter.</i>
$\lambda_{cp}$		
$\mu_0$	<b>g</b> <b>CNST</b> <b><math>\mu_0</math></b>	(-1) {} → {2}
$\mu_B$	etc.	Magnetic constant or vacuum permeability in <i>volt-second per ampere-meter</i> ;
$\mu_e$		Bohr magneton in <i>joule per tesla</i> ;
$\mu_e/\mu_B$		electron magnetic moment in <i>joule per tesla</i> ;
$\mu_n$		ratio of electron magnetic moment to <i>Bohr magneton</i> ;
$\mu_p$		neutron and proton magnetic moments, nuclear magneton, and
$\mu_u$		Muon magnetic moment in <i>joule per tesla</i> .
$\mu_\mu$		
$\pi$	<b>g</b> <b>π</b>	(-1) {} → {2} Recalls $\pi$ .
$\Pi_n$	<b>f</b> <b>ADV</b> <b><math>\Pi_n</math></b> <b>label</b>	<b>Computes</b> a product using the routine specified. See Section 4 of the OM for more. <b>ATTENTION:</b> $\Pi_n$ fills all <i>stack registers</i> with $x$ before calling the routine specified.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Sigma$	<b>g</b> <b><math>\Sigma</math></b>	<b>Menu.</b> See p. 135.
$\sigma$	<b>f</b> <b>STAT</b> <b><math>\sigma</math></b>	(-2) { } → {2} Works like s but returns the <i>standard deviations</i> of the two <i>populations</i> instead. See pp. 217ff.
$\sigma_B$	<b>g</b> <b>CNST</b> <b><math>\sigma_B</math></b>	(-1) { } → {2} <i>Stefan-Boltzmann constant</i> (see p. 143).
$\Sigma^{1/x}$	<b>g</b> <b><math>\Sigma</math></b> <b>▲</b> <b><math>\Sigma^{1/x}</math></b> etc.	(-1) { } → {2}
$\Sigma^{1/x^2}$		Recall the corresponding statistical sums, necessary for means and regressions beyond the linear model. 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. 165ff.).
$\Sigma^{1/y}$		
$\Sigma^{1/y^2}$		
$\Sigma \ln^2 x$	<b>g</b> <b><math>\Sigma</math></b> <b>f</b> <b><math>\Sigma \ln^2 x</math></b> etc.	<b>ATTENTION:</b> Depending on your input data, logarithmic or inverted sums may become infinite or even non-numeric. If this happens no error will be thrown, regardless of the status of SPCRES.
$\Sigma \ln^2 y$		
$\Sigma \ln x$		
$\Sigma \ln xy$		For space reasons, two sums are abbreviated: <b><math>\Sigma \ln xy</math></b> denotes $\Sigma \ln(x)\ln(y)$ .
$\Sigma \ln y/x$	<b>g</b> <b><math>\Sigma</math></b> <b>g</b> <b><math>\Sigma \ln y/x</math></b>	<b><math>\Sigma \ln y/x</math></b> denotes $\Sigma \frac{\ln(y)}{x}$ .
$\Sigma_n$	<b>f</b> <b>ADV</b> <b><math>\Sigma_n</math></b> <b>labl</b>	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.
$\sigma_w$	<b>f</b> <b>STAT</b> <b>f</b> <b><math>\sigma_w</math></b>	(-1) { } → {2} Works like $s_w$ but returns the <i>standard deviation</i> of the <i>population</i> instead. See pp. 217ff.

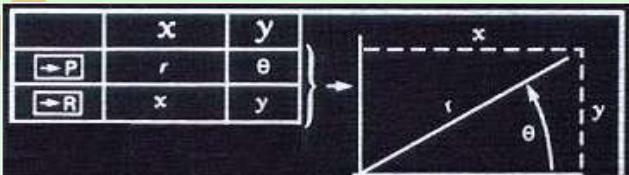
Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Sigma x$	 etc.	
$\Sigma x^2$		
$\Sigma x^2y$		
$\Sigma x^2/y$		
$\Sigma x^3$	 $\Sigma x^3$	
$\Sigma x^4$	etc.	
$\Sigma x \ln y$		
$\Sigma xy$		
$\Sigma x/y$		
$\Sigma y$	 etc.	
$\Sigma y^2$		
$\Sigma y \ln x$		
$\Sigma+^{27}$		<p><math>\{8\} \rightarrow \{2\}</math></p> <p>If <math>X</math> contains an <math>n \times 2</math> matrix then <math>\Sigma+</math> adds <math>n</math> 2D data points to the statistical sums. Then the display will show the last data point added and the matrix will be in <math>L</math>.</p> <p><math>\{1, 2\}</math></p> <p>Adds one 2D data point to the statistical sums.</p>
$\Sigma-^{27}$		<p><math>\{1, 2\}</math></p> <p>Subtracts one 2D data point from the statistical sums.</p>

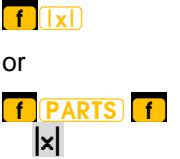
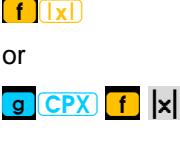
<sup>27</sup>  $\Sigma+$  and  $\Sigma-$  return temporary information as shown in Section 2 of the OM and disable automatic stack lift. Both commands may also be used for 2D vector adding and subtracting (see SUM and the corresponding example in Section 2 of the OM).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Phi$	[g] [CNST] $\Phi$	(-1) {} → {2} Golden ratio;
$\Phi_0$	[g] [CNST] $\Phi_0$	magnetic flux quantum in <i>volt-second</i> .
$\chi^2_e(x)$	[g] [PROB] $\chi^2:$	(1) {2}
$\chi^2_p(x)$	$\chi^2(x)$	Chi-square distribution (with its degrees of freedom given in <b>I</b> ). $\chi^2_e(x)$ equals $Q(\chi^2)$ on HP-21S. See Section 2 of the OM for an application example and pp. 217ff for more.
$\chi^2(x)$	etc.	
$(\chi^2)^{-1}$		
$\chi^2:$	[g] [PROB] $\chi^2:$	Submenu. See p. 130.
$\omega$	[g] [CNST] $\omega$	(-1) {} → {2} Angular velocity of the Earth in <i>radians per second</i> according to WGS84 (see footnote 23 on p. 70).
$(-1)^x$	[g] [X.FN] $\blacktriangle$ [f] $(-1)^x$	(1) {1, 2, 3, 8*, 9*, 10} If $x$ is non-integer, returns $\cos(\pi x)$ .
$[M]^T$	[f] [MATX] $[M]^T$	(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.
$[M]^{-1}$	[f] [MATX] $[M]^{-1}$	(0) {8, 9} Takes the square matrix in <b>X</b> and inverts it in-situ (like INVRT on HP-42S).

Item	Keystrokes	Remarks (see pp. 12ff for general information)										
+	[+]	(2) Returns $y + x$ for compatible objects.										
+/-	[+/-] (for closed input)	(1) 'Unary minus', returns $x \times (-1)$ .  See the tables in the OM, Sect. 2 for details.										
$\pm\infty?$	[g] [INFO] [g] $\pm\infty?$	(0) {2} $\rightarrow$ {1}  Tests $x$ for infinity. Returns  <table style="margin-left: auto; margin-right: auto;"> <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.										
-	[-]	(2) Returns $y - x$ for compatible numeric objects. See the tables in the OM, Sect. 2, for details.										
$-\infty$	[g] [CNST] $-\infty$	(-1) {} $\rightarrow$ {2}  Minus infinity. See p. 143.										
$\times$	[x]	(2) Like $-$ , but returns $y \times x$ .										
$\times\text{MOD}$	[g] [INTS] [f] $\times\text{MOD}$	(3) {1, 2, 10}  Returns $(z \times y) \bmod x$ for $x > 1, y > 0, z > 0$ . See MOD.										
/	[/]	(2) Like $-$ , but returns $y \times x^{-1}$ . Returns $y \div x$ if both $y$ and $x$ are of data type 1 or 10; cf. IDIV.										
$^{\text{MOD}}$	[g] [INTS] [g] $^{\text{MOD}}$	(3) {1, 2, 10}  Returns $(z^y) \bmod x$ for $x > 1, y > 0, z > 0$ . See MOD.										

Item	Keystrokes	Remarks (see pp. 12ff for general information)
→		Reserved symbol for indirect addressing.
→DATE	<b>g</b> <b>CLK</b> →DATE	(3) {1, 2} → {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 <i>date</i> in $x$ . Thus inverts DATE→.
→DEG	<b>g</b> <b>L→</b> →DEG	
→D.MS	<b>g</b> <b>L→</b> →D.MS	
→GRAD	<b>g</b> <b>L→</b> →GRAD	
→HR	<b>f</b> <b>CATALOG</b> <b>FCNS</b> →HR	(1) {5} → {2} Operates on <i>times</i> like →REAL below. Maintained for backward compatibility only.
→H.MS	<b>f</b> <b>h.ms</b> (for closed input)	(1) {1, 2, 5} → {5} Converts $x$ to a sexagesimal <i>time</i> – cf. p. 116.
→INT	<b>f</b> <b>#</b> <b>base</b> (for closed input)	(1) {1, 2, 10} → {10} Converts the integer part of $x$ to a <i>short integer</i> of the base specified. Conversion to decimal may be abbreviated by <b>#</b> <b>D</b> , to hexadecimal by <b>#</b> <b>H</b> . Cf. p. 116.
→MULπ	<b>g</b> <b>L→</b> →MULπ	(1) {1, 2, 4} → {4} Converts angles as described on pp. 152f.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
→POL		{2}; {1} → {2} Assumes X and Y containing 2D Cartesian 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, s. RECTN.
→RAD	→RAD	(1) {1, 2, 4} → {4} Converts angles as described on pp. 152f
→REAL	 (for closed input)	(1) {1, 2, 4, 5, 6, 10} → {2} Converts $x$ to a real number. Any object (e.g. a time) tagged sexagesimal will be converted in a decimal number. For dates, the date format chosen is taken into account. Numbers shown as fractions will be displayed as decimal numbers (cf. FRACT and PROPFR). For returning the real part of a complex number, take RE. For cutting a complex number into its parts, use  or CX→RE.
→REC		{2}; {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 the picture and cf. →POL.  For switching the display format of complex numbers, see RECTN.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\text{X}$		<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{xxyz}</math> works like <math>\text{ENTER} \uparrow</math> (but does <u>not</u> disable <i>automatic stack lift!</i>),</li> <li><math>\text{xyxzt}</math> works like <math>x \leftrightarrow y</math>,</li> <li><math>\text{zyztx}</math> works like <math>R \downarrow</math> in a 4-level stack,</li> <li><math>\text{xtxyz}</math> works like <math>R \uparrow</math> in a 4-level stack,</li> <li>but also <math>\text{zyytt}</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 <i>stack</i> contents and make a mess of the <i>stack</i> easily.</p>
$ M $		<p>(1) {8} <math>\rightarrow</math> {2}; {9} <math>\rightarrow</math> {3}</p> <p>Requires a square matrix in <b>X</b> and returns its determinant. The original matrix is stored in <b>L</b>.</p>
$ x $		<p>(1) {1, 2, 4, 10}</p> <p>Returns the absolute (unsigned) value of <b>x</b>.</p> <p>(1) {8*}</p> <p>Returns a matrix with the absolute values of all input matrix elements. Cf. ENORM.</p>
		<p>(1) {3} <math>\rightarrow</math> {2}</p> <p>Returns the <i>magnitude</i> <math>\sqrt{\text{Re}(x)^2 + \text{Im}(x)^2}</math> in <b>X</b>.</p> <p>(1) {9*} <math>\rightarrow</math> {8}</p> <p>Returns a <i>real</i> matrix with the <i>magnitudes</i> of all input matrix elements. Cf. ENORM.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
	g [X.FN]	(2) {2, 3}; {1} → {2} Returns $\left(\frac{1}{x} + \frac{1}{y}\right)^{-1}$ ; useful in electrical engineering especially. Returns 0. for $x \times y = 0$ .
%	g [FIN] %	(1) {2}; {1} → {2} Returns $\frac{xy}{100}$ , leaving $y$ unchanged.
%MRR	g [FIN] %MRR	(3) {2}; {1} → {2} Returns the mean rate of return in % per period, i.e. $100 \cdot \left( \sqrt[z]{x/y} - 1 \right)$ with $x = FV$ = future value after $z$ periods, $y = PV$ = present value. For $z = 1$ , Δ% returns the same result easier.
%T	g [FIN] %T	(1) {2}; {1} → {2} Returns $\frac{100 x}{y}$ , interpreted as % of total. Leaves $y$ unchanged.
%Σ	g [FIN] %Σ	(1) {2}; {1} → {2} Returns $\frac{100 x}{\sum x}$ .
%+MG	g [FIN] %+MG	(2) {2}; {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 $x$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\sqrt{x}$	<b>g</b> <b>✓</b>	(1) {1, 2, 3, 8*, 9*, 10}; ({1} → {2}, {1, 2} → {3}) Returns the square root of $x$ . Square roots of non-square <i>long integers</i> will return <i>reals</i> . Square roots of negative <i>long integers</i> or <i>reals</i> will return <i>complex numbers</i> if CPXRES is set.
	<b>g</b> <b>EXP</b> <b>✓</b>	
$\infty$	<b>g</b> <b>CNST</b> <b>∞</b>	(-1) {} → {2} Infinity. See p. 143.
$\int$	<b>f</b> <b>ADV</b> <b>∫fdx</b> <b>∫</b> <b>var</b> (listed in programs as <b>∫fd</b> trailed by the integration variable)	{2} <b>Integrates</b> 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. $\int$ returns the (approximated) integral in X and an upper limit of its uncertainty in Y. <b>ATTENTION:</b> $\int$ fills all stack registers with $x$ before calling the routine specified in PGMINT.
	<b>g</b> <b>EQN</b> <b>∫f</b> <b>∫</b>	<b>Integrates</b> the current equation.
$\int f$	<b>g</b> <b>EQN</b> <b>∫f</b>	
$\int f dx$	<b>f</b> <b>ADV</b> <b>∫fdx</b>	<b>Submenus.</b> See pp. 127f.
$\arg$	<b>g</b> <b>✓</b> or <b>g</b> <b>CPX</b> <b>f</b> <b>arg</b> or <b>f</b> <b>PARTS</b> <b>f</b> <b>arg</b>	(1) {3} → {2} Returns the <i>phase</i> or <i>argument</i> $\arg(x) = \arctan\left(\frac{\text{Im}(x)}{\text{Re}(x)}\right)$ . Cf.  x . <span style="float: right;">See Section 4 of the OM for more.</span> (1) {9*} → {8} Returns a matrix with the <i>phases</i> of all input matrix elements. Cf.  x .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>4→</b>	<b>g L→</b>	<b>Menu</b> of angular conversions. See p. 135.
<b>ADV</b>	<b>g PRINT</b> <b>ADV</b>	(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.
<b>CHAR</b>	<b>g PRINT</b> <b>f</b> <b>CHAR n</b>	(0) Sends a single character (with the code specified) to the printer. Character codes <i>n</i> > 127 can only be specified indirectly. <b>MODE</b> setting will be honored. See <b>ADV</b> .
<b>DLAY</b>	<b>g PRINT</b> <b>g</b> <b>DLAY n</b>	(0) Sets a delay of <i>n</i> ticks (see TICKS) to be used with each linefeed on the printer.
<b>LCD</b>	<b>g PRINT</b> <b>LCD</b>	(0) Sends the contents of the entire LCD to the printer, so you get a hardcopy of the screen.
<b>MODE</b>	<b>g PRINT</b> <b>g</b> <b>MODE n</b>	(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.
<b>PROG</b>	<b>g PRINT</b> <b>PROG</b>	(0) Prints the listing of the <i>current program</i> (see Sect. 3 of the OM), one row per step.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
r		(0) Prints the <i>register</i> specified, right adjusted, <u>without</u> labeling the output (note  is a separate label  in this menu). If you want a heading label, compose the string in <b>X</b> first or use . See .
REGS		(1) Interprets <i>x</i> in the form <i>sss.nn</i> . Prints the contents of <i>nn</i> registers starting with number <i>sss</i> . Each <i>register</i> takes one row starting with its label.  <b>ATTENTION for nn = 0 :</b> <ul style="list-style-type: none"><li>• For <i>sss</i> <math>\in [0; 99]</math>, printing will stop at <b>R99</b>.</li><li>• For <i>sss</i> <math>\in [100; 111]</math>, printing stops at <b>K</b>.</li><li>• For <i>sss</i> <math>\geq 112</math>, printing stops at the highest allocated local <i>register</i>.</li></ul>
STK		(0) Prints the entire <i>stack</i> contents. Each of the 4 or 8 <i>registers</i> prints in a separate row starting with its label.
TAB	<i>n</i>	(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  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 .
USER		(0) Prints all variable <i>names</i> and global program labels in alphabetic order. The variable <i>names</i> are printed first; if you are not interested in the program labels, press  to stop the listing.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\text{WIDTH}$		(-1) Returns the number of print columns that $x$ would take in the print mode set. See $\text{MODE}$ . Second use: in $\text{MODE}$ 1 or 2, $\text{WIDTH}$ returns the width of $x$ in px (including the last column being always blank) in the specified font.
$\Sigma$		(0) Prints the summation registers. Each register prints in one row starting with its label.
$\#$		(0) Sends a single byte, without translation, to the printer (e.g. a control code). $n > 127$ can only be specified indirectly. $\text{MODE}$ setting will not be honored. See $\text{ADV}$ .
#		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 $x$ (like on HP-16C).

## Names of Variables and System Flags Provided

There is a *name* overlap between some constants and commands on one side and predefined variables and system flags on the other. Thus, the latter set is kept separate from the other *items*. As required for the *items* above, these *names* must be unique. The current status of the items printed on grey can be seen on the screen directly (e.g. in the *status bar*), for those printed on orange it is returned by STATUS:

Name	Keystrokes if applicable	Remarks (see pp. 12ff for general information)
A		Reserved variable for register <b>A</b>
ACC	[f] [ADV] [ $\int_{fdx}$ ] ACC	Reserved <i>real</i> variable for the accuracy of integration (see Sect. 4 of the OM).
ADM		Reserved integer variable for the <i>ADM</i> : 0: DEG, 1: D.MS, 2: RAD, 3: MUL $\pi$ , 4: GRAD.
ALLSCI		
ALPHA		
ALP.IN		
ASL.BLK		
AUTOFF		
AUTXEQ		
B		Reserved variables for registers <b>B</b> and <b>C</b> .
C		
CARRY		
CPXj		
CPXRES		
D		Reserved variable for register <b>D</b> .
DECIM.		
DENANY		
DENFIX		
DENMAX		Reserved integer variable for the maximum denominator, filled by the command DENMAX.
DMY		
FRACT		

Name	Keystrokes if applicable	Remarks (see pp. 12ff for general information)
FV	<b>g FIN TVM FV</b>	Reserved variable for the future value of your investment or loan in TVM. <sup>28</sup>
GRAMOD		Reserved integer variable determining how the AGRAPH image is displayed: <sup>29</sup> 0: It is merged (OR-ed) with the existing display. 1: It overwrites all pixels in that portion of the display. 2: Duplicate “on” pixels get turned “off”. 3: It is XOR-ed with the existing display.
GROW		<i>System flag</i> – see next chapter.
I		Reserved variable for <i>register I</i> .
IGN1ER		
INTING		<i>System flags</i> – see next chapter.
i%/a	<b>g FIN TVM i%/a</b>	Reserved variable for the annual interest rate of your investment or loan in TVM. <sup>28</sup>
J		
K		
L		
LEAD.0		
LOWBAT		<i>System flags</i> – see next chapter.

<sup>28</sup> See Section 5 of the OM.

<sup>29</sup> Working like flags 34 and 35 in HP-42S.

Name	Keystrokes if applicable	Remarks (see pp. 12ff for general information)
Mat_A	[f] MATX SIM EQ Mat A	Reserved variables for solving systems of linear equations (see <i>Section 2</i> of the OM).
Mat_B	[f] MATX SIM EQ Mat B	
Mat_X	[f] MATX SIM EQ Mat X	
MDY		<i>System flags</i> – see next chapter.
MULTx		
NPER	[g] [FIN] TVM nPER	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>
NUM.IN		<i>System flags</i> – see next chapter.
OVERFL		
PER/a	[g] [FIN] TVM [f] per/a	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	[g] [FIN] TVM PMT	Reserved variable for the payment per period for your investment or loan in <i>TVM</i> . <sup>28</sup>
PRINT		<i>System flags</i> – see next chapter.
PROPFRE		
PRTACT		
PV	[g] [FIN] TVM PV	Reserved variable for the present value of your investment or loan in <i>TVM</i> .
QUIET		<i>System flag</i> – see next chapter.
REALDF		Reserved integer variable for the display format of <i>reals</i> : 0: ALL, 1: FIX, 2: SCI, 3: ENG.

Name	Keystrokes if applicable	Remarks (see pp. 12ff for general information)
RECTN		<i>System flag</i> – see next chapter.
REGS		Reserved variable for the $100 \times 1$ matrix of registers – if required.
RUNIO		
RUNTIM		
SLOW		
SOLVING		
SPCRES		
SSIZE		
ST.A		
ST.B		
ST.C		
ST.D		
ST.T		
ST.X		
ST.Y		
ST.Z		
TDM		
TRACE		<i>System flags</i> – see next chapter.
USER	f [USER]	<i>System flag</i> toggled by [USER] – see next chapter
VMDISP		
YMD		
αCAP		

Name	Keystrokes if applicable	Remarks (see pp. 12ff for general information)
$\text{\texttt{\$}}\text{Lim}$	$f \text{ ADV} \text{ Jfdx }$ $\text{\texttt{\$}}\text{Lim}$ etc.	Reserved <i>real</i> variables for the upper and lower limit of integration (see the OM, Sect. 4).
#DEC		Reserved integer variable for the number of decimals in <i>real</i> number formatting (actually the parameter specified in last ALL, FIX, SCI, or ENG).

## System Flags

The *status bar*, especially its indicators (*SBI*), and the command STATUS return visible information about the system status of your WP 43S (cf. Sections 2 and 5 of the OM). Machine readable status information (e.g. for program control) is available via the 40 named *system flags* as listed below, sorted following the *status bar*:

Purpose	SBI	Flag <sup>30</sup>	Remarks
Time display	Time string	TDM (set)	<p>Set for international 24h time display. Expands the date display in the <i>status bar</i> to four digits for the year.</p> <p>Clear for 12h time display: 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.</p>
Date display	Date string	YMD, DMY, MDY (YMD set)	Set for the respective date format chosen. The commands Y.MD, D.MY, and M.DY set the corresponding flag and clear the two others.

<sup>30</sup> The flags printed on green may be written and read by the user, those printed on yellow are read-only and are written by the system exclusively. Startup default status is given in parentheses for the flags set at startup – all others are clear at startup. Grey and orange colors are used as in previous chapter.

Purpose	SBI	Flag <sup>30</sup>	Remarks
Complex results	C / R	CPXRES	Set for allowing <i>complex</i> results also for <i>real</i> input (e.g. $\sqrt{-1}$ ). Else an error will be thrown in such cases.
Complex letter	—	CPXj	Set for the letter <i>j</i> representing the <i>imaginary</i> number <i>i</i> , clear for <i>i</i> .
Rectangular notation	L / ⊙	RECTN (set)	Set for rectangular display of <i>complex</i> numbers, clear for polar.
Fraction display	—	FRACT	Set if fraction display is chosen, clear for decimal display ( <b>a b/c</b> sets FRACT, <b>.d</b> clears it). See next entries.
Fraction kind 1	—	PROPFRACTION	Set for <i>proper fractions</i> , clear for <i>improper fractions</i> ( <b>a b/c</b> toggles PROPFRACTION: coming from decimal display, it sets it). PROPFRACTION set allows only <i>proper fractions</i> in display (e.g. $1 \frac{2}{3}$ instead of $\frac{5}{3}$ ); any <i>reals</i> (with $ x  < 10^6$ ) will be displayed according to the settings of DENANY, DENFIX, and DENMAX as <i>proper fractions</i> .
Fraction kind 2	see OM	DENANY (set)	Set if <u>any</u> denominator up to DENMAX may appear (DENMAX is indicated in the <i>status bar</i> ). <sup>31</sup> For given DENMAX, this is the most precise way of displaying a decimal number as a fraction. See also next entry.
Fraction kind 3	see OM	DENFIX <sup>32</sup>	Set if the one and only denominator allowed is the value set by DENMAX. Clear if the denominator may be an integer factor of DENMAX. <sup>33</sup>

<sup>31</sup> If e.g. DENMAX = 5 and DENANY is set then this allows denominators 1, 2, 3, 4, and 5.

<sup>32</sup> DENFIX is evaluated only if DENANY is clear.

<sup>33</sup> If DENMAX = 60 and DENFIX is clear, this will allow for denominators 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60. Thus, 60 was a holy number in ancient Babylon.

Purpose	<i>SBI</i>	<i>Flag</i> <sup>30</sup>	Remarks
Carry	$c$ or $\overline{c}$	CARRY	Reflects the status of the carry bit.
Overflow	$o$ or $\overline{o}$	OVERFL	Reflects the status of the overflow bit.
Leading zeros	—	LEAD.0	Set for leading zeros turned on in <i>short integers</i> of bases 2, 4, 8, and 16. <sup>34</sup>
Alpha	A or $\alpha$	ALPHA	Set for AIM, else clear.
Upper case	A / $\alpha$	aCAP (set)	Set for capital letters, clear for lower case.
Running timer	⌚	RUNTIM	Set if the timer is running.
Running I/O	⚡	RUNIO	Set if I/O is in progress.
Printing	🖨️	PRINT	Set if your WP 43S is sending data to the printer.
Tracing	—	TRACE	Set if the print line is in tracing mode. Else prints must be triggered explicitly.
User mode	👤	USER	Set if your WP 43S is in user mode.
Low battery	🔋	LOWBAT	Set if the battery voltage is low (see <i>Section 2</i> of the OM).
Processor speed	—	SLOW	Kept clear for fresh batteries unless the user intervenes, set for battery voltage <2.5V. Speed and power consumption will be reduced to some 50% with SLOW set.
Special results	—	SPCRES	Set for allowing special results of calculations (i.e. $\pm\infty$ and NaN).

<sup>34</sup> Works like flag 3 in HP-16C.

Purpose	SBI	Flag <sup>30</sup>	Remarks
Stack size	—	SSIZE	Set for eight, clear for four <i>stack registers</i> . Note all <i>register</i> contents will remain unchanged if SSIZE is modified (as well as if <i>stack</i> size is changed by any other operation – e.g. by RCLCFG).
Beeper	—	QUIET	Set for disabled beeper.
Radix mark	—	DECIM. (set)	Set for a decimal point, clear for a comma.
Multiplication symbol	—	MULTx (set)	Set for multiplication symbol <b>x</b> , clear for <b>.</b>
Overflow from ALL	—	ALLSCI (set)	Set if numbers exceeding the range displayable in ALL or FIX will be shown in SCientific format, clear for ENGineer's format.
Matrix grow mode	—	GROW	Set (e.g. by M.GROW) if matrices may grow, else clear (e.g. by M.WRAP). See the command J+ above and Section 2 of the OM; see also GROW in the HP-42S Owner's Manual, p. 213.
Automatic OFF	—	AUTOFF (set)	Set if automatic shutdown is enabled. Else your WP 34S will remain ON until you will turn it off manually or battery voltage will drop below the limit.
Automatic execution	—	AUTXEQ	Like flag 11 of HP-42S
Printer activated	—	PRTACT	Like flag 21 of HP-42S
Data entry	—	NUM.IN, ALP.IN	Set for numeric or alphanumeric entry (like flags 22 and 23 of HP-42S).

Purpose	SBI	Flag <sup>30</sup>	Remarks
Disable automatic stack lift	—	ASL.BLK	Set by ENTER, CLX, $\Sigma+$ , and $\Sigma-$ , cleared by all other functions (see the OM, Sect. 1)
Error handling	—	IGN1ER	If set, your WP 43S ignores just 1 arbitrary error and clears IGN1ER then. The operation causing the error will not be executed. This works like flag 25 of HP-42S
Integrating	—	INTING	Set while the integrator is running.
Solving	—	SOLVING	Set while the solver is computing a root.
Variable menu	—	VMDISP	Set while the variable menu is displayed.

## 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**,  **$\alpha$** ,  **$\text{S}$** ,  **$\Delta$** ,  **$\nabla$** ,  **$\Delta$** ,  **$\nabla$** , and  **$\nabla$**  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 (on pp. 120ff) for more about this topic.

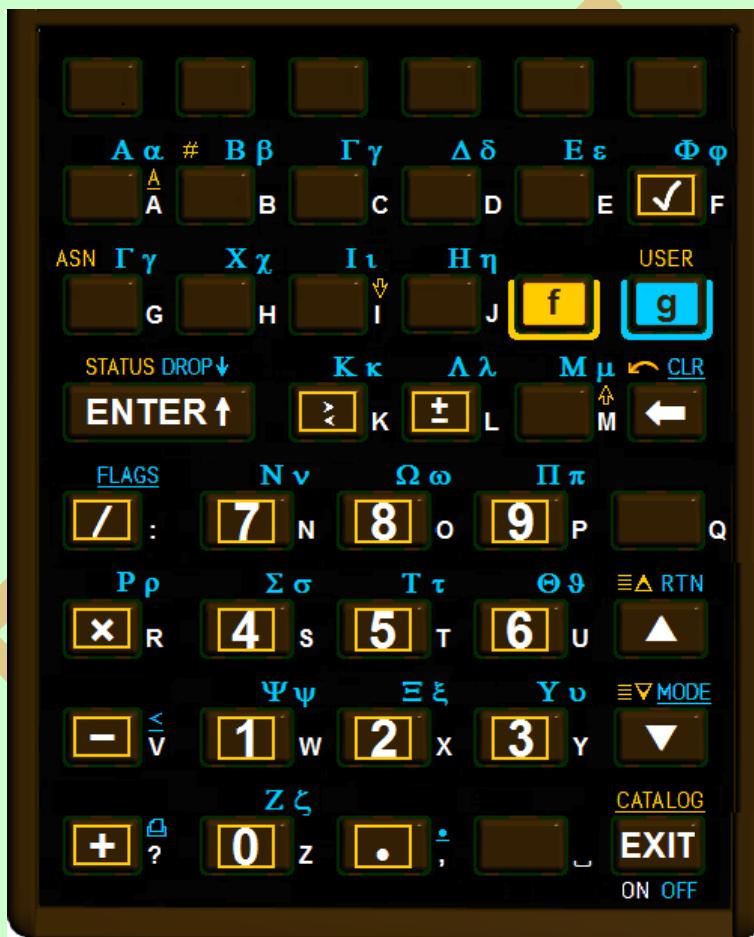
The *browsers RBR* and *STATUS* as well as the *application TIMER* use some keys for particular control purposes (e.g. **STO**, **RCL**, **.**, and numeric keys – see the OM, Section 5).

## 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. 116ff for input in **X** instead). Note that a “character” may be a letter, digit, punctuation mark, etc. The table below lists the respective keys beginning top left on the keyboard:

Keystrokes	Situation	Meaning
<b>A</b> , <b>B</b> , <b>C</b> , <b>D</b> , <b>I</b> , <b>J</b> , <b>K</b> , <b>L</b> , <b>T</b> , <b>X</b> , <b>Y</b> , <b>Z</b>	addressing	Enters the address of a <i>global general purpose register or user flag</i> .
<b>A</b> ... <b>Z</b> <b>g A</b> ... <b>g O</b> <b>f O</b> ... <b>f 9</b>	entering a label, a <i>system flag</i> or variable name	Appends the corresponding Latin or Greek letter or digit to the label, <i>system flag</i> or variable <i>name</i> pending. Use <b>▼</b> and <b>▲</b> to switch cases for letters. See the virtual keyboard on p. 115 (and cf. the OM, Sect. 2).
<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 or user flag address</i> , a <i>system flag</i> or <i>variable name</i> , or a <i>label or alike</i> , and executes the command. Cf. Section 1 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</b> ... <b>9</b>	addressing or specifying	Enters a numeric parameter, an address, or a local label. See Sections 1 and 3 of the OM for valid number ranges.
<b>.</b>	addressing	Header for <i>local registers or user flags</i> .

Keystrokes	Situation	Meaning
<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 the current command was called.



Virtual keyboard in *alpha input mode (AIM)*. AIM is also active when a catalog is entered, so you can use all accessible characters for alphabetic searching (see pp. 124f).

## Alphanumeric Input in X and Closing It

The following table shows what will happen when particular keys are pressed with alphanumeric (incl. numeric) input in X being open still (turn to pp. 114f for command parameter input instead). The table lists the respective keys top left to bottom right on the keyboard:

Keystrokes in mode(s)	Meaning
	A, $\alpha$ 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. Section 2 of the OM.
	A, $\alpha$ Appends #"/> to the <i>alpha string</i> $x$ .
	$\neg(A, \alpha)$ Closes input of a <i>short integer</i>
	$\neg(A, \alpha)$ sexagesimal angle
	$\neg(A, \alpha)$ date
	$\neg(A, \alpha)$ sexagesimal time in X. <sup>35</sup>
	A, $\alpha$ Appends a checkmark  to the <i>alpha string</i> $x$ .
	$\neg(A, \alpha)$ Closes input of the first part (i.e. <i>real</i> part or <i>magnitude</i> ) of a <i>complex</i> number in X and waits for input of its second part (i.e. <i>imaginary</i> part or <i>phase</i> , see the Key Response Table and Section 2 of the OM).
	A, $\alpha$ Prefix making the next character a subscript, if applicable.

<sup>35</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), bases, 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 on next page and the error messages in App. C).

Keystrokes	in mode(s)	Meaning
<b>ENTER↑</b>	arbitrary input pending	<p>If there was input expected but not entered, cancels entry.</p> <p>Else closes input (in <b>X</b>) and checks the following conditions top-down:</p> <ul style="list-style-type: none"> <li>• If this input is <i>alphanumeric</i> (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 <i>purely numeric</i>) if it contains one <b>CC</b>, takes it as a <i>complex number</i>.</li> <li>• Else if it contains two <b>.</b>, takes it as a <i>fraction</i>.</li> <li>• Else if it contains one <b>.</b> or one <b>E</b>, takes it as a <i>real number</i>.</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 <u>previous entry</u> 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 35 and interprets it. Finally, unless an error had to be thrown, copies <b>x</b> into <b>Y</b>.</p>
<b>f xz y</b>	<b>A, α</b>	Appends <b>z</b> to the <i>alpha string</i> <b>x</b> .
<b>+/-</b>	$\neg(A, \alpha)$	Changes the sign of the mantissa or exponent in numeric input as explained in <i>Section 1</i> of the OM.
<b>f +/-</b>	<b>A, α</b>	Appends <b>±</b> to the <i>alpha string</i> <b>x</b> .
<b>E</b>	$\neg(A, \alpha)$	Closes input of the mantissa and waits for input of the exponent (see <i>Section 1</i> of the OM).
<b>f E ( ^ )</b>	<b>A, α</b>	Prefix making the next character a superscript, if applicable.

Keystrokes	in mode(s)	Meaning
	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 alpha string $x$ .
	A, $\alpha$	Appends $/$ to the alpha string $x$ .
	A, $\alpha$	If MULT $x$ then appends $\times$ , else $\cdot$ to the alpha string $x$ .
	$\neg$ (A, $\alpha$ )	Standard numeric input, appending the corresponding digit to $x$ . Note you can enter ... <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 <i>real</i> number or any part of a <i>complex</i> 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 alpha string $x$ .
	$\alpha$	Turns to upper case for the following letters.
	A	Turns to lower case for the following letters.
	A, $\alpha$	Appends $-$ to the alpha string $x$ .
	$\neg$ (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 <b>ENTER↑</b> above).
	A, $\alpha$	Appends $?$ to the alpha string $x$ .
	A, $\alpha$	Appends $+$ to the alpha string $x$ .

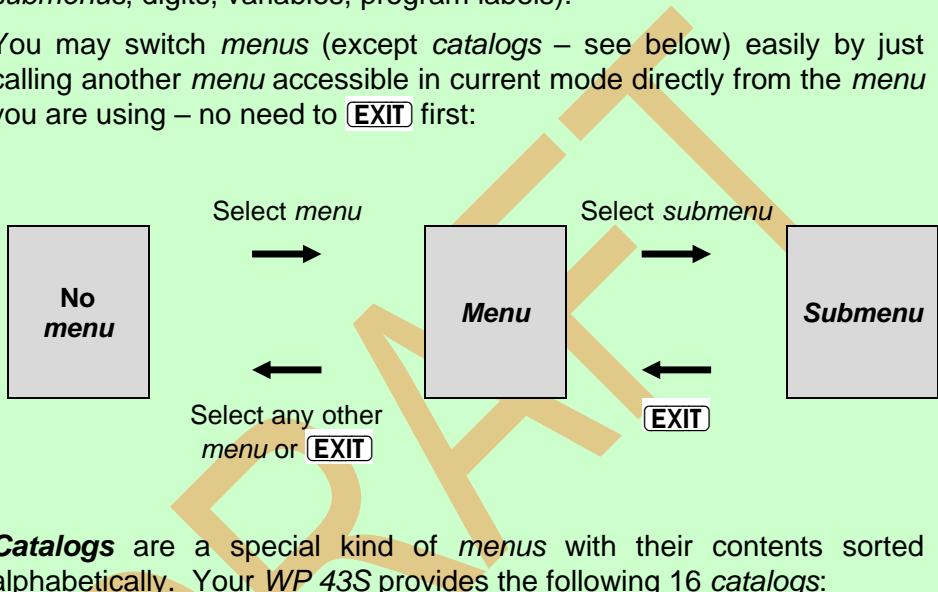
Keystrokes in mode(s)		Meaning
<b>g + (</b>	<b>A, <math>\alpha</math></b>	Appends  to the <i>alpha string x</i> .
	$\neg$ <b>(A, <math>\alpha</math>)</b>	<p>Inserts a radix mark as selected.</p> <p>Separates <i>degrees</i> from <i>minutes</i>, <i>seconds</i>, and <i>hundredths of seconds</i> in angular input, so input format is dddd.dddd.mmmsshh  for sexagesimal angles (cf. p. 116 and <i>Section 2</i> of the <i>OM</i>).</p> <p>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.hhhhh.mmmssffff  for sexagesimal <i>times</i> (cf. p. 116 and <i>Section 2</i> of the <i>OM</i>).</p>
Second	$\neg$ <b>(A, <math>\alpha</math>)</b>	A 2 <sup>nd</sup> in input indicates a fraction. See the <i>OM</i> , Sect. 2 for examples. The 2 <sup>nd</sup> just separates the nominator and the denominator in input. Note you cannot enter <b>E</b> after you entered  twice – but you may delete the 2 <sup>nd</sup> dot while editing the input.
	<b>A, <math>\alpha</math></b>	Appends  to the <i>alpha string x</i> .
<b>f .</b>	<b>A, <math>\alpha</math></b>	Appends  to the <i>alpha string x</i> .
<b>R/S</b>		Closes input and starts its checks and interpretation like <b>ENTER</b> above. Resumes program execution.
	<b>A, <math>\alpha</math></b>	Appends a blank space to the <i>alpha string x</i> .
<b>EXIT</b>	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. 121 and 133ff 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, variables, program labels).

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



**Catalogs** are a special kind of *menus* with their contents sorted alphabetically. Your *WP 43S* provides the following 16 *catalogs*:

- CNST,
- CATALOG'FCNS (the greatest *catalog* by far at startup),
- CATALOG'MENUS,
- CATALOG'DIGITS,
- CATALOG'CHARS'aINTL,
- the nine *submenus* of CATALOG'VARS and
- the two *submenus* of CATALOG'PROGS .

Within *catalogs*, some special operations ease your path accessing the *items* stored therein (as shown on pp. 124f).

## 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. 124f.

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

							Remarks
CATALOG:	FCNS	SYS.FL	CHARS	PROGS	VARS	MENUS	top branches
			DIGITS				
FCNS:	$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	$10^x$	1COMPL	$1/x$	$2^x$	contains some 700 functions provided
	2COMPL	$\sqrt[3]{x}$	ABS	ACOS	$\text{ac} \rightarrow m^2$	$\text{ac}_u \rightarrow m^2$	
	AGM	AGRAPH	ALL	AND	arccos	arcosh	
	...						
	...	#B					
SYS.FL:	ALLSCI	ALPHA	ALP.IN	...			system flags (cf. pp. 104ff)
	...						
CHARS:	$\alpha\text{INTL}$	$\alpha\ldots\Omega$		$\alpha\text{MATH}$	$\text{My}\alpha$	$\alpha\cdot$	character branches
$\alpha\text{INTL}:$	A	$\bar{A}$	$\ddot{A}$	$\check{A}$	$\grave{A}$	...	international Latin letters, see p. 133
$\alpha\text{MATH}:$	<	$\leq$	=	...			mathematical operators and symbols, see p. 134
$\alpha\ldots\Omega:$	A	B	$\Gamma$	$\Delta$	...		Greek letters, see p. 134
$\alpha\bullet:$	!	;	...				punctuation marks, see p. 135

	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Remarks
PROGS:	RAM					FLASH	global labels currently defined
RAM:	...						both branches are empty at startup; they will be filled with your creations
FLASH:	...						
VARS:	L.INTS DATES	S.INTS TIMES	REALS ANGLES	CPXS	STRING	MATRS	branches for various types of variables
ANGLES:	...						all variables currently defined, placed following their <i>data types</i> – all these <i>sub-menus</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 CLK DIGITS ...	A: CLR DSP ...	BITS CNST EQN ...	Binom: CPX EXP ...	Cauch: CPXS Expon: E: 4→	CHARS DATES E: ...	menus and sub-menus currently defined (shown here at startup, but also this list will grow with your creations) – see above and below for fix menu contents
A:	...						(sub-) menus provided unless mentioned above already, see pp. 126ff for predefined contents – here your creations will be inserted as new entries
Binom:	...						
BITS:	...						
...							
...							
DIGITS:	0 6 C	1 7 D	2 8 E	3 9 F	4 A i	5 B I	digits defined

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 ones are fixed size (**FCNS**, **DIGITS**, and **CHARS**) since all functions, digits, and characters are predefined.

Calling CATALOG will display its top level branches. The seven labels shown are pointers to the *submenus* containing all the functions, system flags, digits, characters, programs, variables, and *menus* defined at execution time.

Choosing one of these branches will display 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:

AGM	AGRAPH	ALL	AND	$\arccos$	$\text{arcosh}$
2COMPL	$\sqrt[3]{\cdot}$	ABS	ACOS	$\text{ac} \rightarrow m^2$	$\text{ac}_{us} \rightarrow m^2$
$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	$10^x$	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>36</sup> Select an *item* by pressing the corresponding top row key (headed by **f** or **g** if applicable); e.g. call a function by pressing the corresponding softkey. **EXIT** will just leave this branch without doing anything.

All the over 700 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* (see below). Remember that each and every command featured on your *WP 43S*, the keystrokes calling it, and the necessary particular explanations are listed for your reference in the *I/O* on pp. 12ff.

<sup>36</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.

As mentioned in the OM, 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 the chapter after 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.

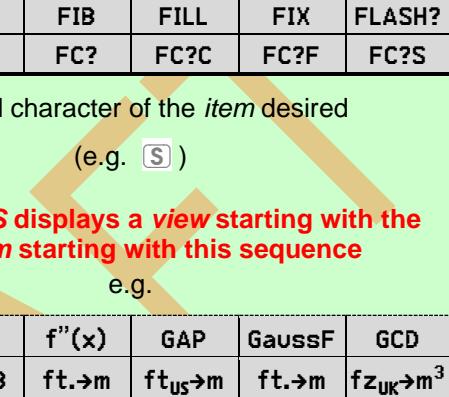
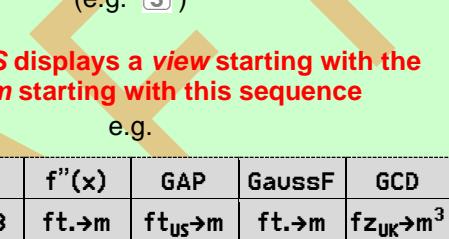
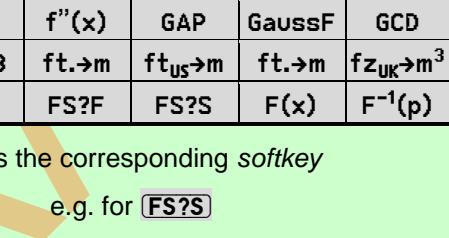
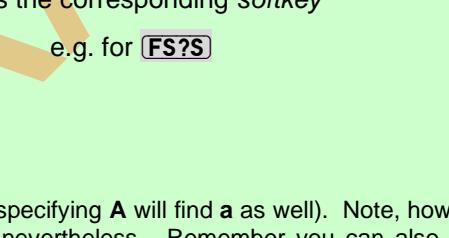
## Accessing Cataloged Items Rapidly

You can browse a *catalog* like any other *menu* just using **▲** and **▼** as explained in previous chapter. In **CNST** and major parts of **CATALOG** (**FCNS**, **SYS.FL**, **MENUS**, **CHARS** **αINTL**, and the *submenus* of **PROGS** and **VARS**), however, you may reach your target significantly faster taking advantage of the alphabetic access method demonstrated here.

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

1 User input  Return	<b>CATALOG FCNS</b>  <b>Your WP 43S displays the first view in this catalog;<sup>37</sup> AIM is on.</b>  <table border="1"><tr><td>AGM</td><td>AGRAPH</td><td>ALL</td><td>AND</td><td>arccos</td><td>arcosh</td></tr><tr><td>2COMPL</td><td><math>\sqrt[3]{x}</math></td><td>ABS</td><td>ACOS</td><td><math>ac \rightarrow m^2</math></td><td><math>ac_{us} \rightarrow m^2</math></td></tr><tr><td><math>{}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}</math></td><td><math>{}^{\circ}\text{F} \rightarrow {}^{\circ}\text{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>	AGM	AGRAPH	ALL	AND	arccos	arcosh	2COMPL	$\sqrt[3]{x}$	ABS	ACOS	$ac \rightarrow m^2$	$ac_{us} \rightarrow m^2$	${}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}$	${}^{\circ}\text{F} \rightarrow {}^{\circ}\text{C}$	$10^x$	1COMPL	$1/x$	$2^x$
AGM	AGRAPH	ALL	AND	arccos	arcosh														
2COMPL	$\sqrt[3]{x}$	ABS	ACOS	$ac \rightarrow m^2$	$ac_{us} \rightarrow m^2$														
${}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}$	${}^{\circ}\text{F} \rightarrow {}^{\circ}\text{C}$	$10^x$	1COMPL	$1/x$	$2^x$														

<sup>37</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.

2 User input	First character of the <i>item</i> desired (e.g. <b>F</b> )																		
Return	<b>Your WP 43S displays a view starting with the first <i>item</i> starting with this character</b> <sup>38</sup> e.g. 																		
	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>FL00R</td><td>FP</td><td>FP?</td><td><math>F_p(x)</math></td><td>FS?</td><td>FS?C</td></tr> <tr> <td><math>F_e(x)</math></td><td>FF</td><td>FIB</td><td>FILL</td><td>FIX</td><td>FLASH?</td></tr> <tr> <td><b>FB</b></td><td><b>FBR</b></td><td><b>FC?</b></td><td><b>FC?C</b></td><td><b>FC?F</b></td><td><b>FC?S</b></td></tr> </table>	FL00R	FP	FP?	$F_p(x)$	FS?	FS?C	$F_e(x)$	FF	FIB	FILL	FIX	FLASH?	<b>FB</b>	<b>FBR</b>	<b>FC?</b>	<b>FC?C</b>	<b>FC?F</b>	<b>FC?S</b>
FL00R	FP	FP?	$F_p(x)$	FS?	FS?C														
$F_e(x)$	FF	FIB	FILL	FIX	FLASH?														
<b>FB</b>	<b>FBR</b>	<b>FC?</b>	<b>FC?C</b>	<b>FC?F</b>	<b>FC?S</b>														
3 User input	Second character of the <i>item</i> desired (e.g. <b>S</b> ) 																		
Return	<b>Your WP 43S displays a view starting with the first <i>item</i> starting with this sequence</b> e.g. 																		
	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td><math>fz_{us} \rightarrow m^3</math></td><td><math>f'(x)</math></td><td><math>f''(x)</math></td><td>GAP</td><td>GaussF</td><td>GCD</td></tr> <tr> <td><math>fm. \rightarrow m</math></td><td><math>fr \rightarrow dB</math></td><td><math>ft \rightarrow m</math></td><td><math>ft_{us} \rightarrow m</math></td><td><math>ft. \rightarrow m</math></td><td><math>fz_{uk} \rightarrow m^3</math></td></tr> <tr> <td><b>FS?</b></td><td><b>FS?C</b></td><td><b>FS?F</b></td><td><b>FS?S</b></td><td><math>F(x)</math></td><td><math>F^{-1}(p)</math></td></tr> </table>	$fz_{us} \rightarrow m^3$	$f'(x)$	$f''(x)$	GAP	GaussF	GCD	$fm. \rightarrow m$	$fr \rightarrow dB$	$ft \rightarrow m$	$ft_{us} \rightarrow m$	$ft. \rightarrow m$	$fz_{uk} \rightarrow m^3$	<b>FS?</b>	<b>FS?C</b>	<b>FS?F</b>	<b>FS?S</b>	$F(x)$	$F^{-1}(p)$
$fz_{us} \rightarrow m^3$	$f'(x)$	$f''(x)$	GAP	GaussF	GCD														
$fm. \rightarrow m$	$fr \rightarrow dB$	$ft \rightarrow m$	$ft_{us} \rightarrow m$	$ft. \rightarrow m$	$fz_{uk} \rightarrow m^3$														
<b>FS?</b>	<b>FS?C</b>	<b>FS?F</b>	<b>FS?S</b>	$F(x)$	$F^{-1}(p)$														
4 User input	Press the corresponding softkey e.g. for <b>FS?S</b> 																		

<sup>38</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*. Also some other characters can be specified in a search – please see the *virtual keyboard* printed on p. 110. 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 **▼** or **▲**.

You may put in more than one character (see overleaf) – though after 3 seconds or after pressing **▼** or **▲**, whatever comes first, the search string will be reset. Then you may continue browsing using **▼** or **▲** 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.

[Return](#)

Your WP 43S  
executes or inserts the command, recalls the  
constant, or inserts the letter selected.  
*AIM* remains on until this *catalog* is exited –  
then your WP 43S returns to the mode as set  
before entering this catalog.

### 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 700);
- 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 αINTL** (or in AIM by **f A**) + 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
	PGMSLV		$f''(x)$			PGMINT	
	$\int f dx$		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 HP-16C and WP 34S
	NAND	NOR	XNOR	MIRROR		ASR	
	SB	BS?	#B	FB	BC?	CB	
	SL	RL	RLC	RRC	RR	SR	
	LJ					RJ	
	1COMPL	2COMPL	UNSIGN	SIGNMT		WSIZE	
<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	
						J/G	
<b>CLR</b>	CL $\Sigma$	CLP	CF	CLMENU	CLCVAR	CLX	almost as in HP-42S
	CLREGS	CLPall	CLFall		CLLCD	CLSTK	
	CLall					RESET	
<b>CNST</b>							catalog of constants, see pp. 135ff
<b>CPX</b>	dot	cross	UNITY	Re	conj	$Re \pm Im$	special complex functions
	CX $\rightarrow$ RE	RE $\rightarrow$ CX		Im	x	$\neq$	
<b>DSP</b>	FIX	SCI	ENG	ALL	ROUNDI	ROUND	display rounding and shifts, formats and settings, mostly for reals
	SDL	SDR			RDP	RSD	
	CHINA	EUROPE	INDIA	JAPAN	UK	USA	
	GAP					DSTACK	

Menu							Remarks
<b>EQN</b>	NEW	EDIT	f''	f'	∫f	Solver	equations (see the OM, Sect. 4)
	DELETE						
<u>Solver</u>							show the <i>names</i> of all variables of the current equation and more
<u>f</u>							
<u>f'</u>							
<u>f''</u>							
<b>EQ.EDI</b>	←	( )	^	:	=	→	Equation Editor
<b>EXP</b>	x <sup>3</sup>	√y	log <sub>x</sub> y	lb x	2 <sup>x</sup>	√x	exponential, logarithmic, and hyperbolic functions
	3√x			ln 1+x	e <sup>x</sup> -1		
	sinh	arsinh	cosh	arcosh	tanh	artanh	
<b>FIN</b>	%	%MRR	%T	%Σ	%+MG	TVM	financial functions and settings (see the OM, Section 5)
TVM	n <sub>PER</sub>	i%/a	per/a	PV	PMT	FV	
	Begin					End	
<b>FLAGS</b>	SF	FS?	FF	STATUS	FC?	CF	
	FS?S	FS?C	FS?F	FC?F	FC?S	FC?C	
						CLFall	
<b>INFO</b>	SSIZE?	MEM?	RM?	SMODE?	WSIZE?	KTYP?	system information plus one non-binary test ( $\pm\infty?$ )
	LocR?	FLASH?	ULP?	NEIGHB	SDIGS?	BATT?	
	WHO?	VERS?	DIM?	±∞?	αPOS?	αLENG?	
<b>INTS</b>	A	B	C	D	E	F	digits for short integers with bases > 10, integer operations
	IDIV	RMD	MOD	×MOD	FLOOR	LCM	
	DBL /	DBLR	DBL ×	^MOD	CEIL	GCD	
	1COMPL	2COMPL	UNSIGN	SIGNMT		WSIZE	
<b>I/O</b>	BEEP	LOAD	LOADP	LOADR	LOADSS	LOADΣ	data exchange and signalling
	TONE				RECV	SEND	

Menu							Remarks
<b>LOOP</b>	DSE	DSZ	DSL	ISE	ISZ	ISG	
	DEC					INC	
<b>MATX</b>	NEW	[M] <sup>-1</sup>	M	[M] <sup>T</sup>	SIM EQ	EDIT	matrix operations (almost as in HP-42S)
	dot	cross	UNITV	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
<b>MODE</b>	SF	DEG	RAD	GRAD	MUL $\pi$	CF	mode settings; SYSTEM is not available on the simulator
			RM		SETSIG	DENMAX	
	SYSTEM						
<b>MyMenu</b>							will show up out of AIM <sup>39</sup>
<b>My<math>\alpha</math></b>							will show up in AIM <sup>39</sup>
<b>PARTS</b>	IP	FP	MANT	EXPT	sign	DECOMP	some overlaps with HP-42S CONVERT
					x	$\frac{d}{dx}$	
					Re	Im	

<sup>39</sup> ... as long as no other menu is called (see Section 6 of the OM).

Menu							Remarks
PRINT	☒x	☒r	☒Σ	☒ADV	☒LCD	☒PROG	the PRINT commands of the HP-42S
	☒STK	☒REGS	☒USER	☒TAB	☒#	☒CHAR	
				☒WIDTH	☒DLAY	☒MODE	

PROB	Norml:	t:	C <sub>yx</sub>	P <sub>yx</sub>	F:	$\chi^2$ :	combinations, permutations, random number generators and 14 probability distributions. Selecting one (e.g. Norml) opens a submenu featuring 4 entries for its PDF (or PMF), CDF, error probability, and quantile function
LgNrm:	Cauch:		Expon:	Logis:	Weibl:		
	NBin:	Geom:	Hyper:	Binom:	Poiss:		
RAN#	SEED	RANI#		InΓ	Γ(x)		
Binom:	Binom <sub>p</sub>	Binom		Binom <sub>e</sub>	Binom <sup>-1</sup>		
Cauch:	Cauch <sub>p</sub>	Cauch		Cauch <sub>e</sub>	Cauch <sup>-1</sup>		
Expon:	Expon <sub>p</sub>	Expon		Expon <sub>e</sub>	Expon <sup>-1</sup>		
F:	F <sub>p</sub> (x)	F(x)		F <sub>e</sub> (x)	F <sup>-1</sup> (p)		
Geom:	Geom <sub>p</sub>	Geom		Geom <sub>e</sub>	Geom <sup>-1</sup>		
Hyper:	Hyper <sub>p</sub>	Hyper		Hyper <sub>e</sub>	Hyper <sup>-1</sup>		
LgNrm:	LgNrm <sub>p</sub>	LgNrm		LgNrm <sub>e</sub>	LgNrm <sup>-1</sup>		
Logis:	Logis <sub>p</sub>	Logis		Logis <sub>e</sub>	Logis <sup>-1</sup>		
NBin:	NBin <sub>p</sub>	NBin		NBin <sub>e</sub>	NBin <sup>-1</sup>		
Norml:	Norml <sub>p</sub>	Norml		Norml <sub>e</sub>	Norml <sup>-1</sup>		
Poiss:	Poiss <sub>p</sub>	Poiss		Poiss <sub>e</sub>	Poiss <sup>-1</sup>		
t:	t <sub>p</sub> (x)	t(x)		t <sub>e</sub> (x)	t <sup>-1</sup> (p)		
Weibl:	Weibl <sub>p</sub>	Weibl		Weibl <sub>e</sub>	Weibl <sup>-1</sup>		
$\chi^2$ :	$\chi^2_p(x)$	$\chi^2(x)$		$\chi^2_e(x)$	$(\chi^2)^{-1}$		

P.FN	INPUT	END	ERR	TICKS	PAUSE	P.FN2	additional programming functions (avoided a multi-view menu here).
	PSTO	PRCL	VARMNU	MVAR	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			
	BACK	CASE	SKIP	AGRAPH	PIXEL	POINT	

Menu							Remarks
<b>STAT</b>	$\Sigma+$	$\bar{x}$	$s$	$s$	$s_m$	SUM	for sample statistics.
	$\Sigma-$	$\bar{x}_w$	$s_w$	$s_w$	$s_{mw}$		
	CLΣ	$\bar{x}_G$	$\epsilon$	$\epsilon_p$	$\epsilon_m$	PLOT	
	L.R.	$r$	$s_{xy}$	Cov	$\hat{x}$	$\hat{y}$	for curve fitting and 2d sample statistics.
		$\bar{x}_H$					
		$\bar{x}_{RMS}$					
	LinF	ExpF	LogF	PowerF		BestF	for choosing the fit model(s)
	OrthoF	GaussF	CauchF	ParabF	HypF	RootF	
<b>STK</b>	x $\vec{\times}$	y $\vec{\times}$	z $\vec{\times}$	t $\vec{\times}$	$\vec{x}$	DROPy	stack related operations.
<b>TEST</b>	$x < ?$	$x \leq ?$	$x = ?$	$x \neq ?$	$x \geq ?$	$x > ?$	binary tests.
	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?			
<b>TRI</b>	sin	arcsin	cos	arccos	tan	arctan	trigonometric & hyperbolic functions (cf. EXP).
	sinh	arsinh	cosh	arcosh	tanh	artanh	
<b>U<math>\uparrow</math></b>	E:	P:	year $\rightarrow$ s	F&p:	m:	x:	unit conversions (see pp. 146ff).
	$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	s $\rightarrow$ year		V:	A:	
	power ratio $\rightarrow$ dB	dB $\rightarrow$ power ratio			field ratio $\rightarrow$ dB	dB $\rightarrow$ field ratio	
A:	acre $\rightarrow$ m <sup>2</sup>	m <sup>2</sup> $\rightarrow$ acre	ha $\rightarrow$ m <sup>2</sup>	m <sup>2</sup> $\rightarrow$ ha	acre <sub>us</sub> $\rightarrow$ m <sup>2</sup>	m <sup>2</sup> $\rightarrow$ acre <sub>us</sub>	
E:	cal $\rightarrow$ J	J $\rightarrow$ cal	Btu $\rightarrow$ J	J $\rightarrow$ Btu	Wh $\rightarrow$ J	J $\rightarrow$ Wh	
F&p:	Ibf $\rightarrow$ N	N $\rightarrow$ Ibf	bar $\rightarrow$ Pa	Pa $\rightarrow$ bar	psi $\rightarrow$ Pa	Pa $\rightarrow$ psi	
	in.Hg $\rightarrow$ Pa	Pa $\rightarrow$ in.Hg	torr $\rightarrow$ Pa	Pa $\rightarrow$ torr	atm $\rightarrow$ Pa	Pa $\rightarrow$ atm	

Menu	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Remarks
<u>m:</u>	<b>lb.<math>\rightarrow</math>kg</b> <b>stone → kg</b>	<b>kg<math>\rightarrow</math>lb.</b> <b>kg → stone</b>	<b>cwt<math>\rightarrow</math>kg</b> <b>cwt<math>\rightarrow</math>kg</b>	<b>kg<math>\rightarrow</math>cwt</b> <b>sh.cwt</b>	<b>oz<math>\rightarrow</math>kg</b> <b>tr.oz → kg</b>	<b>kg<math>\rightarrow</math>oz</b> <b>kg → tr.oz</b>	units of mass
	<b>ton<math>\rightarrow</math>kg</b>	<b>kg<math>\rightarrow</math>ton</b>	<b>short ton → kg</b>	<b>kg → short ton</b>	<b>carat</b>	<b>kg → carat</b>	
<u>P:</u>	<b>hp_E<math>\rightarrow</math>W</b> <b>gl_UK<math>\rightarrow</math>m³</b> <b>floz_UK → m³</b>	<b>W<math>\rightarrow</math>hp_E</b> <b>m³<math>\rightarrow</math>gl_UK</b> <b>m³ → floz_UK</b>	<b>hp_UK<math>\rightarrow</math>W</b> <b>qt.<math>\rightarrow</math>m³</b> <b>barrel → m³</b>	<b>W<math>\rightarrow</math>hp_UK</b> <b>m³<math>\rightarrow</math>qt.</b> <b>m³ → barrel</b>	<b>hp_M<math>\rightarrow</math>W</b> <b>gl_US<math>\rightarrow</math>m³</b> <b>floz_US → m³</b>	<b>W<math>\rightarrow</math>hp_M</b> <b>m³<math>\rightarrow</math>gl_US</b> <b>m³ → floz_US</b>	units of power
<u>V:</u>	<b>mi.<math>\rightarrow</math>m</b> <b>in.<math>\rightarrow</math>m</b>	<b>m<math>\rightarrow</math>mi.</b> <b>m → in.</b>	<b>ly<math>\rightarrow</math>m</b> <b>point → m</b>	<b>m<math>\rightarrow</math>ly</b> <b>m → point</b>	<b>pc<math>\rightarrow</math>m</b> <b>survey foot_US → m</b>	<b>m<math>\rightarrow</math>pc</b> <b>m → survey foot_US</b>	units of volume
<u>X:</u>	<b>au<math>\rightarrow</math>m</b> <b>fathom → m</b>	<b>m<math>\rightarrow</math>au</b> <b>m → fathom</b>	<b>ly<math>\rightarrow</math>m</b> <b>point → m</b>	<b>m<math>\rightarrow</math>ly</b> <b>m → point</b>	<b>pc<math>\rightarrow</math>m</b> <b>survey foot_US → m</b>	<b>m<math>\rightarrow</math>pc</b> <b>m → survey foot_US</b>	units of length
<u>X.FN</u>	<b>AGM</b> <b>FIB</b> <b>J_y(x)</b> <b>sinc</b> <b><math>\Gamma_{xy}</math></b>	<b>B_n</b> <b>g_d</b> <b>ln<math>\beta</math></b> <b>W_m</b> <b><math>\zeta(x)</math></b>	<b>B_n*</b> <b><math>g_d^{-1}</math></b> <b>ln<math>\Gamma</math></b> <b>W_p</b> <b>(-1)^x</b>	<b>erf</b> <b>I<math>_{xyz}</math></b> <b>max</b> <b>W<math>^{-1}</math></b> <b></b>	<b>erfc</b> <b>I<math>_{\Gamma_p}</math></b> <b>min</b> <b><math>\beta(x,y)</math></b> <b></b>	<b>Orthog</b> <b>I<math>^{\Gamma_q}</math></b> <b>NEXTP</b> <b><math>\gamma_{xy}</math></b> <b>  </b>	advanced mathematical functions like Beta, Bessel, etc.
<u>Orthog</u>	<b>H_n</b> <b>H<math>_{np}</math></b>	<b>L_m</b>	<b>L<math>_{m\alpha}</math></b>	<b>P_n</b>	<b>T_n</b>	<b>U_n</b>	orthogonal polynomials

Menu	<input type="checkbox"/>	Remarks					
<a href="#">αINTL</a>	A a	Ā ā	Á á	Ă ĕ	À à	Ä ä	[α] catalog of all Latin letters provided. <sup>40</sup> All letters but 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.
	Ã ã	Â â	Å å	Æ æ	Ą ą	B b	
	C c	Ć č	Č č	Ç ç	D d	Đ đ	
	Ď ð	E e	Ē ē	É é	Ě ě	È è	
	Ë ë	Ê ê	È è	Ě ě	Ę ę	F f	
	G g	Ĝ ĝ	H h	I i	Ĭ ī	Í í	
	Ĭ ī	Ĭ ī	Ĭ ī	Ĭ ī	Ĭ ī	Ĭ ī	
	I i	J j	K k	L l	Ł ł	Ľ ľ	
	Ľ ľ	M m	N n	Ń ń	Ň ň	Ň ň	
	O o	Ó ó	Ó ó	Ó ó	Ò ò	Ó ó	
	Õ õ	Ô ô	Ø ø	Œ œ	P p	Q q	You will reach each and every letter by 3 key-strokes maximum since letters can be accessed alphabetically (cf. pp. 124f).
	R r	Ř ř	Ŕ ŕ	S s	Ծ Ծ	Շ Շ	
	Ծ Ծ	Ծ Ծ	T t	՚ ՚	Ծ Ծ	Ւ ւ	
	Ւ ւ	Ո ո	Ւ ւ	Ւ ւ	Ո ո	Ո ո	
	Ո ո	Ո ո	Վ վ	V v	Ո ո	Ո ո	
	X x	Y y	Ŷ ŷ	Ŷ ŷ	Ŷ ŷ	Z z	
	Ž ž	Ž ž	Ž ž				

<sup>40</sup> See [https://de.wikipedia.org/wiki/Liste\\_lateinischer\\_Alphabete#Erweiterungen](https://de.wikipedia.org/wiki/Liste_lateinischer_Alphabete#Erweiterungen).

Menu							Remarks
<a href="#">αMATH</a>	<	≤	=	≈	≥	>	[α] for comparison symbols, parentheses & brackets, as well as more mathematical and related symbols. You can reach every character by 3 keystrokes maximum.
	{	[	(	)	]	}	
	x / . <sup>41</sup>	÷	∫	∞	∞	∞	
	¬	¬	¬	≠		&	
	✗	✗	✗	✗	✗	✗	
	✗	✗	✗	✗	✗	✗	
	:=	≈	≡	E	C	R	
	⊗	⊗	⊕				
<a href="#">α.FN</a>	x→α	αRL	αRR	αSL	αPOS?	α→x	dedicated functions for <i>alpha strings</i> , plus font browser
					αLENG?		
	FBR						
<a href="#">Α...Ω</a>	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>42</sup> Note the two kinds of lowercase Σ. See αINTL for more.
	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	Ŷ Ÿ	Փ Փ	Խ Խ	Ψ Ψ	
	Ω ω	ά	έ	ή	ի	Ւ Ւ	
	Ϊ ՚	ó	ú	ÿ ü	ö	ó	

<sup>41</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 [αMATH](#).

<sup>42</sup> The Greek alphabet (sic!) goes alpha, beta, gamma, delta, e-epsilon, zeta, eta, theta, iota, kappa, lambda, mu, nu, xi, o-mikron, pi, rho, sigma, tau, y-psilon, phi, chi, psi, o-mega. Note ancient Greek Η, Θ, and Υ 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 – these suffice: there is no goose named Seitsemän, Kahdeksan, Yhdeksän, nor Kymmenen in that novel).

Menu							Remarks
$\alpha\bullet$	!	;	-	'	"	✓	[ $\alpha$ ] for punctuation marks, currency symbols, arrows, and further special characters.
	ı	ż	ſ	ø	~	＼	
	\$	€	%	&	£	¥	
	←	↑	↓	↓	→	↖	
	«	»	»	⌚	•	*	
	⌚	⌚	⌚	⌚	@	*	
	„	”	…				
$\Sigma$	n	$\Sigma x$	$\Sigma x^2$	$\Sigma xy$	$\Sigma y^2$	$\Sigma y$	all the sums necessary for the statistics in STAT.
		$\Sigma \ln x$	$\Sigma \ln^2 x$	$\Sigma \ln xy$	$\Sigma \ln^2 y$	$\Sigma \ln y$	
	$\Sigma x^2 y$	$\Sigma x \ln y$		$\Sigma \ln y/x$		$\Sigma y \ln x$	
	$\Sigma x^2/y$	$\Sigma^1/x$	$\Sigma^1/x^2$	$\Sigma x/y$	$\Sigma^1/y^2$	$\Sigma^1/y$	
	$\Sigma x^3$	$\Sigma x^4$					
$\frac{d}{dx}$	$\rightarrow$ DEG	$\rightarrow$ RAD	$\rightarrow$ GRAD		$\rightarrow$ D.MS	$\rightarrow$ MUL $\pi$	angular conversions, cf. pp. 152f.
	DEG $\rightarrow$	RAD $\rightarrow$	GRAD $\rightarrow$		D.MS $\rightarrow$	MUL $\pi$ $\rightarrow$	
	D $\rightarrow$ R	R $\rightarrow$ D		D $\rightarrow$ D.MS	D.MS $\rightarrow$ D		

## Constants

Your WP 43S contains a catalog of 79 physical, astronomical, and mathematical constants sorted alphabetically:

G	$G_0$	$G_C$	$g_e$	$GM_{\oplus}$	$g_{\oplus}$	
$c_1$	$c_2$	e	$e_E$	$F_{\alpha}$	$F_{\delta}$	
1/2	a	$a_0$	$a_M$	$a_{\oplus}$	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>43</sup> We use commas as radix marks for better visibility and multiplication dots for space reasons. Formulas are printed where applicable.

Name	Numeric value and <i>rel. SD</i>	Remarks
<b>1/2 (0)</b> <sup>44</sup>	0,5	Trivial but helpful constant for some iterations.
<b>a</b>	365,242 5 d ( <i>per definition</i> )	<i>Gregorian year</i>
<b>a<sub>0</sub></b>	$5,291\,772\,109\,03 \cdot 10^{-11}$ m $(1,5 \cdot 10^{-10})$	<i>Bohr radius</i> $a_0 = \alpha / 4\pi R_\infty$

<sup>43</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 the **fundamental** constants (printed **bold** in the table) of physics all feature less than 16 significant digits.

*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> giving 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>44</sup> The counting numbers in parentheses are to support determination of parameters for CONST – see the *IOI*.

Name	Numeric value and <i>rel. SD</i>	Remarks
$a_{\text{Moon}}$	$3,844 \cdot 10^8 \text{ m}$ $(1 \cdot 10^{-3})$	Semi-major axis of the Moon's orbit around the earth $\approx 1,3$ light seconds.
$a_{\oplus}$	$1,495\,979 \cdot 10^{11} \text{ m}$ $(1 \cdot 10^{-6})$	Semi-major axis of the Earth's orbit around the sun. Within the uncertainty stated here, it equals 1 <i>astronomic unit</i> $\approx 499$ light seconds $\approx 8$ light minutes.
$c$ (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.
$c_1$	$3,741\,771\,852\dots \cdot 10^{-16} \text{ W m}^2$ <i>(exact)</i>	First radiation constant $c_1 = 2\pi h c^2$
$c_2$	$0,014\,387\,768\,77\dots \text{ m}\cdot\text{K}$ <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> $e = \frac{2}{K_J R_K} = \Phi_0 G_0$
$e_E$	$2,718\,281\,828\,459\,045\,2\dots$	Euler's $e$ .
$F$ (10)	$96\,485,332\,12\dots \text{ A s/mol}$ <i>(exact)</i>	Faraday constant $F = e N_A$
$F_\alpha$	$2,502\,907\,875\,095\,892\,8\dots$	<i>Feigenbaum's</i> $\alpha$ and $\delta$
$F_\delta$	$4,669\,201\,609\,102\,990\,6\dots$	
$G$	$6,674\,30 \cdot 10^{-11} \text{ m}^3/\text{kg s}^2$ $(2,2 \cdot 10^{-5})$	Newtonian constant of gravitation; also known as $\gamma$ from other authors. See $GM_{\oplus}$ below for a more precise value.

Name	Numeric value and <i>rel. SD</i>	Remarks
$G_0$	$7,748\,091\,729\dots \cdot 10^{-5} / \Omega$ (exact)	Conductance quantum $G_0 = 2e^2/h = e^2/R_K = eK_j$
$G_C$ (15)	0,915 965 594 177 219 0...	Catalan's constant
$g_e$	-2,002 319 304 362 56 ( $1,7 \cdot 10^{-13}$ )	Landé's electron g-factor
$GM_{\oplus}$	$3,986\,004\,418 \cdot 10^{14} \text{ m}^3/\text{s}^2$ ( $2,0 \cdot 10^{-9}$ )	Newtonian constant of gravitation times the Earth's mass with its atmosphere included (according to WGS84 <sup>45</sup> )
$g_{\oplus}$	$9,806\,65 \text{ m/s}^2$ (per def.)	Standard earth acceleration
$\hbar$	$6,626\,070\,15 \cdot 10^{-34} \text{ J s}$ (exact)	<b>Planck constant</b>
$\hbar$ (20)	$1,054\,571\,817\dots \cdot 10^{-34} \text{ J s}$ (exact)	Reduced Planck constant $\hbar = h/2\pi$
$k$	$1,380\,649 \cdot 10^{-23} \text{ J/K}$ (exact)	<b>Boltzmann constant</b> $k = R/N_A$
$K_J$	$4,835\,978\,484\dots \cdot 10^{14} \text{ Hz/V}$ (exact)	Josephson constant $K_J = 2e/h$
$l_{PL}$	$1,616\,255 \cdot 10^{-35} \text{ m}$ ( $1,1 \cdot 10^{-5}$ )	Planck length $l_{PL} = t_{PL}c$
$m_e$	$9,109\,383\,701\,5 \cdot 10^{-31} \text{ kg}$ ( $3,0 \cdot 10^{-10}$ )	Electron mass $\doteq 511,00 \text{ keV}$
$M_{\text{Moon}}$ (25)	$7,349 \cdot 10^{22} \text{ kg}$ ( $5 \cdot 10^{-4}$ )	Mass of the Moon

<sup>45</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 <i>rel. SD</i>	Remarks
$m_n$	$1,674\,927\,498\,04 \cdot 10^{-27} \text{ kg}$ $(5,7 \cdot 10^{-10})$	Neutron mass $\triangleq 939,57 \text{ MeV}$
$m_n/m_p$	$1,001\,378\,419\,31$ $(4,9 \cdot 10^{-10})$	Neutron to proton mass ratio
$m_p$	$1,672\,621\,923\,69 \cdot 10^{-27} \text{ kg}$ $(3,1 \cdot 10^{-10})$	Proton mass $\triangleq 938,27 \text{ MeV}$
$m_{PL}$	$2,176\,435 \cdot 10^{-8} \text{ kg}$ $(1,1 \cdot 10^{-5})$	Planck mass $m_{PL} = \sqrt{\hbar c/G} \approx 22 \mu\text{g}$
$m_p/m_e$ (30)	$1\,836,152\,673\,43$ $(6,0 \cdot 10^{-11})$	Proton to electron mass ratio
$m_u$	$1,660\,539\,066\,60 \cdot 10^{-27} \text{ kg}$ $(3,0 \cdot 10^{-10})$	Atomic mass constant $\approx 10^{-3} \text{ kg}/N_A$
$m_u c^2$	$1,492\,418\,085\,60 \cdot 10^{-10} \text{ J}$ $(3,0 \cdot 10^{-10})$	Energy equivalent of the atomic mass constant $\approx 931,49 \text{ MeV}$
$m_\mu$	$1,883\,531\,627 \cdot 10^{-28} \text{ kg}$ $(2,2 \cdot 10^{-8})$	Muon mass $\triangleq 105,66 \text{ MeV}$
$M_\odot$	$1,989\,1 \cdot 10^{30} \text{ kg}$ $(5 \cdot 10^{-5})$	Mass of the Sun
$M_\oplus$ (35)	$5,973\,6 \cdot 10^{24} \text{ kg}$ $(5 \cdot 10^{-5})$	Mass of the Earth. See $GM_\oplus$ above for a more precise value.
$N_A$	$6,022\,140\,76 \cdot 10^{23} / \text{mol}$ <b>(exact)</b>	<b>Avogadro's number</b>
NaN	<i>Not a Number</i>	See p. 172 and the corresponding entry in Section 5 of the OM.
$p_0$	101 325 Pa <i>(per def.)</i>	Standard atmospheric pressure

Name	Numeric value and <i>rel. SD</i>	Remarks
R	8,314 462 618... J/mol K <i>(exact)</i>	Molar gas constant
r <sub>e</sub> (40)	2,817 940 326 2·10 <sup>-15</sup> m <i>(4,5·10<sup>-10</sup>)</i>	Classical electron radius $r_e = \alpha^2 a_0$
R <sub>K</sub>	25 812,807 45... Ω <i>(exact)</i>	Von Klitzing constant $R_K = h/e^2$
R <sub>Moon</sub>	1,737 530·10 <sup>6</sup> m <i>(5·10<sup>-7</sup>)</i>	Mean radius of the Moon
R <sub>∞</sub>	10 973 731,568 160 / m <i>(1,9·10<sup>-12</sup>)</i>	Rydberg constant $R_\infty = \frac{\alpha^2 m_e c}{2 h}$
R <sub>⊕</sub>	6,96·10 <sup>8</sup> m <i>(5·10<sup>-3</sup>)</i>	Mean radius of the sun
R <sub>⊕</sub> (45)	6,371 010·10 <sup>6</sup> m <i>(5·10<sup>-7</sup>)</i>	Mean radius of the Earth
S <sub>a</sub>	6,378 137 0·10 <sup>6</sup> m <i>(per definition)</i>	Semi-major axis
S <sub>b</sub>	6,356 752 314 2·10 <sup>6</sup> m <i>(1,6·10<sup>-11</sup>)</i>	Semi-minor axis
S <sub>e</sub> <sup>2</sup>	6,694 379 990 14·10 <sup>-3</sup> <i>(1,5·10<sup>-12</sup>)</i>	First eccentricity squared
S <sub>e'</sub> <sup>2</sup>	6,739 496 742 28·10 <sup>-3</sup> <i>(1,5·10<sup>-12</sup>)</i>	Second eccentricity squared
S <sub>f</sub> <sup>-1</sup> (50)	298,257 223 563 (per def.)	Flattening parameter
T <sub>0</sub>	273,15 K (per definition)	= 0°C, standard temperature

Name	Numeric value and <i>rel. SD</i>	Remarks
$T_p$	$1,416\,785 \cdot 10^{32} \text{ K}$ $(1,1 \cdot 10^{-5})$	<i>Planck temperature</i> $T_p = \frac{c^2}{k} \sqrt{\frac{\hbar c}{G}} = \frac{M_p c^2}{k} = \frac{E_p}{k}$
$t_{PL}$	$5,391\,245 \cdot 10^{-44} \text{ s}$ $(1,1 \cdot 10^{-5})$	<i>Planck time</i> $t_{PL} = l_{PL}/c$
$V_m$	$0,022\,413\,969\,54\dots \text{ m}^3/\text{mol}$ <i>(exact)</i>	Molar volume of an ideal gas at standard conditions $V_m = \frac{RT_0}{p_0} \approx 22,4 \text{ l/mol}$
$Z_0$ (55)	$376,730\,313\,668 \Omega$ $(1,5 \cdot 10^{-10})$	Characteristic impedance of vacuum
$\alpha$	$7,297\,352\,569\,3 \cdot 10^{-3}$ $(1,5 \cdot 10^{-10})$	Fine-structure constant $\alpha = \frac{e^2}{2\epsilon_0 h c} \approx \frac{1}{137}$
$\gamma$	$6,674\,30 \cdot 10^{-11} \text{ m}^3/\text{kg s}^2$ $(2,2 \cdot 10^{-5})$	Newtonian constant of gravitation; also known as G from other authors. See $GM_\oplus$ below for a more precise value.
$\gamma_E M$	$0,577\,215\,664\,901\,532\,9\dots$	<i>Euler-Mascheroni constant</i>
$\gamma_p$	$2,675\,221\,874\,4 \cdot 10^8 \text{ Hz/T}$ $(4,2 \cdot 10^{-10})$	Proton gyromagnetic ratio $\gamma_p = 4\pi \frac{\mu_p}{h}$
$\Delta\nu_{Cs}(60)$	<b>9 192 631 770 Hz (exact)</b>	Hyperfine transition frequency of $^{133}\text{Cs}$
$\epsilon_0$	$8,854\,187\,812\,8 \cdot 10^{-12} \frac{\text{A s}}{\text{V m}}$ $(1,5 \cdot 10^{-10})$	Vacuum electric permittivity $\epsilon_0 = \frac{1}{\mu_0 c^2}$ (note the so-called Coulomb's constant is just $1/4\pi\epsilon_0 \approx 8,987\,55 \cdot 10^9 \text{ V m/A s})$

Name	Numeric value and <i>rel. SD</i>	Remarks
$\lambda_c$	$2,426\,310\,238\,67 \cdot 10^{-12} \text{ m}$ $(3,0 \cdot 10^{-10})$	
$\lambda_{Cn}$	$1,319\,590\,905\,81 \cdot 10^{-15} \text{ m}$ $(5,7 \cdot 10^{-10})$	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
$\lambda_{Cp}$	$1,321\,409\,855\,39 \cdot 10^{-15} \text{ m}$ $(3,1 \cdot 10^{-10})$	
$\mu_0$ (65)	$1,256\,637\,062\,12 \cdot 10^{-6} \frac{\text{V s}}{\text{A m}}$ $(1,5 \cdot 10^{-10})$	Vacuum magnetic permeability
$\mu_B$	$9,274\,010\,078\,3 \cdot 10^{-24} \frac{\text{J}}{\text{T}}$ $(3,0 \cdot 10^{-10})$	<i>Bohr magneton</i> $\mu_B = e\hbar/2m_e$
$\mu_e$	$-9,284\,764\,704\,3 \cdot 10^{-24} \frac{\text{J}}{\text{T}}$ $(3,0 \cdot 10^{-10})$	Electron magnetic moment
$\mu_e/\mu_B$	$-1,001\,159\,652\,181\,28$ $(1,7 \cdot 10^{-13})$	Ratio of electron magnetic moment to <i>Bohr's magneton</i>
$\mu_n$	$-9,662\,365\,1 \cdot 10^{-27} \frac{\text{J}}{\text{T}}$ $(2,4 \cdot 10^{-7})$	Neutron magnetic moment
$\mu_p$ (70)	$1,410\,606\,797\,36 \cdot 10^{-26} \frac{\text{J}}{\text{T}}$ $(4,2 \cdot 10^{-10})$	Proton magnetic moment
$\mu_u$	$5,050\,783\,746\,1 \cdot 10^{-27} \frac{\text{J}}{\text{T}}$ $(3,1 \cdot 10^{-10})$	Nuclear magneton $\mu_u = e\hbar/2m_p$
$\mu_\mu$	$-4,490\,448\,30 \cdot 10^{-26} \frac{\text{J}}{\text{T}}$ $(2,2 \cdot 10^{-8})$	Muon magnetic moment

Name	Numeric value and <i>rel. SD</i>	Remarks
$\sigma_B$	$5,670\,374\,419\dots \cdot 10^{-8} \frac{W}{m^2 K^4}$ <i>(exact)</i>	Stefan-Boltzmann constant $\sigma_B = \frac{2\pi^5 k^4}{15 h^3 c^2}$
$\Phi$	1,618 033 988 749 894 8...	Golden ratio $\Phi = \frac{1}{2}(1 + \sqrt{5})$
$\Phi_0$ (75)	$2,067\,833\,848\dots \cdot 10^{-15} V \cdot s$ <i>(exact)</i>	Magnetic flux quantum $\Phi_0 = \frac{h}{2e}$
$\omega$	$7,292\,115 \cdot 10^{-5} \text{ rad/s}$ <i>(<math>2 \cdot 10^{-8}</math>)</i>	Angular velocity of the Earth according to WGS84 (see footnote 45 on p. 138)
$-\infty$	$-\infty$	Note both these ‘constants’ are counted as numeric values in your WP 43S.
$\infty$	$\infty$	
$0$	0	Auxiliary numeric constants, featuring 54 decimals unless specified differently below
180	180,000...	Semicircle in <i>degrees</i> , <i>gradians</i> , <i>radians</i> , and <i>multiples of <math>\pi</math></i>
200	200,000...	
$\pi$	3,141 592 653 589 793...	
1	1,000...	
90	90,000...	
100	100,000...	
$\pi/2$	1,570 796 326 794 896...	Quadrant in <i>degrees</i> , <i>gradians</i> , <i>radians</i> , and <i>multiples of <math>\pi</math></i>
0_5	0,500...	
45	45,000...	
50	50,000...	
$\pi/4$	0,785 398 163 397 448...	
$\chi_4$	0,250 000...	One-eighth of a circle in <i>degrees</i> , <i>gradians</i> , <i>radians</i> , and <i>multiples of <math>\pi</math></i>
...		
		41 unit conversion factors (see next chapter)

Name	Numeric value and <i>rel. SD</i>	Remarks
-4	-4,000...	
-1	-1,000...	
1E-37	1,000... $\cdot 10^{-37}$	
1E-24, 1E-6, 1E-4, 1/10		
1/3	0,333 333 333 333 333...	
eγ	0,577 215 664 901 532...	
ln2	0,693 147 180 559 945...	
root2/2	0,707 106 781 186 547...	
9/10, 9/5, 2		
ln10	2,302 585 092 994 046...	
3π/4	2,356 194 490 192 345...	
3, 5, 2π, 10, 20, 21		
γR	23,118 910 000...	
32, 36, 47		
180/π	57,295 779 513 082 33...	
60	60,000...	
200/π	63,661 977 236 758 14...	
205, 360, 400, 1000, 3600, 9999, 10000, 1E6, 1E8, 1E9		
2p32	4 294 967 296,000...	$2^{32}$
γC00 ... γC29		30 values for xxx
2π	6,283 185 307 179 586...	1065 digits of $2\pi$
0, 1E-6, 1E-4, 1/2, 1, 2π, 1000, 1E6		8 auxiliary constants featuring 34 digits

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 for estimates:

Radius of an atomic nucleus	$\sim 10^{-15}$ m
Radius of an atom <sup>46</sup>	$\sim 10^{-10}$ m
Radius of the observable universe <sup>47</sup>	$\approx 45 \times 10^9$ 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 far within the range of *real* numbers on your *WP 43S* (see App. B). Precision of physical constants is seldom more precisely known than twelve digits (cf. the table above). Please take these facts into account when assessing small differences as well as talking about very large numbers.

<sup>46</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).

<sup>47</sup> For more information, please see [https://en.wikipedia.org/wiki/Observable\\_universe](https://en.wikipedia.org/wiki/Observable_universe) (or [https://de.wikipedia.org/w/index.php?title=Beobachtbares\\_Universum&oldid=18000000](https://de.wikipedia.org/w/index.php?title=Beobachtbares_Universum&oldid=18000000) or [https://fr.wikipedia.org/w/index.php?title=Univers\\_observable&oldid=18000000](https://fr.wikipedia.org/w/index.php?title=Univers_observable&oldid=18000000) etc. – the latter site includes a picture [https://es.wikipedia.org/w/index.php?title=Universo\\_observable&oldid=18000000#media/Archivo:Universoobservable.PNG](https://es.wikipedia.org/w/index.php?title=Universo_observable&oldid=18000000#media/Archivo:Universoobservable.PNG) explaining the difference between the radius printed above and the naïve assumption of  $13.8 \times 10^9$  l.y. for it; this picture is not found on the other sites).

## Unit Conversions

Your WP 43S features 14 angular conversions provided in 4→ (cf. p. 135) 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 p. 131 for more details of the structure.

Conversions contained in U→ either begin or end in one of the seven 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	<i>degree Celsius</i>	$\theta[\text{°C}] = T[\text{K}] - 273.15$
Force	<i>newton</i>	$1 \text{ N} = 1 \text{ kg m/s}^2$
Pressure	<i>pascal</i>	$1 \text{ Pa} = 1 \text{ N/m}^2 = 1 \text{ kg/m s}^2$
Energy	<i>joule</i>	$1 \text{ J} = 1 \text{ N m} = 1 \text{ kg m}^2/\text{s}^2$
Power	<i>watt</i>	$1 \text{ W} = 1 \text{ V A} = 1 \text{ J/s}$
Electric potential	<i>volt</i>	$1 \text{ V} = 1 \text{ W/A}$
Charge	<i>coulomb</i>	$1 \text{ C} = 1 \text{ A s}$

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 below is beneficial, covering 36 orders of magnitude:

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  $\text{U}\rightarrow$  and  $\text{A}\rightarrow$  are explained in alphabetical order below. Numeric values 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 here for better visibility.

Softkey	Calculation	Remarks	Branch
$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	$x 1,8 + 32$	These <i>acres</i> are based on the ' <i>international feet</i> ', see below	$\text{U}\rightarrow$
$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	$- 32 ) / 1,8$		
$\text{acre} \rightarrow \text{m}^2$	$x 4\,046,86$	These <i>acres</i> are based on the ' <i>international feet</i> ', see below	$\text{U}\rightarrow$ $f$ A:
$\text{acre}_{\text{US}} \rightarrow \text{m}^2$	$x 4\,046,87$	These <i>acres</i> are based on the ' <i>U.S. survey feet</i> ', see below	$\text{U}\rightarrow$ $f$ A:
$\text{atm} \rightarrow \text{Pa}$	$x 1,013\,25 \times 10^5$	<i>Atmospheres</i>	$\text{U}\rightarrow$ F&p:
$\text{au} \rightarrow \text{m}$	$x 1,495\,98 \times 10^{11}$	<i>Astronomic units</i>	$\text{U}\rightarrow$ x:
$\text{barrel} \rightarrow \text{m}^3$	$x 0,158\,987$	<i>Barrels (U.S.) of oil, abbr. bbl</i>	$\text{U}\rightarrow$ $f$ V:
$\text{bar} \rightarrow \text{Pa}$	$x 10^5$	$1 \text{ mbar} = 1 \text{ hPa}$	$\text{U}\rightarrow$ F&p:
$\text{Btu} \rightarrow \text{J}$	$x 1\,055,06$	<i>British thermal units</i>	$\text{U}\rightarrow$
$\text{cal} \rightarrow \text{J}$	$x 4,186\,8$	<i>Calories</i>	$\text{U}\rightarrow$ E:
$\text{carat} \rightarrow \text{kg}$	$x 0,000\,2$		$\text{U}\rightarrow$
$\text{cwt} \rightarrow \text{kg}$	$x 50,802\,4$	(Long) hundredweight := 112 lbs	$\text{U}\rightarrow$ m:
$\text{dB} \rightarrow \text{field ratio}$	$10^{\text{R}_{\text{dB}}/20}$	<i>Decibels</i>	$\text{U}\rightarrow$ ▼
$\text{dB} \rightarrow \text{power ratio}$	$10^{\text{R}_{\text{dB}}/10}$		
$\text{fathom} \rightarrow \text{m}$	$x 1,828\,8$	$1 \text{ fathom} := 6 \text{ feet}$	$\text{U}\rightarrow$ x:
$\text{field ratio} \rightarrow \text{dB}$	$20 \lg(a_1/a_2)$	Also known as <i>amplitude ratio</i>	$\text{U}\rightarrow$ ▼
$\text{floz}_{\text{UK}} \rightarrow \text{m}^3$	$x 2,841\,31 \times 10^{-5}$	<i>Fluid ounces</i>	$\text{U}\rightarrow$ $f$ V:
$\text{floz}_{\text{US}} \rightarrow \text{m}^3$	$x 2,957\,35 \times 10^{-5}$		

Softkey	Calculation	Remarks	Branch
ft. → m	× 0,304 8	These are the so-called ' <i>international feet</i> ' of 1959 1 foot := 12 inches	U ↗ x:
gl.uk → m³	× 4,546 09×10 <sup>-3</sup>	Gallons	U ↗ f v:
gl.us → m³	× 3,785 42×10 <sup>-3</sup>		
ha → m²	× 10 000	Hectares	U ↗ f A:
hp_E → W	× 746	Electric horsepower	
hp_M → W	× 735,498 8	So-called ' <i>metric</i> ' horsepower (equivalent to PS in German)	U ↗ P:
hp_UK → W	× 745,699 9	British Imperial horsepower	
in. → m	× 0,025 4	1 inch := 1 000 mil	U ↗ x:
in.Hg → Pa	× 3 386,39	Inches of mercury	U ↗ F&p:
J → Btu	/ 1 055,06		
J → cal	/ 4,186 8	Joules	U ↗ E:
J → Wh	/ 3 600		
kg → carat	/ 0,000 2		
kg → cwt	/ 50,802 4		
kg → oz	/ 0,028 349 5		
kg → lb.	/ 0,453 592		
kg → sh.cwt	/ 45,359 2	1 t [(metric) ton] = 1 000 kg	U ↗ m:
kg → short ton	/ 907,185		
kg → stone	/ 6,350 29		
kg → ton	/ 1 016,05		
kg → tr.oz	/ 0,031 103 5		
lbf → N	× 4,448 22	Pounds force	U ↗ F&p:

Softkey	Calculation	Remarks	Branch
lb. → kg	$\times 0,453\,592$	Pounds; 1 lb := 16 ounces	(U→ m:
ly → m	$\times 9,460\,73 \times 10^{15}$	Light years	(U→ x:
m <sup>2</sup> → acre	/4 046,86	Square meters;	
m <sup>2</sup> → acre <sub>us</sub>	/4 046,87	1 a [are] = 100 m <sup>2</sup> ,	(U→ f A:
m <sup>2</sup> → ha	/10 000	1 ha [hectare] = 10 000 m <sup>2</sup> ,	
m <sup>3</sup> → barrel	/0,158 987	1 km <sup>2</sup> = 100 ha = 1 000 000 m <sup>2</sup>	
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>	Cubic meters;	
m <sup>3</sup> → gl <sub>UK</sub>	/4,546 09 × 10 <sup>-3</sup>	1 l [liter] = 10 <sup>-3</sup> m <sup>3</sup> ,	(U→ f v:
m <sup>3</sup> → gl <sub>US</sub>	/3,785 42 × 10 <sup>-3</sup>	1 ml [milliliter] = 1 cm <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	Meters	(U→ x:
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	Newtons	[U] F&p:
oz → kg	× 0,028 349 5	Ounces	[U] m:
Pa → atm	/1,013 25×10 <sup>5</sup>		
Pa → bar	/10 <sup>5</sup>	Pascals; 1 mbar = 1 hPa	
Pa → in.Hg	/3 386,39		[U] F&p:
Pa → psi	/6 894,76		
Pa → torr	/133,322		
pc → m	× 3,085 68×10 <sup>16</sup>	Parsecs	[U] x:
point → m	× 352,778×10 <sup>-6</sup>	(Typographical) points	
power ratio → dB	10 lg(p <sub>1</sub> /p <sub>2</sub> )		[U] ▽
psi → Pa	× 6 894,76	Pounds per square inch	[U] F&p:
qt. → m <sup>3</sup>	× 1,1365×10 <sup>-3</sup>	(Imperial) quarts	[U] f V:
short cwt → kg	× 45,359 2	1 short hundredweight = 100 lbs	
short ton → kg	× 907,185	1 short ton = 2000 lbs	[U] m:
stone → kg	× 6,350 29		
survey foot <sub>US</sub> → m	× 0,304 801	1 U.S. survey foot := $\frac{1200}{3937}$ m	[U] x:
s → year	/31 556 952		[U]
ton → kg	× 1 016,05	1 Imperial ton = 200 (long) cwt = 2 240 lbs	[U] m:
torr → Pa	× 133.322	1 torr = 1 mm Hg	[U] F&p:
tr.oz → kg	× 0,031 103 5	Troy ounces	[U] m:
Wh → J	× 3 600	Watt-hours	[U] E:

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

<b>[L→] ...</b>	Remarks
<b>DEG→</b>	Takes an integer or <i>real</i> <sup>48</sup> $x$ as an angular input in <i>decimal</i> or <i>sexagesimal degrees</i> , respectively, and converts it to the current ADM.
<b>D.MS→D</b>	Takes an integer or <i>real</i> <sup>48</sup> $x$ as an angular input in <i>sexagesimal degrees</i> (formatted dddd.d.msshh) and converts it to an <i>angle</i> in <i>decimal degrees</i> (corresponding to the old command H.MS→H).
<b>D→R</b>	Takes an integer or <i>real</i> <sup>48</sup> $x$ as an angular ... radians. <sup>49</sup>
<b>D→D.MS</b>	input in <i>decimal degrees</i> ... <i>sexagesimal degrees</i> (corresponding to the old command H→H.MS).

<sup>48</sup> If  $x$  is neither integer nor *real* (i.e. neither data type 1 nor 2), error 24 will be thrown. Conversions of integer values to *angles* in *sexagesimal degrees* do not make real sense but are allowed nevertheless.

<sup>49</sup> Note that *real* angles given in *radians* cannot represent full circles (or simple fractions of  $\pi$  like  $\pi/2$ ,  $\pi/3$ ,  $\pi/4$ ,  $\pi/5$ , etc.) exactly but with an accuracy of 34 digits 'only'. If you want to avoid most rounding errors caused by that, *multiples of  $\pi$*  may be a better choice here. Note large numeric inputs in trigonometric functions 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 <i>real</i> <sup>48</sup> $x$ as an angular input in ... ... multiples of $\pi$ ... ... and converts it to the current ADM.
<b>RAD→</b>	... radians <sup>49</sup> ...
<b>R→D</b>	Takes an integer or <i>real</i> <sup>48</sup> $x$ as an angular input in radians and converts it to decimal degrees (equaling the old command R→D). <sup>49</sup>
<b>→DEG</b>	Takes an integer or <i>real</i> (data type 2) $x$ as an angular input in the current ADM and converts it to decimal degrees, sexagesimal degrees, grad/gon, multiples of $\pi$ , or radians, respectively. <sup>49</sup>
<b>→D.MS</b>	
<b>→GRAD</b>	If $x$ is a tagged <i>real</i> (data type 4), on the other hand, this information is used in conversion (e.g. if $x = 1.5\pi$ then →GRAD will return 300° regardless of current ADM).
<b>→MULπ</b>	
<b>→RAD</b>	If $x$ is neither of data type 1, 2, nor 4, error 24 will be thrown ('illegal input data type for this operation').

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	Numeric parameter	Alpha par.
AGRAPH CONVG? DEC DSE DSL DSZ INC INPUT ISE ISG ISZ KEY? KTyp? PUTK RCL RCLCFG RCLS RCL+ RCL- RCL $\times$ RCL/ RCL $\downarrow$ RCL $\downarrow$ STO STOCFG STOS STO+ STO- STO $\times$ STO/ STO $\uparrow$ STO $\downarrow$ t $\gtrless$ VIEW x $\gtrless$ x=? x $\neq$ ? x $\approx$ ? x<? x $\leq$ ? x $\geq$ ? x>? y $\gtrless$ z $\gtrless$ aLENG? aPOS? aRL aRR aSL a $\rightarrow$ x 	Register number	Variable name
ALL ENG FIX GAP RDP RSD SCI SDL SDR	Number of decimals	
ASR MASKL MASKR RL RLC RR RRC SL SR WSIZE	Number of bits	
BACK CASE SKIP	Number 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	User flag number	System flag name
CONST	Constant number	
DSTACK	Number of stack registers	
ERR MSG	Error number	
f'(x) f''(x) GTO LBL LBL? PGMINT PGMSLV XEQ $\Pi_n$ $\Sigma_n$		Program label
GTO.	Number of program step	Label

Operations requiring one trailing parameter	Numeric parameter	Alpha par.
INDEX MVAR M.DIM M.EDIN SOLVE VARMNU ]		Variable name
LocR	Number of local registers	
PAUSE █DLAY	Number of ticks	
RM █MODE	Mode number	
SIM_EQ	Number of unknowns	
TDISP	Time format number	
TONE	Tone number	
→INT	Base	
█CHAR	Character code	
█TAB	Column number	
█#	Byte	

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

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

Operations requiring two trailing parameters	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> $J_y(x)$ LN LN $\beta$ LN $\Gamma$ LOG <sub>10</sub> LOG <sub>2</sub> LOG <sub>x,y</sub> MANT POISS... 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 50	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
	$x \rightarrow \alpha$	7	X
	M.GET M.NEW	8 or 9	X
	→INT	10	X

<sup>50</sup> The functions printed on yellow background will return *long integers (data type 1)* wherever possible.

Input <i>DT</i>	Operation(s)	Output <i>DT</i>	Output registers involved
2	AND CEIL DATE $\rightarrow$ DAY D $\rightarrow$ J EXPT FLOOR IDIV IDIVR IP MONTH NAND NEXTP NOR NOT OR ROUNDI SIGN WDAY XNOR XOR YEAR $\pm\infty$ ?	1	X
	DECOMP	1	X, Y
	SLVQ	2 or 3	X, Y, Z
	RE $\rightarrow$ CX	3	X
	arccos arcsin arctan and all angular conversions	4	X
	$\rightarrow$ H.MS	5	X
	x $\rightarrow$ DATE DATE $\rightarrow$	6	X
	x $\rightarrow$ $\alpha$	7	X
	M.GET M.NEW	8 or 9	X
	$\rightarrow$ INT	10	X
3	ABS CROSS IM RE  x  $\neq$	2	X
	CX $\rightarrow$ RE	2	X, Y
	SLVQ	2 or 3	X, Y, Z
4	cos sin tan	2	X
5	$\rightarrow$ HR	2	X
6	DAY D $\rightarrow$ J MONTH WDAY YEAR	1	X
	DATE $\rightarrow$	1	X, Y, Z
	$\rightarrow$ REAL	2	X
7	$\alpha \rightarrow$ x	1	X

Input <i>DT</i>	Operation(s)	Output <i>DT</i>	Output registers involved
8	M.DIM?	1	X, Y
	DET DOT ENORM  M	2	X
	$\Sigma +$	2	X, Y, statistic registers
	$\sqrt[4]{\cdot}$	4	X
9	M.DIM?	1	X, Y
	ENORM	2	X
	DET DOT  M	3	X
	ABS IM RE ROUND I  x	8	X
10	SIGN	1	X
	$e^x \text{ LN } \text{LOG}_{xy} \rightarrow \text{REAL}$	2	X
	$x \rightarrow \alpha$	7	X

DRAFT

## APPENDIX A: HARDWARE

Overall dimensions: wedge-shaped: 77 mm  $\times$  144 mm  $\times$  13 mm or 8 mm (see p. 161)

Mass with battery: ~100 g

LCD dimensions: about 58.8 mm  $\times$  35.3 mm visible area,  
400  $\times$  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. 165ff),  
8 kB 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  $\mu$ A.

Buzzer frequency:  $\geq$  1 Hz up to  $>$  20 kHz in steps of 1 Hz.

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

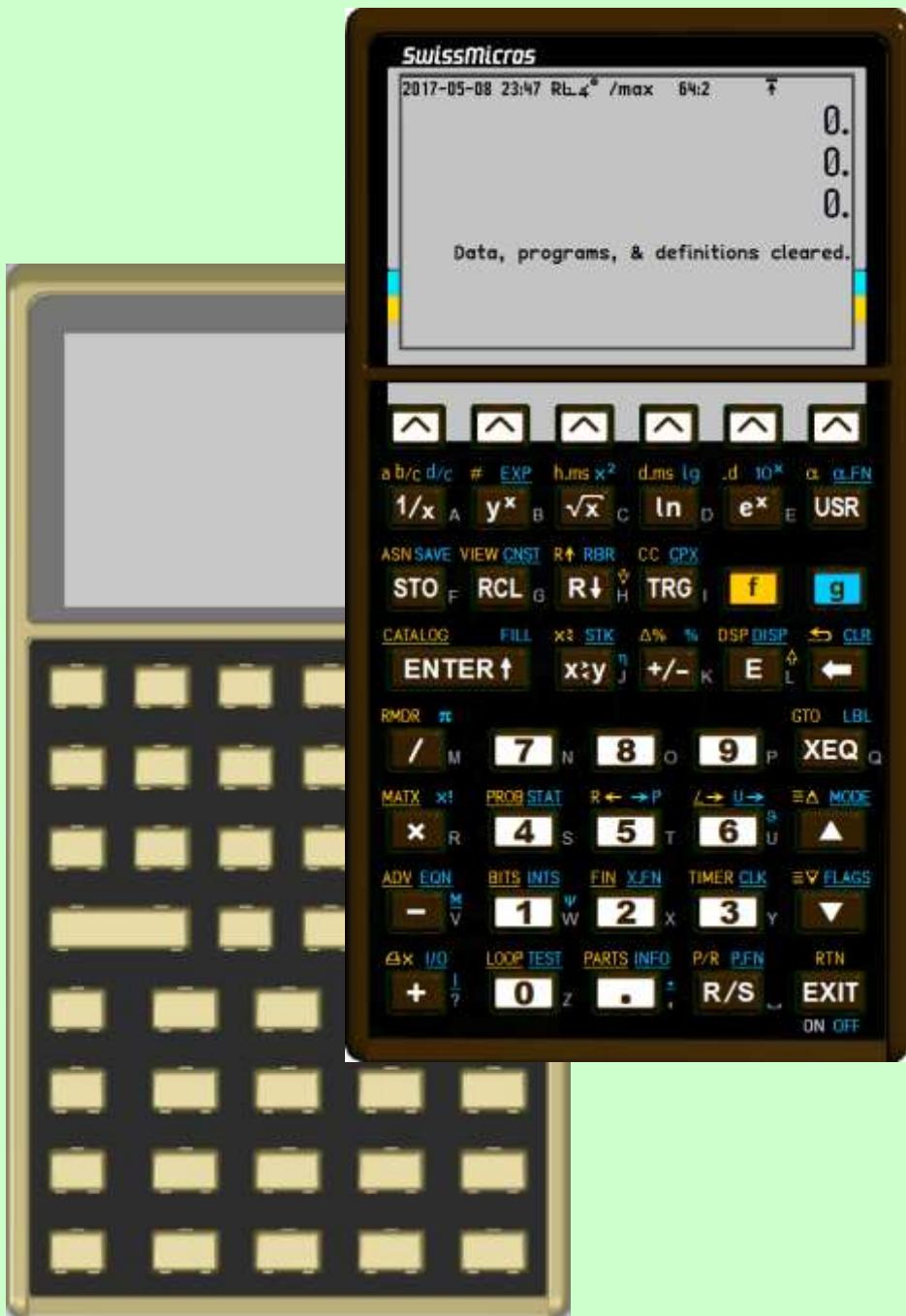
Self-test: initiated by **xxx**

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 (pp. 212f).



Seven pictures of the hardware are displayed here and on the three 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. Find the printed circuit board (PCB) displayed thereafter.







See here the internals. 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.



This picture shows the *PCB* of an early *DM42* of spring 2017.



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

## APPENDIX B: MEMORY MANAGEMENT

### Data Types

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

- 7-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*),
- *flag words* for storing 128 (i.e. 112 global plus 16 local) *user flags* and the same amount of *system flags*,<sup>51</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>52</sup>					<i>data type</i> (as specified below) - 1				

<sup>51</sup> Up to 256 *flags* would be possible in total. We need far less *system flags* so far.

<sup>52</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>53</sup>	$\geq 4 + 2 + 4 = 10 \dots 422$
2	$\mathbb{R}$ Real number <sup>54</sup> ( <i>real34</i> )	$4 + 16 = 20$
3	$\mathbb{C}$ Complex number ( <i>complex34</i> )	$4 + 2 \times 16 = 36$
4	Angle <sup>55</sup> ( <i>angle34</i> )	$4 + 16 = 20$
5	Time <sup>56</sup>	$4 + 16 = 20$
6	Date <sup>57</sup>	$4 + 16 = 20$
7	Alpha string (each character requires 16 bits) <sup>58</sup>	$4 + 2 + n \times 2$
8	Real matrix (featuring $n$ rows and $m$ columns)	$4 + n \times m \times 16$
9	Complex matrix (featuring $n$ rows and $m$ columns)	$4 + n \times m \times 32$
10	Short integer <sup>59</sup>	$\leq 4 + 8 = 8 \text{ or } 12$
11	n/a	n/a
12	n/a	n/a
13	n/a	n/a

<sup>53</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* following 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. Maximum integer size is 3328 *bits* (= 416 *bytes*) equivalent to 1001 decimal digits. Look up the display limits further below.

<sup>54</sup> Deviating from the WP 34S, standard *reals* on your WP 43S feature 128 *bits* and 34-digits precision. See the chapter after next.

<sup>55</sup> A tagged *angle* is stored as a *real* number, just with a specific header.

<sup>56</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. The format allows for expressing intervals of some 100 million years with *femtoseconds* precision.

<sup>57</sup> A *date* is stored as *real* number of *seconds* passed since -4713-01-01 12:00:00. This is date and time zero for *Julian Day Number* counting.

<sup>58</sup> 2 *bytes* are for the size (in *bytes*) of the string following, including the trailing zero. The size must be even.

<sup>59</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	Constant <sup>60</sup>	4 + 0 = 4
15	Extended precision <i>real</i> (39 digits, exclusively for internal use, not exposed to the user) <sup>61</sup>	4 + 32 = 36
16	<i>Label</i> (each character requires 16 bits)	4 + 7 × 2 = 18
17	System integer (for internal use only)	4 + 4 = 8
18	System and user flags (128 flags each)	4 + 2 = 6
19	User-created menu (limited to 1 view)	4 + 18 × 7 × 2 = 256
20	Predefined menu (featuring <i>n</i> views)	4 + <i>n</i> × 18 × 14
21	Configuration (as stored by STOCFG) <sup>62</sup>	4 + M
22	Program step, may be stored as alpha string (7) <sup>63</sup>	4 + M
23	Program, containing <i>n</i> program steps	4 + M
24	Expression (for members of EQN), may be stored as alpha string (7)	4 + M
25	Directory (proposed by P. 2012-12)	4 + M

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.

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<sup>60</sup> A pointer is sufficient regardless of the precision of the constant itself.

<sup>61</sup> There are also even longer (i.e. more precise) *reals* used in internal computations. See further below.

<sup>62</sup> The size will vary according to the number of user assignments being part of the configuration (see Section 6 of the OM).

<sup>63</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 14 of the *WP 34S* and *WP 31S* 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. 58 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  $\Sigma+$  or  $\Sigma-$ ; it is de-allocated and the memory is returned to the pool by  $\text{CLS}$ .

## Range of Real Numbers

Your *WP 43S* could calculate with *real numbers* of more than 12 000 orders of magnitude. Within a range of  $10^{-6143} \leq |x| < 10^{+6145}$ , it computes with 34 digits precision.<sup>64</sup> Results should be accurate within

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<sup>64</sup> The *WP 43S* software is based on the *decNumber library* supporting arbitrary precision *BCD* numbers. As mentioned at some places in the *I/OI*, 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 about thousand digits for proper reduction to the standard range for trigonometric functions).

More elaborate algorithms may be coded as keystroke programs to save flash space (for the cost of execution speed and the loss of a few digits of accuracy). The internal formats used for storing numbers in your *WP 43S* (as shown just above) 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 for obvious reasons. Your *WP 43S* returns

- $8,999\,999\,999\,999\,999\,999\,999\,999\,937\,535 = 9 - 6,246\,5 \cdot 10^{-29}$ .

If you are interested how other calculators have performed in that test, look at <http://www.rskey.org/~mwsebastian/miscpri/results.htm>.

$\pm 1 \times 10^{-33}$  (e.g.  $n \text{ } \frac{1}{\sqrt{x}}$   $2n \text{ } \times$  returns a plain 2 for all primes  $< 500$  – just  $7 \text{ } \frac{1}{\sqrt{x}}$   $1 \text{ } 4 \text{ } \times$   $2 \text{ } -$  returns  $1 \times 10^{-33}$ , and for 67 and 83 results are  $-1 \times 10^{-33}$ ); note that also rounding errors due to calculating with a finite number of digits will accumulate as demonstrated by two examples in the footnote here. – Results  $|x| < 10^{-999}$  are set to zero. For results  $|x| \geq 10^{999}$ , error 4 or 5 will appear unless SPCRES is set (see App. C).

All these effects are caused by the **internal representation of reals**: Standard floating point numbers are stored in sixteen bytes using an internal format coarsely following decimal128 packed coding,<sup>65</sup> though with some exceptions:

- 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 as pure integer in eleven groups of three digits. Each such group is packed into 10 bits straight forward, meaning e.g.  $555_{10} = 10\ 0010\ 1100_2 = 22B_{16}$  or  $999_{10} = 11\ 1110\ 0111_2 = 3E7_{16}$ . So the 33 rightmost decimal digits of the *significand* take the least significant 110 bits. Trailing zeroes are omitted, so the *significand* will be right adjusted.
- The most significant (128<sup>th</sup>) bit takes the sign of the mantissa.
- The remaining 17 bits are used for the exponent and the leftmost digit of the mantissa. Of those 17, the lowest 12 are reserved for

---

Another simple test discussed in the net works as follows: Enter 1,000 000 1 and then press  $\text{x}^2$  just 27 times. Your WP 43s will return

- 674 530,470 741 084 559 382 689 184 727 772 2.

This is the most precise result known of a pocket calculator so far (WP 34S in Double Precision and Free42 concur, computing with 34 digits as well). Nevertheless, only the first 25 digits of this output are correct! Calculating with unlimited precision returns

- 674 530,470 741 084 559 382 689 178 029 746 812 844 444 143 410 34

instead for the first 50 of the  $10^9$  digits of the complete result (note you get over 1000 decimals after 8 presses of  $\text{x}^2$  already).

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

<sup>65</sup> It comes close to what is called quadruple (precision) in this text about floating point arithmetic: <https://people.eecs.berkeley.edu/~wkahan/ieee754status/IEEE754.PDF> . Find out about decimal128 in [https://en.wikipedia.org/wiki/Decimal128\\_floating-point\\_format](https://en.wikipedia.org/wiki/Decimal128_floating-point_format) .

the exponent ( $< 4096$ ). For the top 5 bits (below the sign bit) it becomes complicated.<sup>66</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;
- **11uuu** then **t** will be added to  $1000_2$  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 (see below).

The maximum absolute value of the stored exponent is  $10\ 1111\ 1111\ 1111_2 = 12\ 287_{10}$ . For reasons becoming obvious below, 6176 must be subtracted from the stored value to get the true exponent of the floating point number represented. Thus and since  $12287 - 6176 + 34 = 6145$  as well as  $-6176 + 34 = -6142$ , *data type 2* could support 34-digit numbers within  $10^{-6143} \leq |x| < 10^{+6145}$  (keyboard input is limited to  $10^{-999} \leq |x| < 10^{+999}$ , cf. p. 145 for the reasons).

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 18 bits in binary notation	Stored exponent
1.	22 08 00 00 00 00 00 00 00 00 00 00 00 00 00 01		0010 0010 0000 1000 00	6176
-1.	a2 08 00 00 00 00 00 00 00 00 00 00 00 00 00 01		1010 0010 0000 1000 00	6176
111.	22 08 00 00 00 00 00 00 00 00 00 00 00 00 00 6f	06f	0010 0010 0000 1000 00	6176

<sup>66</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 18 bits in binary notation	Stored exponent
<b>111.111</b> $(=111\ 111 \times 10^{-3})$	22 07 40 00 00 00 00 00 00 00 00 00 00 01 bc 6f	06f 06f	0010 0010 0000 0111 01	6173
<b>-123.000 123</b> $(= -123\ 000\ 123 \times 10^{-6})$	a2 06 80 00 00 00 00 00 00 00 00 00 07 b0 00 7b	07b 000 07b	1010 0010 0000 0110 10	6170
<b>9.99x10<sup>99</sup></b> $(= 999 \times 10^{97})$	22 20 40 00 00 00 00 00 00 00 00 00 00 00 03 e7	3e7	0010 0010 0010 0000 01	6273
<b>1x10<sup>-99</sup></b>	21 ef 40 00 00 00 00 00 00 00 00 00 00 00 00 01		0010 0001 1110 1111 01	6077
<b>-1x10<sup>-999</sup></b>	a1 0e 40 00 00 00 00 00 00 00 00 00 00 00 00 01		1010 0001 0000 1110 01	5177

You will lose one digit precision if you divide  $10^{-6143}$  by 10 and one more for each such division following. At  $10^{-6176}$ , only one digit will be left, stored as hexadecimal 1.

Divide this by 1.999 999 999 999 999 999 999 999 999 999 and the result will remain  $10^{-6176}$  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 upper end of our numeric range now:

Floating point number	Hexadecimal value stored	Bottom bits in groups of 10	Top 18 bits in binary notation	Stored exp.
<b>9.999 999 999</b> <b>999 999 999</b> <b>999 999 999</b> <b>999 999x10<sup>998</sup></b> $(= 99\dots 999 \times 10^{965})$	6e f9 7e 7f 9f e7 f9 fe 7f 9f e7 f9 fe 7f 9f e7	9 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7	0110 1110 1111 1001 01	7141

This *real* number (featuring 36 times the digit 9) is the maximum which can be keyed in directly. In startup default format, it will be displayed on your *WP 43S* as  $1.000\ 000\ 000\ 000\times10^{99}$  – its full content  $9.999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\times10^{98}$  will be only unveiled by SHOW (see p. 73). The greatest legal *significand* is  $9\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999 = 10^{34} - 1$ .

Additionally, your *WP 43S* features three ‘special reals’:

Floating point ‘number’	Hexadecimal value stored	Top 8 bits in binary notation
$+\infty$	78 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	0111 1000
$-\infty$	F8 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00	1111 1000
NaN	7C 00 00 00 00 00 00 00 00 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 SPCRES is set** – no error will be thrown then. ‘Not a Number’ (NaN) covers poles as well as regions where a function result is not defined at all – see the corresponding entry in Section 5 of the OM and examples in next chapter. Note that  **$+\infty$  and  $-\infty$  may be also legal numeric inputs on your *WP 43S* while NaN is not.**

Remember not every 34-digit number displayed will be true to 34 digits – cf. footnote 64 on pp. 168f. And errors accumulate as explained in footnote 43 on pp. 136f.

As mentioned above, some calculations are executed in “*internal high precision*”. This means even more digits than 34 – it may go up to some hundred digits in special cases.

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

## Special Results (as of 2019-12-29)

Within this chapter, SPCRES is presumed to be set. Thus, infinities and non-numeric results are legal – no error message will be thrown if such results happen to occur (cf. the end of previous chapter).

The following monadic functions, if called with **R lit** (i.e. CPXRES clear), return either  $\infty$ ,  $-\infty$ , or **NaN** under the conditions stated below:

Input $x$	Operation(s)	Output for <b>R lit</b> <sup>67</sup>
0.	$1/x$	$\infty$
0 or 0.	$\ln$ , $\lg$ , $\operatorname{lb} x$	$-\infty$
0 or 0.	$\Gamma(x)$	<b>NaN</b>
$\operatorname{Re}(x) < 1$	$\operatorname{arcosh}$	<b>NaN</b>
$ \operatorname{Re}(x)  > 1$	$\operatorname{arccos}$ , $\operatorname{arcsin}$	<b>NaN</b>
1.	$\operatorname{artanh}$	$\infty$
$\operatorname{Re}(x) > 1$	$\operatorname{artanh}$	<b>NaN</b>
$\pm 90^\circ$ or equivalents in other ADM	$\tan$	<b>NaN</b>

And the following monadic functions operate also on infinities:

Input $x$	Operation(s)	Output for <b>R lit</b>
$-\infty$	$x^3$ , $\sqrt[3]{x}$	$-\infty$
$-\infty$	$\operatorname{arctan}$	$-90^\circ$ or equivalents
$-\infty$	$e^x$ , $10^x$ , $2^x$	0.

<sup>67</sup> In this chapter, results were crosschecked against the *WP 34S* wherever possible. Deviations are highlighted. Additionally, *Wolfram Alpha* was used for checking results with finite arguments. Red results in the tables are considered wrong although they may concur with the *WP 34S*.

Input $x$	Operation(s)	Output for R lit
$-\infty \leq x < 0$	[ln], [lg], lb x	NaN
$-\infty$ or $\infty$	[1/x], sinc	0.
$-\infty$ or $\infty$	[x <sup>2</sup> ]	$\infty$
$\infty$	tanh	1.
$\infty$	arctan	90. <sup>o</sup> or equivalents
$\infty$	[ln], [e <sup>x</sup> ], [sqrt], [lg], [10 <sup>x</sup> ], lb x, $x^3$ , $\sqrt[3]{x}$ , sinh, cosh	$\infty$
$-\infty$ or $\infty$	cos, sin, tan, arcosh, arsinh, artanh	NaN

For dyadic functions, we combined the respective tables:

Input $y$	$x$	Op.(s)	Output for R lit
$\infty$	arbitrary $x \neq -\infty$	[+]	$\infty$ <sup>68</sup>
$-\infty$	arbitrary $x \neq \infty$		$-\infty$ <sup>68</sup>
$-\infty$	$\infty$	[+]	NaN <sup>68</sup>
$\infty$	arbitrary $x \neq \infty$	[-]	$\infty$ <sup>69</sup>
$-\infty$	arbitrary $x \neq -\infty$		$-\infty$ <sup>69</sup>
$-\infty$	$-\infty$	[-]	NaN
$\infty$	$\infty$		
$\infty$	arbitrary $x > 0$	[x]	$\infty$ <sup>68</sup>
$-\infty$	arbitrary $x < 0$		
$\infty$	arbitrary $x < 0$	[x]	$-\infty$ <sup>68</sup>
$-\infty$	arbitrary $x > 0$		
0 or 0.	$-\infty$ or $\infty$	[x]	NaN <sup>68</sup>

<sup>68</sup> Swapping  $x$  and  $y$  will return the same result here.

<sup>69</sup> Swapping  $x$  and  $y$  will return the result times -1.

Input	$y$	$x$	Op.(s)	Output for $\mathbb{R}$ lit
$0 < y \leq \infty$	0.		$/$	$\infty$
$-\infty \leq y < 0$				$-\infty$
$-\infty$ or $\infty$	$-\infty$ or $\infty$		$/$	NaN
0 or 0.	0.		$/$ , $y^x$	NaN
$-\infty$ or $\infty$	0. or 0		$y^x$	NaN
$-\infty < y < 0$	non-integer $x$		$y^x$	NaN (cf. $\tan^{\sin(-6)}(-6) \in \mathbb{C}$ as calculated by WA and in MoHPC)
$-\infty$	odd $x > 0$		$y^x$	$-\infty$
$-\infty$	even $x > 0$			$\infty$
$\infty$	arbitrary $x > 0$		$y^x$	$\infty$
arbitrary $y \neq 0$	$-\infty$		$y^x$	0.
	$\infty$			$\infty$
0.	$0 < x < \infty$		$\log_xy$	$-\infty$

The functions printed on light yellow background in the three tables above will return NaN also with *complex* results allowed (i.e. CPXRES set). Others will change their output when  $\mathbb{C}$  is lit. Some particular returns of elementary transient functions operating near  $\pm\infty$  are listed here:<sup>70</sup>

Input	$\text{Re}(x)$	$\text{Im}(x)$	$r(x)$	$\varphi(x)$	Op.	Output for $\mathbb{C}$ lit	
$-\infty$	—	—	—	—	$\sqrt{x}$	$\infty \notin 90^\circ = 0.+i\infty$	
$-\infty$	0	$\infty$	$10^{999}$	$180^\circ$		NaN+i $\infty$ (WP 34S returns 0.+i $\infty$ )	
-10 <sup>999</sup>		$10^{999}$				$\rightarrow \infty \notin 90^\circ = 0.+i\infty$	

<sup>70</sup> Following an article of HP about the HP-71, complex infinities should be treated in polar notation (see <http://hparchive.com/Journals/HPJ-1984-07.pdf>, p. 27, left column for the reasons).

Input		$\operatorname{Re}(x)$	$\operatorname{Im}(x)$	$r(x)$	$\varphi(x)$	Op.	Output for C lit	
0.	10 <sup>999</sup>	10 <sup>999</sup>		10 <sup>999</sup>	90°	$\sqrt[2]{\cdot}$	$\rightarrow \infty \not\in 180^\circ = -\infty + i \times 0.$	
	$\infty$	$\infty$		$\infty$			$-\infty + i \times \text{NaN}$	
- $\infty$	—	—	—	—	—	$\sqrt[3]{\cdot}$	$-\infty$	
- $\infty$	0	$\infty$	—	$\infty$	45°		$\infty \not\in 45^\circ = \infty + i \times \infty$ (34S: $\text{NaN} + i \times \text{NaN}$ )	
-10 <sup>999</sup>			—	10 <sup>999</sup>			$1 \times 10^{333} \not\in 60^\circ =$ $5 \times 10^{332} + i \times 8.660\ 254\ 037\ 8 \times 10^{332}$ $= 5 \times 10^{332} (1 + i \times \sqrt{3})$	
—	—	—	—	10 <sup>333</sup>	60°	$\sqrt[3]{\cdot}$	$1 \times 10^{999} \not\in -180^\circ = -1 \times 10^{999} + i \times 0.$ $\rightarrow -\infty + i \times 0$	
- $\infty$	—	—	—	—	—	$\sqrt[3]{\cdot}$	$-\infty$	
- $\infty$	0	$\infty$	—	$\infty$	180°		$\text{NaN} + i \times \text{NaN}$	
-10 <sup>999</sup>			—	10 <sup>999</sup>			$-1 \times 10^{2997} + i \times 0.$ $\rightarrow -\infty + i \times 0$	
$\infty$	—	—	—	—	—	$\ln(\cdot)$	$\infty$	
$\infty$	0	$\infty$	—	$\infty$	0°		$\infty + i \times \infty$ (WP 34S returns $\infty + i \times 0.$ )	
10 <sup>999</sup>			—	10 <sup>999</sup>			$\rightarrow \infty + i \times 0$	
-10 <sup>999</sup>	0	$\infty$	—	10 <sup>999</sup>	180°	$\ln(\cdot)$	$\rightarrow \infty + i\pi$	
- $\infty$			—	$\infty$			$\infty + i \times \infty$ (WP 34S = $\infty + i\pi$ )	
- $\infty$	—	—	—	—	—		$\text{NaN}$	
$\infty$	$\infty$	$\infty$	$\infty$	$\infty$	45°	$\ln(\cdot)$	$\infty + i \times \infty$	
10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	45°		$\rightarrow \infty + i\pi/4$ (confirmed by 34S & WA)	
$\infty$	$\infty$	$\infty$	$\infty$	$\infty$	-45°	$\ln(\cdot)$	$\infty - i \times \infty$	
10 <sup>999</sup>	-10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	-45°		$\rightarrow \infty - i\pi/4$ (confirmed by 34S & WA)	
0.	$\infty$	$\infty$	$\infty$	$\infty$	90°	$\ln(\cdot)$	$\infty + i \times \infty$	
	10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	90°		$\rightarrow \infty + i\pi/2$ (confirmed by 34S & WA)	

Input		$r(x)$	$\varphi(x)$	Op.	Output for C lit	
$\text{Re}(x)$	$\text{Im}(x)$					
0.	-∞	∞	-90°	ln	NaN+i×NaN	
	-10 <sup>999</sup>	10 <sup>999</sup>			→ ∞ - i π/2 (confirmed by 34S & WA)	
-∞	∞	∞	135°	ln	NaN+i×NaN	
	-10 <sup>999</sup>	10 <sup>999</sup>			→ ∞ + i 3π/4 (conf. by 34S & WA)	
-∞	-∞	∞	-135°	ln	NaN+i×NaN	
	-10 <sup>999</sup>	-10 <sup>999</sup>			→ ∞ - i 3π/4 (conf. by 34S & WA)	
0.	0.	0.	0.	exp	NaN+i×NaN	
10 <sup>-999</sup>	0.	10 <sup>-999</sup>	0.		→ -∞ + i × 0	
0.	—	—	—		-∞	
0.	∞	∞	90°	exp	NaN+i×NaN	
	10 <sup>999</sup>	10 <sup>999</sup>			1.0 4 -45° (WP 34S: NaN+i×NaN) = 0.707 106 781 186... - i×0.707 1... = $\frac{1}{2}(\sqrt{2} - i\sqrt{2})$	
0.	-∞	∞	-90°	exp	NaN+i×NaN	
	-10 <sup>999</sup>	10 <sup>999</sup>			1.0 4 45° (WP 34S: NaN+i×NaN) = 0.707 106 781 186... + i×0.707 1... = $\frac{1}{2}(\sqrt{2} + i\sqrt{2})$	
-∞	0	∞	180°	exp	0.+i×0.	
-10 <sup>999</sup>	10 <sup>-999</sup>	10 <sup>999</sup>			0.+i×0.	
-∞	—	∞			NaN+i×NaN	
-∞	∞	∞	135°	exp	NaN+i×NaN	
-10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>			0.+i×0.	
-∞	-∞	∞	-135°	exp	NaN+i×NaN	
-10 <sup>999</sup>	-10 <sup>999</sup>	10 <sup>999</sup>			0.+i×0.	

Computation of  $\text{tg}$  and  $\text{lb } x$  is derived from  $\text{ln}$ . The same applies for  $e^x$ ,  $10^x$ , and  $2^x$ .

At the bottom line, we hope confusion is limited (and I recommend keeping off  $\pm\infty$  in *complex* plane).

## Limitations

### Maximum Numeric Input for *Data Type* ...

- 1:  $\pm 10^{999}$  (if your patience will suffice for the input)
- 2:  $\pm 9.999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999 \times 10^{998}$
- 3:  $\pm 9.999\dots \times 10^{998}$  for either part
- 4:  $\pm 9.999\dots \times 10^{998}$  in arbitrary *ADM*, so the actual absolute maximum is  $9.999\dots \times 10^{998} \pi$
- 5: times
- 6: dates
- 8:  $\pm 9.999\dots \times 10^{998}$  for each matrix element
- 9:  $\pm 9.999\dots \times 10^{998}$  for either part of each matrix element
- 10: FF FF FF FF FF FF FF FF<sub>16</sub> in unsigned mode, equivalent to some  $1.8 \times 10^{19}$ .

### Internal Limits:

- PRIME? works up to  $3.3 \times 10^{24}$ .
- Trigonometric functions actually operate between  $+\pi$  and  $-\pi$  (or their equivalents) only. The necessary modulo reduction ensures that these functions return correct 34-digit results for the entire legal input range ( $-10^{999} < x < 10^{999}$ ).
- Any intermediate results exceeding  $-10^{999} < x < 10^{999}$  (or  $-10^{999} \leq x \leq 10^{999}$  for *long integers*) will be rated as  $-\infty$  or  $+\infty$ , respectively, and will then be treated according to the actual system settings at calculation time (cf. SPCRES in particular).

- ...

## Maximum Numeric Output for *Data Type* ...

- 1:  $\pm 10^{999}$  with full 999-digit precision (though you can see a maximum of 294 digits “only” of such a number (cf. SHOW on p. 73)).
- 2, 3, 8, 9, and 10: the maxima are as specified for input above.
- 4: For angular conversions, the maxima are as specified for input above. The functions ARCSIN, ARCCOS, ARCTAN return values between  $+\pi$  and  $-\pi$  (or their equivalents) only.
- 5: xxx
- 6: xxx

## Program Step Size

Program step size is assumed to be 4 *bytes* typically. But compare *data type* 22 on p. 167.

## **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, s, 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* here):

	EC	Explanations, countermeasures and examples
An argument exceeds the function domain	1	{1, 2, 3, 4, 10} 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 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>71</sup>
Bad time or date input	2	{2, 5, 6} Invalid date format or incorrect date 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	Predefined variables or menus cannot be deleted.
Distribution parameter out of valid range	16	{1, 2} 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>71</sup> Note that e.g.  $\tan(90^\circ)$  and logs of 0 are legal operations on {1, 2, 3} if SPCRES is set. See the end of this appendix.

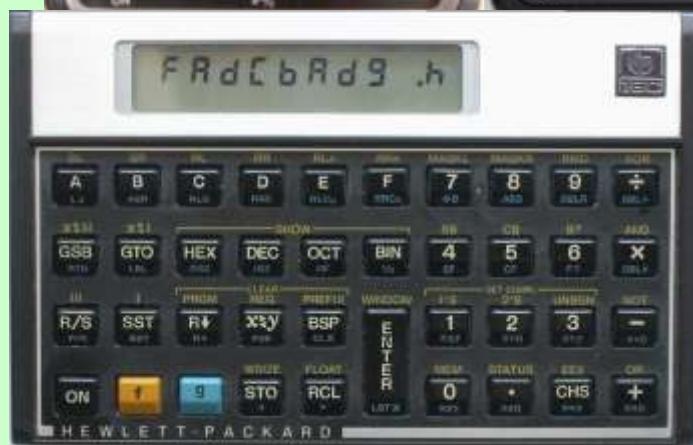
	EC	Explanations, countermeasures and examples
<b>Flash memory is write protected</b>	19	There was an attempt to edit or delete program steps in <i>FM</i> . See PRCL and PSTO to circumvent.
<b>Function to be coded for that data type</b>	30	Functions may not be coded yet during FW development.
<b>Illegal 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. “operation is undefined in this mode”.
<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	Functions may not be coded yet 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 Solver did not converge.
<b>No such function</b>	7	Returned when calling a nonexistent function via <b>[XEQ] [α] ... [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 <i>real-number</i> operation in AIM. Cf. "illegal input data type for this operation".
Out of range	8	<p>{1, 2, 3, 10}</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, short 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} unless SPCRES 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. 168).</li> </ul>
Overflow at $-\infty$	5	<p>{1, 2, 3, 8, 9} unless SPCRES 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. 168).</li> <li>Logarithm of 0 (note a logarithm of <math>-0</math> will return NaN).</li> </ul>
Please enter a NEW name	26	Trying to define a new variable or user <i>menu</i> with a <i>name</i> 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. 165ff 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. SSIZE set and STOS 93.
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 SPCRES 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. 135ff and the tables on pp. 172ff). E.g., **0 In** will return  $-\infty$  then.

Each error message will be displayed in **Z** numeric row and is *temporary information* (see Section 2 of the OM). So **⌫** 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: 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. 191, one for the *HP-21S* on p. 193, and another one for the *WP 34S* on p. 195. Functions newly introduced with *WP* calculators are compiled on pp. 199ff.

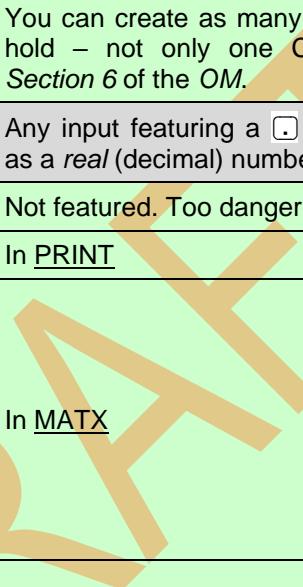
**Functional differences of homonymous commands are covered in the *IOI* (on pp. 12ff).**

### **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*.

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

HP-42S	WP 43S	Remarks
AOFF	CF ALPHA	
AON	SF ALPHA	
ARCL	Dispensable	Any register or variable can take an alpha string. Simply press <b>RCL</b> instead.
AROT	$\alpha RL$ or $\alpha RR$	In <u><math>\alpha.FN</math></u>
ASHF	$\alpha SL$	
ASINH	<b>arsinh</b>	In <u>EXP</u>
ASTO	Dispensable	Any register or variable can take an alpha string. Simply press <b>STO</b> instead.
ATANH	<b>artanh</b>	In <u>EXP</u>
ATOX	$\alpha \rightarrow x$	In <u><math>\alpha.FN</math></u>
AVIEW	Dispensable	Any register or variable can take an alpha string. Simply press <b>VIEW</b> instead.
<b>BASE</b>	<b>INTS</b> or <b>BITS</b>	
BASE+	Dispensable	Your WP 43S executes these arithmetic commands automatically for <i>short integer</i> inputs.
BASE-		
BASE $\times$		
BASE $\div$		
BASE $+\text{-}$		
BINM	Dispensable	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>	<b>≡ A ( ▲ )</b>	Shortcut works if no <i>multi-view menu</i> is open.
CLA	<b>0 [STO] K</b>	
CLD	Dispensable	Any keystroke will clear <i>temporary information</i> .
<b>CLEAR</b>	<b>CLR</b>	
CLKEYS	n/a	See Section 6 of the OM.
CLRG	<b>CLREGS</b>	In <u>CLR</u>
CLST	<b>CLSTK</b>	Press <b>0 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 <i>complex</i> numbers directly using <b>CC</b> as explained in <i>Section 2</i> of the OM.
<b>CONVERT</b>	<b>L→</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	Dispensable	Any input featuring a <b>.</b> or an <b>E</b> is interpreted as a <i>real</i> (decimal) number.
DEL	n/a	Not featured. Too dangerous, in our opinion.
DELAY	<b>DLAY</b>	In <u>PRINT</u>
DELR	<b>M.DELR</b>	 In <u>MATX</u>
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>‡</b>	
FCSTY	<b>ÿ</b>	In <u>STAT</u>
FNRM	<b>ENORM</b>	In <u>MATX</u> . Euclid is older than Frobenius.
GAMMA	$\Gamma(x)$	In <u>PROB</u>
GETKEY	<b>KEY?</b>	In <u>P.FN</u>
GETM	<b>M.GET</b>	In <u>MATX</u>
GROW	<b>M.GROW</b>	
HEXM	Dispensable	Press <b># H</b> for converting any closed integer number or integer part in $x$ to hexadecimal.
H.MS+	Dispensable	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	$\int$	In <u>ADV</u>
INVRT	$[M]^{-1}$	In <u>MATX</u>
KEYASN	Disposable	Not needed since no CUSTOM <i>menu</i> is featured (see CUSTOM).
LAST $x$	RCL L	
LBL		Press <u>LBL</u> .
LCLBL	Disposable	Obsolete since no CUSTOM <i>menu</i> 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 $\blacksquare$ PROG instead.
LOG	$\text{LOG}_{10}$	Press <u>Ig</u> .
MAN	CF T	Manual print mode is <i>startup default</i> here.
MAT?	MATR?	In <u>TEST</u>
MEAN	$\bar{x}$	In <u>STAT</u>
MODES	MODE	
N!	$x!$	
NEWMAT	M.NEW	In <u>MATX</u>
NORM	n/a	Not featured.
OCTM	Disposable	Press $\blacksquare$ 8 for converting any closed integer number or integer part in $x$ 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	$\pi$	Press <u>π</u> .
POSA	$\alpha$ POS	In <u><math>\alpha</math>.FN</u>
PRA	$\blacksquare$ r K	In <u>PRINT</u>

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
<b>PRGM</b>	<b>P/R</b>	
PRLCD	<b>LCD</b>	In <u>PRINT</u>
PROFF	<b>CF</b>	
PROMPT	Disposable	Use <b>VIEW</b> , <b>STOP</b> instead.
PRON	<b>SF</b>	
PRP	<b>PROG</b>	In <u>PRINT</u>
PRSTK	<b>STK</b>	
PRUSR	<b>USER</b>	
PRV	<b>r</b>	
PRX	<b>r</b>	Press <b>[Ex]</b> .
PRΣ	<b>Σ</b>	In <u>PRINT</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</b> , <b>RLC</b> , <b>RR</b> , and <b>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	$\sqrt{x}$	
<b>SST</b>	(  )	Shortcut works if no <i>multi-view menu</i> is open.
STR?	<b>STRI?</b>	In <u>TEST</u>
<b>TOP.FCN</b>	Disposable	Obsolete since no top functions are overwritten.

HP-42S	WP 43S	Remarks
TRACE	SF	
TRANS	$[M]^T$	In <u>MATX</u>
UVEC	UNITY	In <u>MATX</u> and <u>CPX</u>
VARMENU	VARMNU	Truncated to 6 characters to fit the <i>menu</i> space.
VIEW		Press .
WMEAN	$\bar{x}_w$	In <u>STAT</u>
WRAP	M.WRAP	In <u>MATX</u>
XTOA	$x \rightarrow \alpha$	The conversion is done in X.
$X < 0?, X < Y?$	$x < ?$	In <u>TEST</u>
$X \leq 0?, X \leq Y?$	$x \leq ?$	
$X = 0?, X = Y?$	$x = ?$	
$X \neq 0?, X \neq Y?$	$x \neq ?$	
$X \geq 0?, X \geq Y?$	$x \geq ?$	
$X > 0?, X > Y?$	$x > ?$	
YINT	L.R.	In <u>STAT</u>
$y^x$		Press .
$\Sigma REG$	Disposable	There are 100 global general purpose <i>registers</i> always. Statistical registers are separate.
$\Sigma REG?$		
$\rightarrow DEC$	$\rightarrow INT 10$	Press .
$\rightarrow HR$		Press .
$\rightarrow H.MS$		... for closed input. Press .
$\rightarrow OCT$	$\rightarrow INT 8$	Press .
$\rightarrow POL$		Press .
$\rightarrow REC$		Press .
%CH	$\Delta\%$	Press .
$\div$		Cf. ISO 80000-2: "The symbol $\div$ 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.

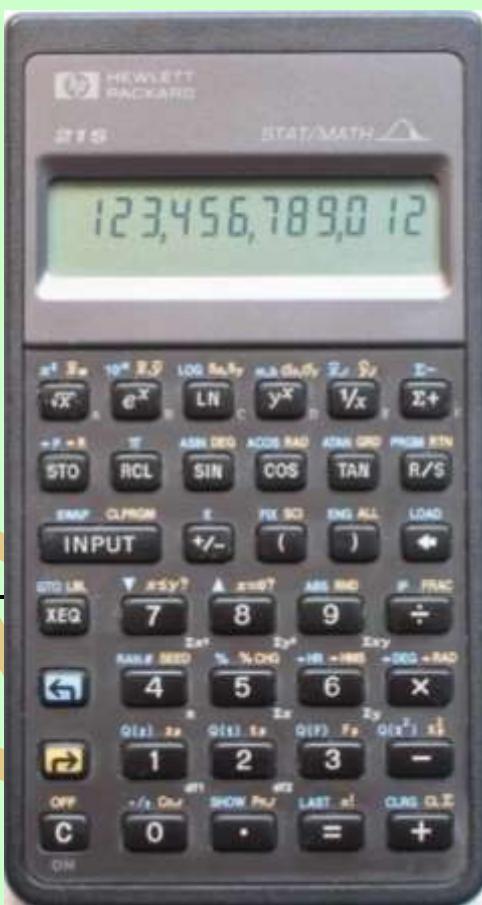
<b>HP-16C</b>	<b>WP 43S</b>	<b>Remarks</b>
<b>RL</b> , <b>RLn</b>	<b>RL</b>	
<b>RR</b> , <b>RRn</b>	<b>RR</b>	
<b>RLC</b> , <b>RLCn</b>	<b>RLC</b>	In <u>BITS</u>
<b>RRC</b> , <b>RRCn</b>	<b>RRC</b>	
<b>÷</b>	<b>/</b>	(see also ISO 80000-2: "The symbol $\div$ should not be used.")
<b>DBL÷</b>	<b>DBL/</b>	In <u>INTS</u>
<b>x<math>\geq</math>(i)</b> <b>x<math>\geq</math>l</b>	Superfluous	Any register may be used for indirection.
<b>SHOW HEX</b>	n/a	
<b>SHOW DEC</b>		
<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>SF LEAD.0s</b>	In <u>FLAGS</u> . Control display of leading zeros.
<b>CF [3]</b>	<b>CF LEAD.0s</b>	
<b>SF [4]</b> , <b>CF [4]</b>	<b>SF [C] , CF [C]</b>	Carry. SF and CF live in <u>FLAGS</u> .
<b>SF [5]</b> , <b>CF [5]</b>	<b>SF [B] , CF [B]</b>	Overflow.
<b>F?</b>	<b>FS?</b>	In <u>FLAGS</u>

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

## 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>	<b>x&gt;y</b>	
<b>CLPRGM</b>	<b>CLP</b>	In <u>CLR</u>
<b>INPUT</b>	Disposable	This functionality is contained in ENTER. Also your <i>WP 43S</i> features a command called INPUT but this works in programs.
<b>(</b> , <b>)</b>	Disposable	You can forget these keys in <i>RPN</i> .

<b>HP-21S</b>	<b>WP 43S</b>	<b>Remarks</b>
<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>
<b>FRAC</b>	<b>FP</b>	
<b>÷</b>	<b>/</b>	Cf. ISO 80000-2: "The symbol $\div$ should not be used."
<b>SEED</b>	<b>SEED</b>	In <u>PROB</u>
<b>%CHG</b>	<b><math>\Delta\%</math></b>	
<b>Q(z)</b>	<b>Norm<sub>e</sub></b>	In submenus of <u>PROB</u> .  Note your <i>WP 43S</i> features the normal distribution for arbitrary $\mu$ and $\sigma$ instead of the standardized one ( $\mu=0$ , $\sigma=1$ ). And the implementation of inverse distribution functions deviates on both calculators: your <i>WP 43S</i> calculates with the probability $P$ while the <i>HP-21S</i> calculates with the error probability $Q = 1 - P$ as input (cf. the OM, Section 2). Labeling these functions on the <i>HP-21S</i> using the letter $p$ may add some confusion.
<b>z<sub>p</sub></b>	<b>Norm<sub>l</sub><sup>-1</sup></b>	
<b>Q(t)</b>	<b>t<sub>e</sub>(x)</b>	
<b>t<sub>p</sub></b>	<b>t<sup>-1</sup>(p)</b>	
<b>Q(F)</b>	<b>F<sub>e</sub>(x)</b>	
<b>F<sub>p</sub></b>	<b>F<sup>-1</sup>(p)</b>	
<b>Q(<math>\chi^2</math>)</b>	<b><math>\chi^2_e(x)</math></b>	
<b>X<sup>2</sup><sub>p</sub></b>	<b>(<math>\chi^2</math>)<sup>-1</sup></b>	
<b>Cn.r</b>	<b>COMB</b>	
<b>Pn.r</b>	<b>PERM</b>	In <u>PROB</u>
<b>LAST</b>	<b>RCL L</b>	
<b>=</b>	<b>Dispensable</b>	You can forget this key in <i>RPN</i> .
<b>n!</b>	<b>x!</b>	
<b>CLRG</b>	<b>CLREGS</b>	In <u>CLR</u>

## 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.

WP 34S	WP 43S	Remarks
ANGLE	4	
Binom <sub>u</sub>	Binom <sub>e</sub>	
Cauch <sub>u</sub>	Cauch <sub>e</sub>	
CLa	0 [STO] [K]	Check the OM for the conditions when this register is used.
CONST	CNST	For keyboard space reasons.
CONV	U→	
DBLOFF	Disposable	Your WP 43S features 34-digit data types – it does neither need nor feature a double precision mode.
DBLON		
Expon <sub>u</sub>	Expon <sub>e</sub>	
F <sub>u</sub> (x)	F <sub>e</sub> (x)	
dRCL	Disposable	Your WP 43S features various data types.

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
gCLR, gDIM, gDIM?, gFLP, gPIX?, gPLOT, gSET	n/a	The LCD of your WP 43S features $240 \times 400$ px rows compared to $6 \times 43$ px of HP-30b – the graphic paradigm of WP 34S makes no sense on your WP 43S. On the other hand, it was not our objective designing a graphing calculator. Thus, we include just the basic graphic support of the HP-42S (AGRAPH, CLLCD, PIXEL) plus POINT.
Geom <sub>u</sub>	Geom <sub>e</sub>	
GTO <sub>a</sub>	Disposable	Use GTO with an appropriate parameter instead.
H.MS+, H.MS-	Disposable	Your WP 43S features a dedicated <i>data type</i> for times, so + and - suffice for adding or subtracting sexagesimal times, respectively.
INTM?	Disposable	Your WP 43S features dedicated <i>data types</i> for integers – it does neither need nor feature an integer mode.
iRCL	Disposable	Your WP 43S features various <i>data types</i> .
I <sub>x</sub>	I <sub>xyz</sub>	This is a triadic function after all.
Lgnrm <sub>u</sub>	LgNrm <sub>e</sub>	
L <sub>n</sub>	L <sub>m</sub>	Renamed to avoid search conflict with LN.
L <sub>na</sub>	L <sub>ma</sub>	Renamed in consequence to L <sub>m</sub> .
Logis <sub>u</sub>	Logis <sub>e</sub>	
MROW+ <sub>x</sub> , MROW <sub>x</sub>	Disposable	Obsolete matrix commands.
MROW <sub>↔</sub>	M.R <sub>↔</sub> R	
M+ <sub>x</sub>	Disposable	Obsolete matrix command.
M <sup>-1</sup>	[M] <sup>-1</sup>	
M-ALL, M-COL, M-DIAG, M-ROW	Disposable	Obsolete matrix commands.

WP 34S	WP 43S	Remarks
Mx	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>	Norm <sub>e</sub>	
Poiss <sub>u</sub>	Poiss <sub>e</sub>	
REALM?	Disposable	Your WP 43S features a dedicated <i>data type</i> for <i>reals</i> – it does not need a <i>real</i> mode.
REGS, REGS?	Disposable	The number of global general purpose <i>registers</i> is fixed to 100 on your WP 43S.
SENDA, SENDP, SENR, SEND $\Sigma$	SEND	SEND combines all those four commands of the WP 34S.
SEPOFF, SEPON	GAP	
SHOW	RBR	
sRCL	Disposable	Your WP 43S features various <i>data types</i> .
TRANSP	[M] <sup>T</sup>	
TSOFF	GAP 0	
TSON	GAP 3	
t <sub>u</sub> (x)	t <sub>e</sub> (x)	
VIEWa, VWa+	Disposable	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 $+$ as shown in Sect. 2 of the OM.
Weibl <sub>u</sub>	Weibl <sub>e</sub>	

WP 34S	WP 43S	Remarks
XEQa	Disposable	Use <b>[XEQ]</b> with an appropriate parameter instead.
XTAL?	Disposable	A quartz crystal is installed by default.
YDOFF, YDON	Disposable	Your WP 43S displays <i>y</i> whenever possible and wanted. See DSTACK.
αDATE, αDAY	Disposable	You can combine text and numeric data easily using <b>[+]</b> as shown in <i>Section 2</i> of the OM.
αGTO	Disposable	Use <b>[GTO]</b> with an appropriate parameter instead.
αIP, αMONTH	Disposable	You can combine text and numeric data easily using <b>[+]</b> as shown in <i>Section 2</i> of the OM.
αRCL, αRC#	Disposable	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	Disposable	Simply press <b>[STO]</b> instead (any <i>register</i> can take an <i>alpha string</i> ).
αTIME	Disposable	See αDATE.
αXEQ	Disposable	Use <b>[XEQ]</b> with an appropriate parameter instead.
β	$\beta(x,y)$	
Γ	$\Gamma(x)$	
ΔDAYS	Disposable	Simply subtract two <i>dates</i> .
ζ	$\zeta(x)$	
Φ(x) ...	Disposable	Use NORML... with $\mu=0$ and $\sigma=1$ instead.
$X^2 u(x)$	$X^2 e(x)$	
→H	→HR	
■PLOT	n/a	See gCLR.
■CrXY	Disposable	Use <b>[Cr]</b> instead. <b>[Cx]</b> is on the keyboard.
■a, ■a+, ■+a	Disposable	You can combine text and numeric data easily using <b>[+]</b> as shown in <i>Section 2</i> of the OM. Then use <b>[Cr]</b> . <b>[Cx]</b> is on the keyboard.
■?	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
<code>2<sup>x</sup> AGM</code>	●	—	new
<code>ALL</code>	●	●	extended
<code>AND ASR NOT OR XOR</code>	●	—	extended
<code>BACK CASE SKIP</code>	●	—	new
<code>BATT?</code>	●	●	new
<code>BC? FB</code>	●	—	new
<code>BestF</code>	extended	●	●
<code>Binom Binom<sub>p</sub></code> (of <i>Binomial distribution</i> )	●	●	new
<code>B<sub>n</sub> B<sub>n</sub>* CEIL FLOOR</code>	●	—	new
<code>Cauch Cauch<sub>p</sub> Cauch<sub>e</sub> Cauch<sup>-1</sup></code>	●	●	new
<code>CauchF GaussF HypF ParabF RootF</code>	new	—	—
<code>CLCVAR</code>	new	—	—
<code>CLFall CLPall CONJ CONVG? COV</code>	●	—	new
<code>CX→RE RE→CX</code>	new	—	—
<code>DATE TIME</code>	●	—	(●)
<code>DATE→ DAY MONTH YEAR →DATE</code>	●	—	new
<code>DEC DSL INC ISE</code>	●	—	new
<code>DECOMP</code>	●	●	new
<code>DEG→ D.MS→ GRAD→ RAD→</code>	●	—	new

Command	WP 43S	WP 31S	WP 34S
DROP	●	—	new
DROPy DSTACK	new	—	—
D→J J→D	●	—	new
EIGVAL EIGVEC	new	—	—
ENTRY?	●	—	new
EQ.DEL EQ.EDI EQ.NEW	new	—	—
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
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	—	—
INT? I <sub>xyz</sub> IΓ <sub>p</sub> IΓ <sub>q</sub>	●	—	new

Command	WP 43S	WP 31S	WP 34S
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
LN $\beta$ LN $\Gamma$ LOADP LOADR LOADSS LOAD $\Sigma$ LocR LocR? LOG <sub>2</sub> LOG <sub>x,y</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
MUL $\pi$ MUL $\pi$ $\rightarrow$	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 $\downarrow$ RCL $\uparrow$ STO $\downarrow$ STO $\uparrow$	●	—	new
RDP RECV SEND	●	—	new
Re $\zeta$ Im	new	—	—
RJ	●	—	new
RL RLC RR RRC	●	—	extended

Command	WP 43S	WP 31S	WP 34S
RMD	●	●	extended
RM RM? ROUNDI RSD RTN+1 R-CLR R-COPY R-SORT R-SWAP	●	—	new
SDIGS? SETSIG	new	—	—
SDL SDR SETCHN SETEUR SETIND SETJPN SETUK SETUSA	●	—	new
SETDAT SETTIM	●	—	(●)
SIGNMT sinc	●	—	new
SL SR	●	—	extended
SLVQ SMODE? SPEC?	●	—	new
S <sub>m</sub> S <sub>mw</sub> S <sub>w</sub>	●	●	new
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
$\bar{x}_G$	●	●	new
$\bar{x}_H$ $\bar{x}_{RMS}$ x→DATE	new	—	—
x< ? x≤ ? x= ? x≠ ? x≥ ? x> ?	extended	—	extended
x=+0? x=-0? x≈?	●	—	new
Y.MD	●	●	new

Command	WP 43S	WP 31S	WP 34S
$\alpha\text{LENG?}$	extended	—	●
$\alpha\text{POS?}$	extended	—	—
$\alpha\text{RL}$ $\alpha\text{RR}$ $\alpha\text{SL}$ $\alpha\text{SR}$	●	—	extended
$\beta(x,y)$ $\Gamma_{xy}$ $\gamma_{xy}$ $\epsilon$ $\epsilon_m$ $\epsilon_p$ $\zeta(x)$ $\Pi$ $\Sigma$ $\sigma_w$	●	—	new
$\Sigma^1/x$ $\Sigma^1/x^2$ $\Sigma^1/y$ $\Sigma^1/y^2$ $\Sigma\ln y/x$ $\Sigma x^2/y$ $\Sigma x^3$ $\Sigma x^4$ $\Sigma x/y$	new	—	—
$\Sigma\ln^2x$ $\Sigma\ln^2y$ $\Sigma\ln x$ $\Sigma\ln xy$ $\Sigma\ln y$ $\Sigma x$ $\Sigma x^2$ $\Sigma x^2y$ $\Sigma x\ln y$ $\Sigma xy$ $\Sigma y$ $\Sigma y\ln x$ $\Sigma y^2$ (callable by names)	●	●	new
$\chi^2_p(x)$ $\chi^2(x)$ (of chi-square distribution)	●	●	new
$(-1)^x$ $x\text{MOD}$ $\wedge\text{MOD}$	●	—	new
$\pm\infty?$	new	—	—
$\rightarrow\text{DEG}$ $\rightarrow\text{RAD}$	●	●	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 (please see its manual).

## 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> ).

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 Owner's Handbook 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> <sup>72</sup> <i>HP-42S Programming Examples and Techniques</i> <sup>73</sup>

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 please check footnote 80 on p. 226 below as well as the last paragraph on p. 16 of the OM).

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<sup>72</sup> If you want this manual of 1988 only, you can download it for free at <http://www.hp41.net/forum/fileshp41net/manual-hp42s-us.pdf>.

<sup>73</sup> If you just want this manual of 1988, you can download it for free at <http://www.hp41.net/forum/fileshp41net/hp42s-programming-examples.pdf>.

## APPENDIX E: 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 <https://www.msys2.org>. Install it following the on-site instructions until beginning of step 6. Then enter in the black window:

```
pacman -S mingw-w64-x86_64-gcc git base-devel  
mingw-w64-x86_64-gtk3
```

**cd wp43s** for changing to the proper directory.  
**git pull** for pulling the changed files from gitlab repository.<sup>74</sup>  
**make** for building a new *wp43s.exe*.<sup>75</sup>  
**rm backup.bin** for starting with the simulator reset to default.  
**./wp43s** for starting the simulator. Continue with c).

- 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*.

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

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<sup>74</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 this into your language). Then enter **git reset --hard** and try again thereafter.

<sup>75</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 also other obstacles; then **make mrproper** will clean the field for a subsequent **make** (this can not, however, overcome real errors in the software).

(These pictures of the simulator surface 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. The ten digits as well as **[.**, **ENTER↑**, **+**, **-**, **×**, and **/** may also be entered via the numeric keypad directly, **←** via [**←Backspace**], **▲** and **▼** via the cursor keys. Further computer keyboard shortcuts to simulator keys are listed overleaf.





Pressing ...

- ... h copies the entire simulator screen image to the clipboard.
- ... x copies the full content of **X** to the clipboard.
- ... z copies the full contents of all 12 lettered *registers* thereto.
- ... **Z** copies the full contents of all 112 global *registers* thereto.

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).

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<sup>76</sup> Capitals are printed green here for better differentiation.

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

There are two ways to get your *WP 43S*, in principle:

1. You can flash an existing *DM42* or
2. you can buy a *WP 43S* off the shelf.

Way 1 allows you to repurpose a *DM42* you own already, so you may save costs – on the other hand, you will have to live with stickers on the keys then. This way is explained in next chapter. The chapter thereafter describes the way to update your *WP 43S* when a new firmware becomes available.

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

#### **1) Under Windows:**

Start your computer. Take your *DM42* and turn it on. Then press



- [5] System
- [2] Enter system menu
- [4] Reset to *DMCP* menu

Now connect your computer to the calculator *USB* socket using a proper data transfer cable. The flash disk of your *DM42* should show up as an external mass storage volume after you pressed ...

- [6] Activate *USB* Disk

Start the internet browser on your computer and go to [https://gitlab.com/Over\\_score/wp43s/tree/master/DM42%20binary](https://gitlab.com/Over_score/wp43s/tree/master/DM42%20binary).

Copy *WP43S.pgm* to the *DM42* flash disk. (Option: Copy also *keymap.bin* to the *DM42* flash disk. This will reassign keys to

match the *WP 43S* layout also when leaving *WP 43S*.)

Then press from *Free42*: **SETUP** **5** **2** **4** **3** *WP43S.pgm* **ENTER** **ENTER**. Wait for flashing completed. Then press **EXIT** **1** **EXIT**. Your *WP 43S* is up and waiting for your orders..

The two files *Key\_stickers.xcf* and *WP43S\_overlay.xcf* are *GIMP* images to make your life easier. Print them, cut, and apply (see this picture of an earlier layout) as long as you converted a *DM42* to get your *WP 43S*.



To leave the *WP 43S* program, enter **g** **MODE** **▲** **g** **SYSTEM** to return to the *DMCP* system. If you chose the option above, the key assignments will stay as they were in *WP 43S* when navigating therein (due to *keymap.bin*).

To retrieve the original *DM42* keyboard layout (cf. p. 161), copy the file *original\_DM42\_key\_map.bin* to the *DM42* flash disk, rename it

keymap.bin and RESET the DM42. Look here for more information:  
[http://www.swissmicros.com/dm42-devel/dmcp\\_devel\\_manual/](http://www.swissmicros.com/dm42-devel/dmcp_devel_manual/)

## 2) Under OSX (Mac):

Here is *Harald Overbeek*'s step by step solution if you want the WP 43S running on OSX:

- a) Install XCode from the App Store.
- b) Clone the source code of the WP 43S project by opening Xcode and clone it using [https://gitlab.com/Over\\_score/wp43s.git](https://gitlab.com/Over_score/wp43s.git). Cloning the project has some advantages over downloading the code. It makes sure XCode tracks the changes, for example.
- c) Install MacPorts using  
<https://guide.macports.org/chunked/installing.macports.html>
- d) Thereafter install the following MacPorts one by one:

```
sudo port install gcc9
sudo port install gtk3
sudo port install freeType
sudo port install pkgconfig
sudo port install x11
sudo port install dbus
```
- e) Then run the *makefile* form the root directory of the project (probably **wp43s**)
- f) When the project has successfully compiled, run the program, for example like this: **./wp43s**

In the terminal window the following warning may appear:

Gtk-WARNING \*\*: 11:23:52.903: Locale not supported by C library.  
Using the fallback 'C' locale.

Solve this by entering:

```
export LC_ALL="en_US"
export LANG="en_US"
export LANGUAGE="en_US"
```

```
export C_CTYPE="en_US"
export LC_NUMERIC=
export LC_TIME=en"en_US"           ... or similar locale settings.
```

If you get this error:

```
dbus[1369]: Dynamic session lookup supported but failed: launchd did not
provide a socket path, verify that org.freedesktop.dbus-session.plist
is loaded!
```

use this:

```
sudo launchctl load -w /Library/LaunchDaemons/org.freedesktop dbus-
system.plist
```

```
launchctl load /Library/LaunchAgents/org.freedesktop dbus-session.plist
export DBUS_SESSION_BUS_ADDRESS="launchd:env= DBUS_FINK_
SESSION_BUS_SOCKET"
```

After that I get no more warnings or error messages.

On the first 'make' I got error messages about header files that could not be found. I solved this by adding the following lines to the *makefile*.

After:

```
else ifeq ($(detected_OS),Darwin) # Mac OS X
CFLAGS += -D OSX
```

add:

```
CFLAGS += -I/opt/local/include/
CFLAGS += -I/opt/local/include/glib-2.0/
CFLAGS += -I/opt/local/lib/glib-2.0/include/
CFLAGS += -I/opt/local/include/gtk-3.0/
CFLAGS += -I/opt/local/include/pango-1.0/
CFLAGS += -I/opt/local/include/cairo/
CFLAGS += -I/opt/local/include/gdk-pixbuf-2.0/
CFLAGS += -I/opt/local/include/atk-1.0/
CFLAGS += -I/opt/local/include/freetype2
```

On my machine I put the project into ~/wp43s. However, the application searches for the `wp43s_pre.css` in the local home directory. If no calculator window comes up, copy the css-file:

```
cp wp43s_pre.css ~
```

Let me know if this does not work.

## How to Update Your WP 43S

If you have *Free42* still running on your calculator then proceed as demonstrated in previous chapter.

Else there is *WP 43S* installed on your calculator already. Then:

- Start your computer.
- Take your calculator and turn it on.

Leave *WP 43S* pressing **g MODE** **▲** **g SYSTEM** to return to the *DMCP* system. If you had copied *keymap.bin* of *WP 43S* before last flashing, key assignments will stay as they were when navigating in the *DMCP* system – else the *Free42* assignments will become valid (cf. p. 161).

- Connect your computer to the calculator *USB* socket using a proper data transfer cable. The flash disk of your calculator should show up as an external mass storage volume after you pressed ...

**6** Activate *USB* Disk

- Start the internet browser on your computer and go to [https://gitlab.com/Over\\_score/wp43s/tree/master/DM42%20binary](https://gitlab.com/Over_score/wp43s/tree/master/DM42%20binary).

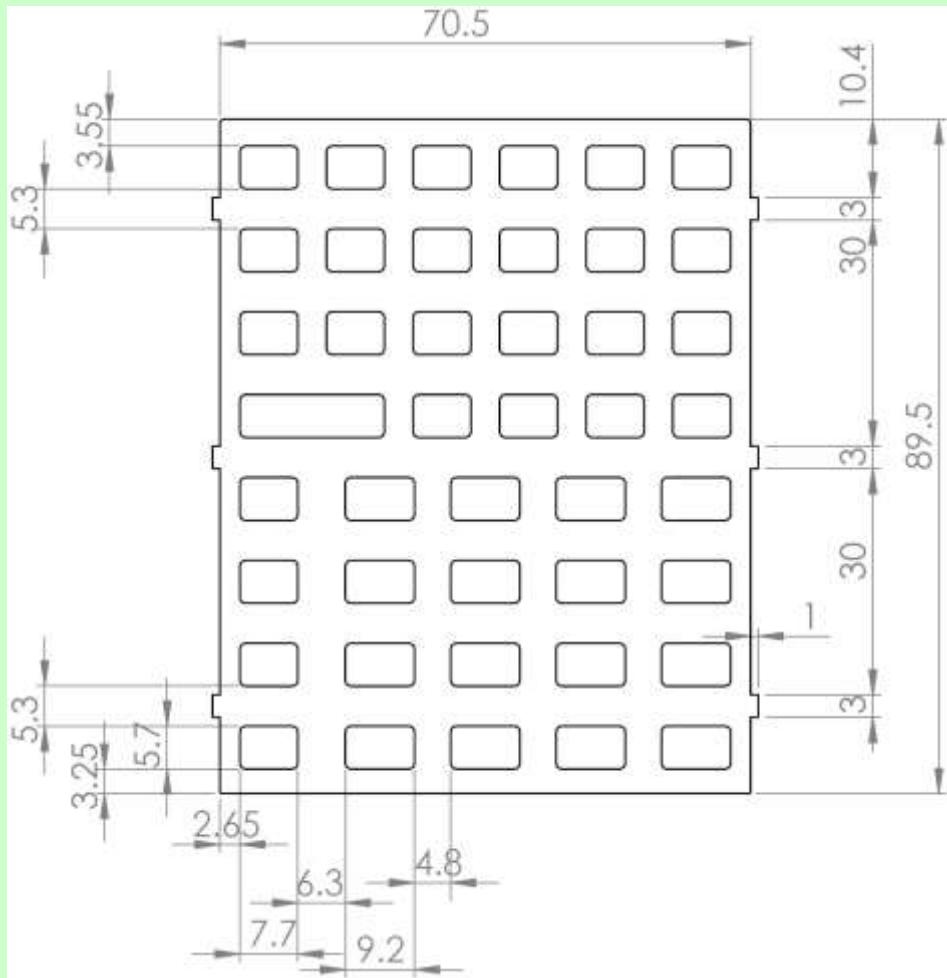
Copy *WP43S.pgm* to the *DM42* flash disk.

Option: Copy *keymap.bin* to the *DM42* flash disk. This will reassign keys to match the *WP 43S* layout also when leaving *WP 43S*.

- Then press **EXIT** **ENTER** **3** (Load Program), select *WP43S.pgm*, and press **ENTER** **ENTER**.
- Wait for flashing completed. Then press **EXIT** **EXIT** **1** **EXIT**. Your updated *WP 43S* is up and waiting for your orders.

## Overlays

See here the drawing for a blank overlay – all dimensions are given in mm. Note the overall width is 72.5 mm.



## **APPENDIX G: TROUBLESHOOTING GUIDE**

There are several ways to put your calculator in a freeze state wherein it will not react on any keys you press, even without flashing *WP 43S*. Usually, pressing the RESET button on its rear side should bring it back to life. If this does not work, however, the following should do:

1. Open your calculator by unfastening the two bolts at the top of its backside. You will probably find a printed circuit board (*PCB*) whose top looks like this →

(cf. p. 164 for a *PCB* of an early *DM42*)

In any case, you will see two small buttons, one labeled **RESET**.

The other one is called **PGM**.



2. Now, do the following:

- a. Press and hold the PGM button.
- b. Press and release the RESET button.
- c. Release the PGM button.

This sequence shall reset your *DM42* and put it in bootloader mode.<sup>77</sup>

3. Then you can reflash your calculator using `dm_tool.exe` as described in [https://www.swissmicros.com/dm42/doc/dm42\\_user\\_manual/](https://www.swissmicros.com/dm42/doc/dm42_user_manual/).

---

<sup>77</sup> If this method should not work, however, this may point to a real hardware problem. We recommend contacting SwissMicros then.

## 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 X: $B_n = (-1)^{n+1} \cdot n \cdot \zeta(1 - n)$ $B_n^*$ works with the old definition instead:
$B_n^*$	See p. 250 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 59, 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. 217): In a <i>Galton box</i><sup>78</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>Generally, <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 <i>complex domain</i>.</p>
FIB	<p>For integers, FIB returns the <i>Fibonacci</i> number <math>f_n</math> with <math>n = x</math>. The <i>Fibonacci</i> 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 UNSIGN, <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 <i>real</i> or <i>complex</i> number <math>x</math>, with <math>\Phi = \frac{1+\sqrt{5}}{2}</math> denoting the golden ratio.</p>

<sup>78</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  $p_0$  in I and the sample size  $n$  in J.*

$\text{BINOM}_P$  returns

$$p_B(g; n; p_0) = \binom{n}{g} \cdot p_0^g \cdot (1 - p_0)^{n-g} = C_{n,g} \cdot p_0^g \cdot (1 - p_0)^{n-g} \quad (\text{see COMB on p. 216 for the explanation of the notation}).$$

$\text{BINOM}$  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] 9 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>79</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

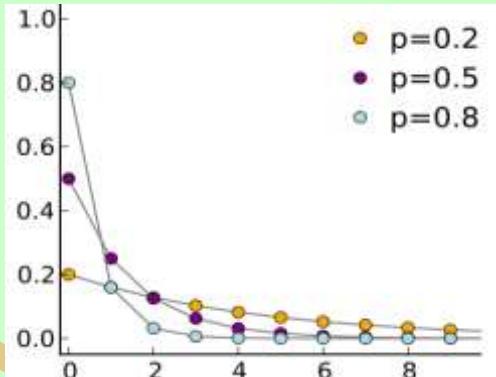
$$p_{Ge}(n) = p_0(1 - p_0)^n$$

GEOM returns

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

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

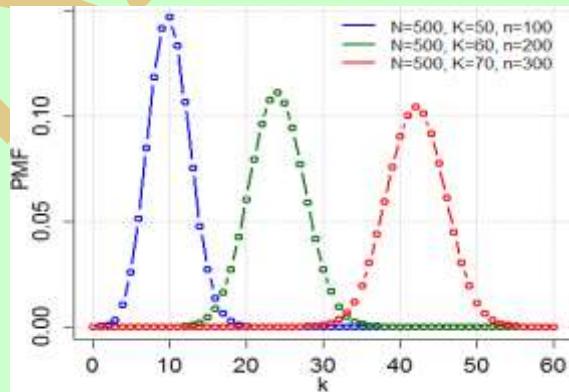
The probability  $p_0$  for a success in each such experiment must be specified in I.



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>79</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. 216 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  $\mathbf{X}$ , the gross probability of a success in a single draw  $p_0$  in  $\mathbf{I}$ , and  $n$  in  $\mathbf{J}$ .

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. 216 and cf. BINOM).

Start reading here for more:

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

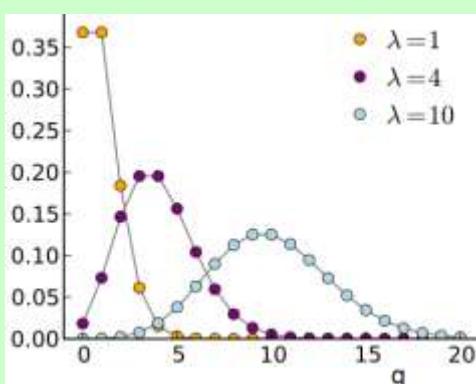
**Poiss:** Poisson distribution with the number of successes  $g$  in  $\mathbf{X}$  and the Poisson parameter  $\lambda$  in  $\mathbf{J}$ .

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  $\mathbf{X}$ .

The Poisson distribution provides the mathematically



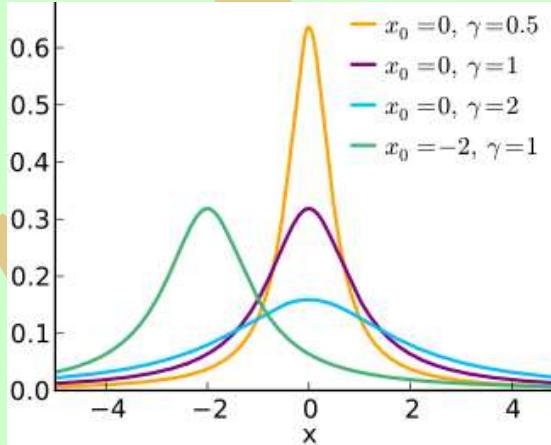
simplest model for industrial sampling tests – use  $\lambda = np_0$  with the gross error probability  $p_0$  and the sample size  $n$  (cf. BINOM). For the example introduced with BINOM above, POISS returns 0.638.

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**.



$$\text{CAUCH}_P \text{ returns } f_{Ca}(x) = \frac{1}{\pi \gamma} \cdot \left[ 1 + \left( \frac{x - x_0}{\gamma} \right)^2 \right]^{-1},$$

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

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

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).

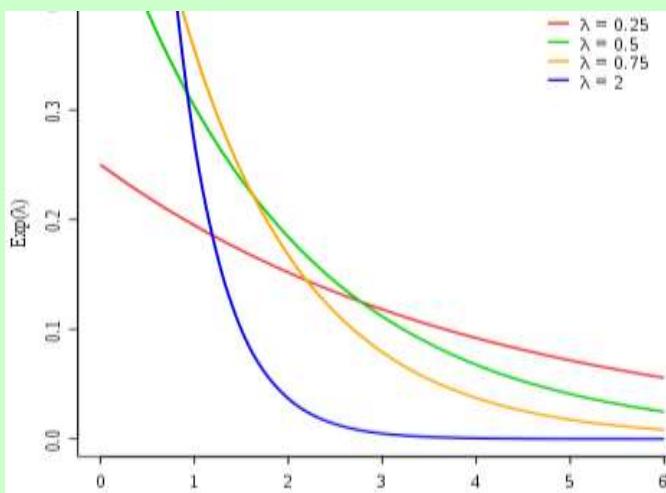
**Expon:** Exponential distribution with the rate  $\lambda$  in I.

EXPON<sub>P</sub> returns  $f_{Ex}(x) = \lambda \cdot e^{-\lambda x}$ .

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

Read here for more information:

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

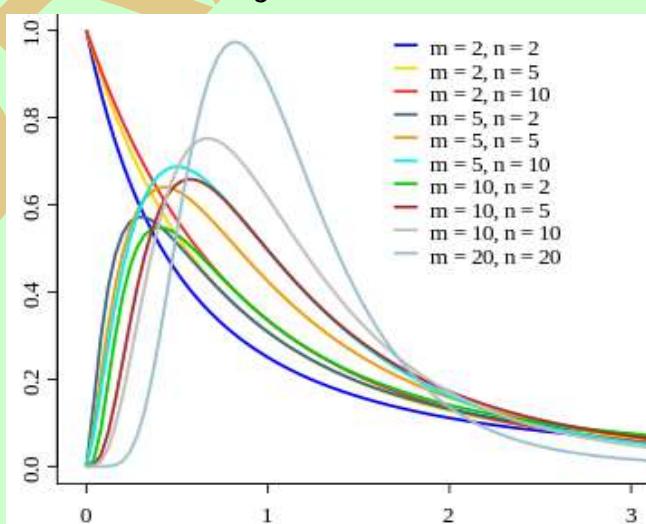


**F(x):** Fisher's F distribution with the degrees of freedom in I and J.

It is used e.g. for analyses of variance (ANOVA).

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

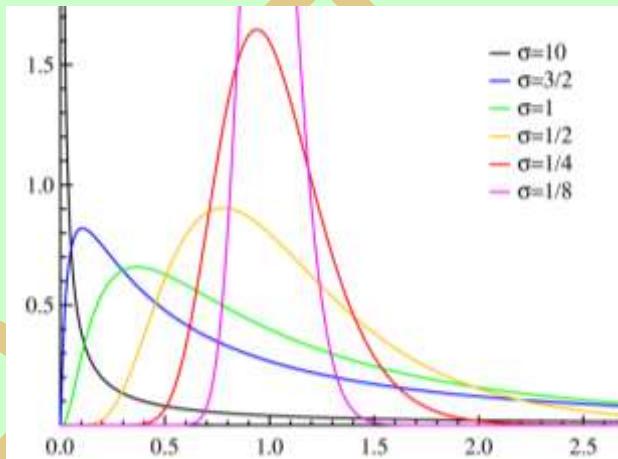
Read here for more information:



**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. 225.



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**.

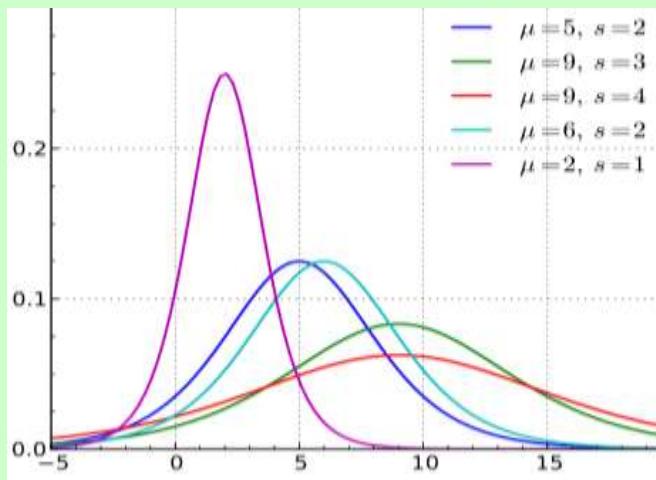
Substituting  $\xi = \frac{x-\mu}{s}$ ,

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

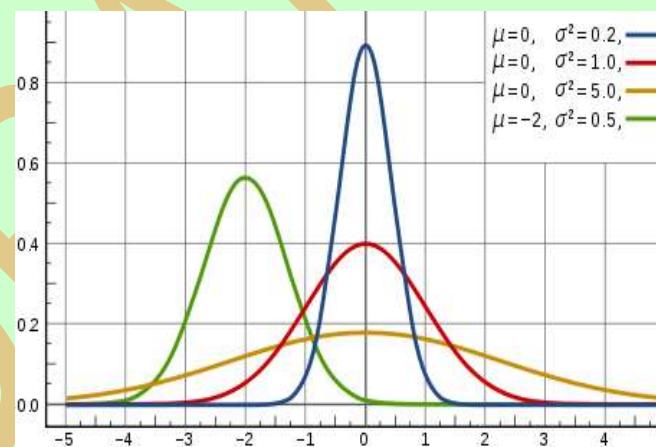
LOGIS returns  $F_{Lg}(x) = \frac{1}{1+e^{-\xi}}$ .

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

Start reading here for more:  
[http://en.wikipedia.org/wiki/Logistic\\_distribution](http://en.wikipedia.org/wiki/Logistic_distribution).



**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

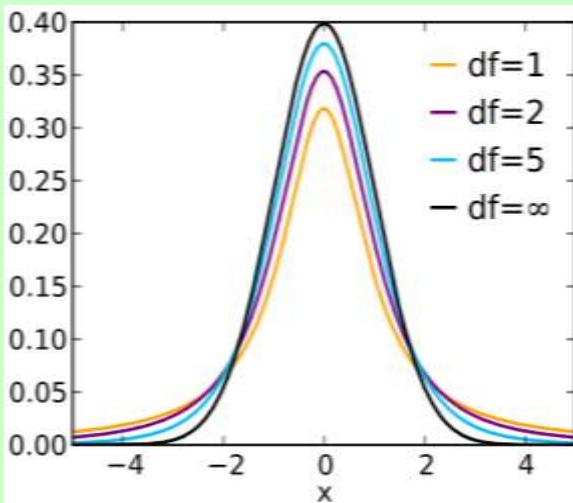
NORML returns  $F_N(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$  with  $\Phi(z)$  denoting the standard normal (or Gaussian) CDF as presented on p. 225.

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. 223).



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.

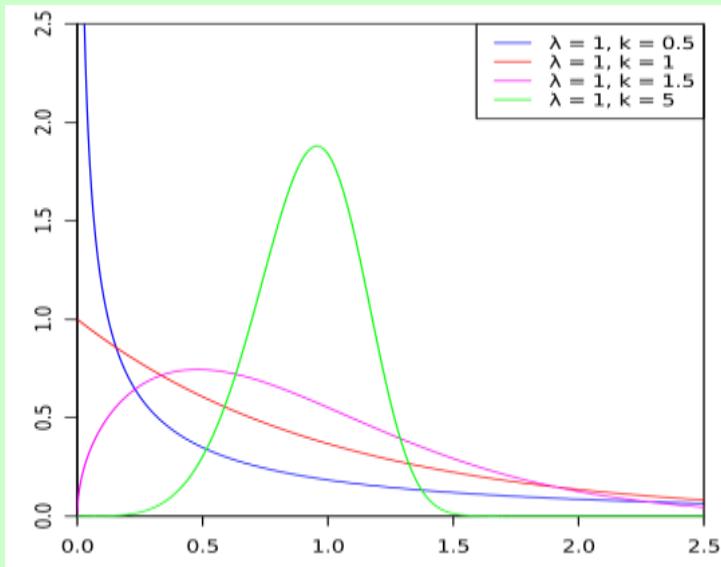
WEIBL returns  $F_W(t) = 1 - e^{-(t/T)^b}$

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

Read here for more information:

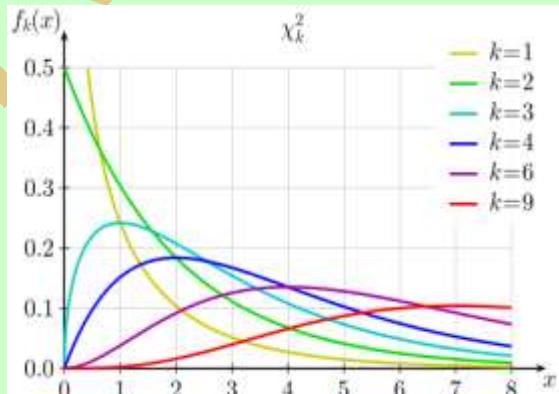
<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3668.htm>.

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. 223), while  $\Phi(x) = \int_{-\infty}^x \varphi(\tau) d\tau$  is the corresponding *CDF* (cf. the *error function* on p. 247). 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>80</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:

---

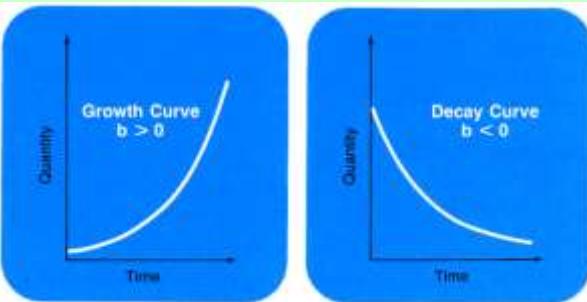
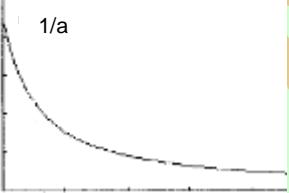
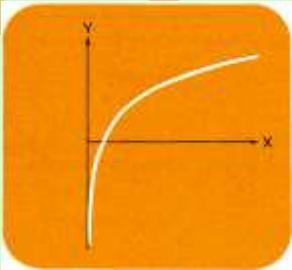
<sup>80</sup> Generally, the statistical model shall be chosen that matches observations best – within their statistical errors. In real-life cases, however, dramatic deviations from the model distribution are often found – then you cannot expect the calculated consequences matching reality any better.

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 with fools becoming busy”), a former boss of mine used to say (cf. also D.T. recently).

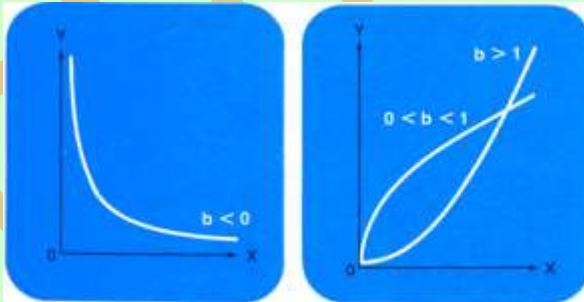
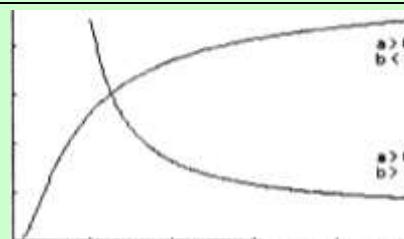
By the way: Since the *PDF* of the *Gaussian* distribution will never reach zero, this statistical model tells you to expect individual items far, far away from the mean value when your sample becomes large enough. This, however, does not match reality. So we must conclude nothing at all is really *Gaussian* 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>81</sup> See p. 220 for 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</p> $r = \frac{s_{xy}}{s_x \cdot s_y}$ . See $s_{XY}$ and $s$ below. <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. 224).</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>81</sup> Note that *least squares regression* is best for data point errors in direction  $y$  being significantly greater than the errors in direction  $x$ . See pp. 232ff for the formulas and more about the fit models provided.

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>81</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>82</sup>  <p>The figure contains two side-by-side plots. Both plots have 'Quantity' on the vertical axis and 'Time' on the horizontal axis. The left plot, labeled 'Growth Curve b &gt; 0', shows a curve starting near the origin and increasing rapidly at first, then leveling off. The right plot, labeled 'Decay Curve b &lt; 0', shows a curve starting near the origin and decreasing rapidly at first, then leveling off towards zero.</p>
GaussF	Selects a Gauss peak fit model $R(x) = a_0 e^{\frac{(x-a_1)^2}{a_2}}$ for least squares regression. <sup>81</sup> See p. 223 for the shapes of such peaks.
HypF	 <p>The figure shows a graph of a hyperbolic decay curve. The curve starts at a high value on the y-axis and decreases as x increases, asymptotically approaching the x-axis.</p> Selects the hyperbolic fit model $R(x) = \frac{1}{(a_0 + a_1 x)}$ for least squares regression. <sup>81</sup>
LinF	Selects the linear fit model $R(x) = a_0 + a_1 x$ for least squares regression. <sup>81</sup> Generally, this will be a good choice if the measured data follow a straight line, raising or falling (but compare ORTHOF).
LogF	 <p>The figure shows a graph of a logarithmic curve. The curve passes through the point (1, 0) and continues to rise more slowly as x increases, asymptotically approaching a horizontal asymptote.</p> Selects the logarithmic curve fit model $R(x) = a_0 + a_1 \ln(x)$ for least squares regression. <sup>81</sup> Generally, this will be a good choice if the measured data follow a curve looking like drawn at left.

<sup>82</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. 224).</p>
OrthoF	Selects the linear fit model $R(x) = a_0 + a_1x$ like LINF, but assuming data point errors in $\mathbf{x}$ are equal to those in $\mathbf{y}$ (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. 232ff 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>81</sup>
PowerF	<p>Selects the power curve fit model <math>R(x) = a_0 x^{a_1}</math> for least squares regression.<sup>81</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>82</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>81</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> $s_{mw} = \frac{1}{\sum y_i} \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i - 1}}$
$\bar{x}$	<p>The <i>arithmetic mean</i> is calculated as <math>\bar{x} = \frac{1}{n} \sum x_i</math></p>
$\bar{x}_G$	<p>The <i>geometric mean</i> is calculated as <math>\bar{x}_G = \sqrt[n]{(\prod x_i)} = e^{\left[\frac{1}{n} \sum \ln(x_i)\right]}</math>.</p>
$\bar{x}_H$	<p>The <i>harmonic mean</i> is calculated as <math>\bar{x}_H = \frac{n}{\sum \frac{1}{x_i}}</math>.</p>
$\bar{x}_{RMS}$	<p>The <i>quadratic mean</i> is calculated as <math>\bar{x}_{RMS} = \sqrt{\frac{1}{n} \sum x_i^2}</math>.</p>

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 $\Sigma+$ ) 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 $s_m$ .
$\varepsilon_p$	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 $\sigma$ .
$\sigma$	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 $\Sigma+$ ) is $\sigma_w = \sqrt{\frac{\sum y_i (x_i - \bar{x}_w)^2}{\sum y_i}}$

## 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. 228ff):
  - 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. 232 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. 232 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. 232 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  $R(x) = \frac{1}{[a_0(x + a_1)^2 + a_2]}$  will be specified by:

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

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

- 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 *IOI*). 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. from LINF).

## About Error Propagation

Experimental data are always attended with errors (cf. footnote 43), caused by e.g. the uncertainty of the measuring method, the instrument used, and/or 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 its error

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

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

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

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 of  $f$ , 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.

## 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

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

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*:

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

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

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

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. 239, we will get the following new set:

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

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

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

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

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

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

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

For solving a two-dimensional 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:

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

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

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

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

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

## 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 display="block">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 <math>\mathbb{Y}</math>, solving the same differential equation. See the first five polynomials plotted below.</p>

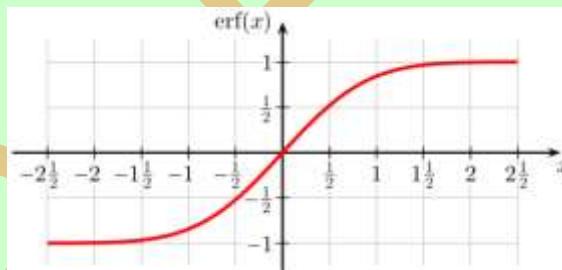
Name	Remarks (see pp. 12ff for general information)
$L_m$	<p><b>Laguerre polynomials</b> (compare <math>L_{n\alpha}</math> below):</p> $L_n(x) = \frac{e^x}{n!} \cdot \frac{d^n}{dx^n} (x^n e^{-x}) = L_n^{(0)}(x)$ with $n$ in $\mathbb{Y}$ , solving the differential equation $x \cdot f''(x) + (1-x) \cdot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

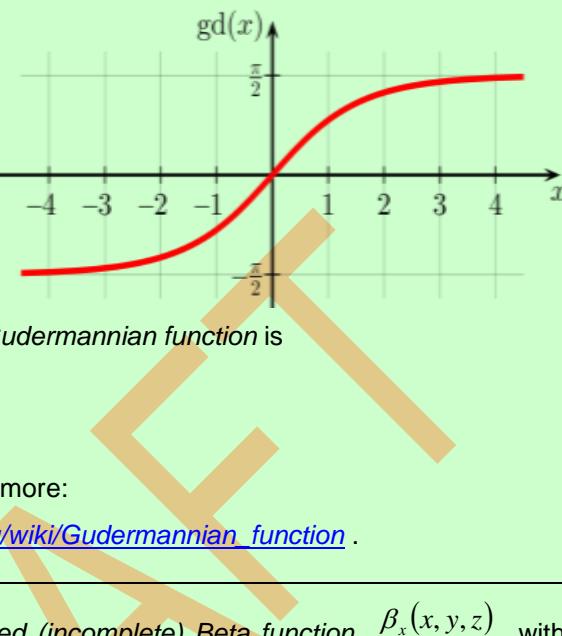
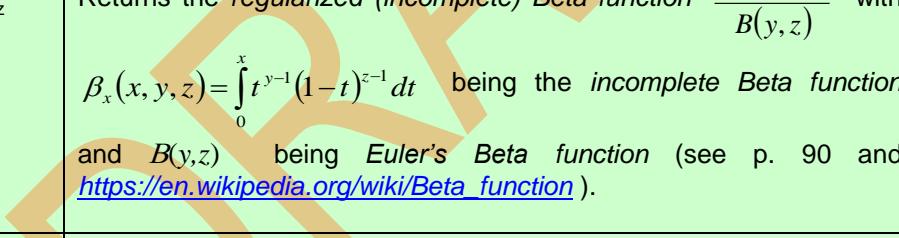
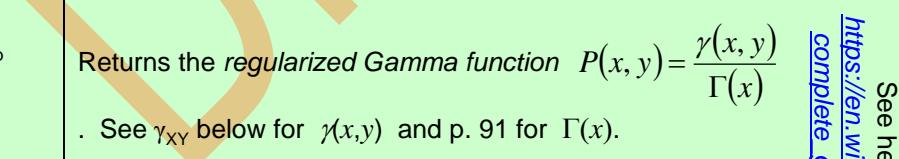
Name	Remarks (see pp. 12ff for general information)
$P_n$	<p><b>Legendre polynomials:</b> <math>P_n(x) = \frac{1}{2^n n!} \cdot \frac{d^n}{dx^n} [(x^2 - 1)^n]</math> with <math>n</math> in <b>Y</b>, solving the differential equation</p> $\frac{d}{dx} \left[ (1 - x^2) \cdot \frac{d}{dx} f(x) \right] + n(n+1)f(x) = 0.$ <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 <b>Y</b>,</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 plot 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. <math>T_0(x) = 1</math> is a constant black line. <math>T_1(x) = \cos(\pi x)</math> is a red line. <math>T_2(x) = \frac{1}{2}(3\cos(\pi x) - 1)</math> is a blue line. <math>T_3(x) = \frac{1}{4}(5\cos(3\pi x) + 3\cos(\pi x))</math> is a green line. <math>T_4(x) = \frac{1}{8}(35\cos(4\pi x) + 30\cos(2\pi x) + 3)</math> is an orange line. <math>T_5(x) = \frac{1}{16}(61\cos(5\pi x) + 105\cos(3\pi x) + 45\cos(\pi x))</math> is a black line.</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 plot 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. <math>U_0(x) = 2x</math> is a red line. <math>U_1(x) = 4x^3 - 3x</math> is a black line. <math>U_2(x) = 16x^5 - 20x^3 + 5x</math> is a blue line. <math>U_3(x) = 96x^8 - 144x^6 + 56x^4 - 3x^2</math> is a green line. <math>U_4(x) = 512x^{11} - 1152x^9 + 912x^7 - 336x^5 + 48x^3 - 3x</math> is an orange line. <math>U_5(x) = 3072x^{14} - 8640x^{12} + 11520x^{10} - 7680x^8 + 2880x^6 - 480x^4 + 3x^2</math> is a black line.</p>

## Even More Mathematical Functions

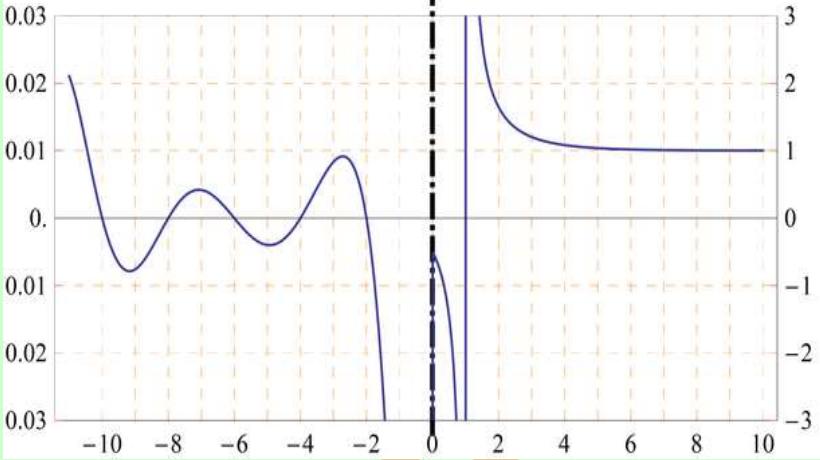
All the following functions are found in X.FN. Some of them are for pure mathematics only but were useful at some stages of the *WP 34S* or *WP 43S* projects, so we made them accessible for the public.

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> $\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-\tau^2} d\tau$ .  Note that $\text{erf}\left(\frac{x}{\sqrt{2}}\right) = 2 \cdot \Phi(x) - 1$ with $\Phi(x)$ representing the standard normal CDF as described on p. 225. Beyond statistics, the <i>error function</i> may be helpful in heat conduction and diffusion problems, for instance.
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 <i>real</i> 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> 
$II\Gamma_p$	<p>Returns the <i>regularized Gamma function</i> <math>P(x, y) = \frac{\gamma(x, y)}{\Gamma(x)}</math></p> <p>. See <math>\gamma_{XY}</math> below for <math>\gamma(x, y)</math> and p. 91 for <math>\Gamma(x)</math>.</p> <p>See here for more:  <a href="https://en.wikipedia.org/wiki/Incomplete_gamma_function">https://en.wikipedia.org/wiki/Incomplete_gamma_function</a></p> 
$II\Gamma_q$	<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>

Name	Remarks (see pp. 12ff for general information)
$J_y(x)$	<p>Generally, the <i>Bessel functions</i> solve the differential equation</p> $x^2 f''(x) + x f'(x) + (x^2 - \nu^2) f(x) = 0 \quad \text{with } \nu \in \mathbb{C}.$ <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 <i>real</i> 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{II}\Gamma_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{II}\Gamma_q</math> above.</p>
$\zeta(x)$	<p>Returns <i>Riemann's Zeta</i> for <i>real</i> 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>

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. 217ff) is a competent source. And *Mathworld* (quoted on pp. 247ff) 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.

# Building WP 43S Almost from Scratch

## How to build the simulator on Windows:

1. Navigate to <https://www.msys2.org/>. Download and run msys2-x86\_64-yyyymmdd.exe
2. Click **Next**
3. Enter the installation folder **C:\msys2\_64** and click **Next**
4. Tick **Run MSYS2 now** and click **Finish**

The following **commands printed blue** must be executed in the black MSYS2 window:

5. **pacman -Syu** . Confirm each question with ENTER and wait until finished.
6. Close the black window by Alt-F4.
7. Reopen *MSYS2 MinGW 64-bits* (every time you need to open MSYS2, open the 64-bits version).
8. **pacman -Syu** . Confirm each question with ENTER.
9. **pacman -S mingw-w64-x86\_64-gcc git base-devel mingw-w64-x86\_64-gtk3** . Confirm each question with ENTER.
10. **cd ~** to navigate to your home directory.
11. **git clone https://gitlab.com/Over\_score/wp43s.git** to get a local copy of the gitlab source repository on your PC.
12. **cd ~/wp43s** to navigate to the *WP 43S* program sources.
13. **git pull** to get the latest version from gitlab.com.
14. **make mrproper** to clean the build environment (this is not required but recommended).
15. **make** to build the *WP 43S* simulator.
16. **./wp43s** to run the simulator.
17. Return to step 13. (or to *App. F*) to get a new version of the sources.

## How to build the WP43S.pgm for the *DM42* hardware:

1. Navigate to <http://gnutoolchains.com/arm-eabi/>, download and run **arm-eabi-gcc9.2.1.exe** or a more recent version.
2. Installation directory **C:\msys2\_64\arm-eabi** shall be the same base directory as in step 3 on previous page.
3. Select **Current user**
4. Tick **Hardlink duplicate files**
5. Untick **Add binary directory to %PATH%**
6. Tick **I accept the terms of the license agreement**
7. Click **Install**
8. Click **OK** on the Installation succeeded dialog.
9. Start *MSYS2 64 bits* if not yet started.
10. **cd ~/wp43s/DMCP\_build** to navigate to the *DMCP* build directory.
11. **./build\_GMP\_static\_ARM\_library** this is a long process: about 12 minutes on my PC.
12. **cd ~/wp43s/DMCP\_build** to navigate to the *DMCP* build directory if not yet there.
13. **git pull** to get the latest version from **gitlab.com**
14. **./build\_WP43S.pgm\_for\_DM42\_hardware** to build *WP43S.pgm* for the *DM42*. Maybe the first time the process ends with an error – then run the same command a second time.
15. Copy the file **~/wp43s/DMCP\_build/build/WP43S.pgm** via *USB* to your *DM42* and flash it (cf. *App. F*).
16. Loop to step 12.

# Index of Everything Provided

This index lists each and every item provided, be it a command, constant (C), menu or submenu (M unless trailed by a colon), predefined label (L) or variable (V), reserved character (c), or system flag (S). Note that the sorting order in your *WP 43S* deviates for good reasons from the order *MS Word* applied here:

$\hat{x}$	84	$\uparrow$ LIM (V)	109	$\blacksquare$ STK	103	arccos	18
-	96	$\rightarrow$ (c)	97	$\blacksquare$ TAB	103	arcosh	18
$\bar{x}$	84	$\rightarrow$ D.MS	97	$\blacksquare$ USER	103	arcsin	18
$\bar{x}_w$	85	$\rightarrow$ DATE	97	$\blacksquare$ WIDTH	104	arctan	19
$\downarrow$ (M)	102	$\rightarrow$ DEG	97	$\blacksquare$ $\Sigma$	104	artanh	19
$\bar{x}_G$	84	$\rightarrow$ GRAD	97	$\frac{1}{2}$ (C)	16	ASIN	19
#	104	$\rightarrow$ H.MS	97	$1/x$	16	ASL.BLK (S)	113
#B	104	$\rightarrow$ HR	97	$10^x$	16	ASR	19
#DEC (V)	109	$\rightarrow$ INT	97	$1\text{COMPL}$	16	ASSIGN	19
%	100	$\rightarrow$ MUL $\pi$	97	$2\text{COMPL}$	16	ATAN	19
%+MG	100	$\rightarrow$ POL	97	$2^x$	16	atm $\rightarrow$ Pa	20
%MRR	100	$\rightarrow$ RAD	98	$-\infty$	96	au $\rightarrow$ m	20
%T	100	$\rightarrow$ REAL	98	$\infty$ (C)	101	AUTOFF (S)	113
% $\Sigma$	100	$\rightarrow$ REC	98	$a_{\oplus}$ (C)	20	AUTXEQ (S)	113
$(-1)^x$	95	$\downarrow$ LIM (V)	109	$a_{\ominus}$ (C)	17	B (V)	105
$(\chi^2)^{-1}$	95	$\gtrless$	99	$a_{\times}$ (V)	105	BACK	20
/	96	$^{\circ}\text{C} \rightarrow \text{F}$	16	$A \dots \Omega$ (M)	89	bar $\rightarrow$ Pa	20
$[\text{M}]^{-1}$	95	$^{\circ}\text{F} \rightarrow \text{C}$	16	A:	20	BATT?	20
$[\text{M}]^T$	95	$\mu_0$ (C)	92	$a_0$ (C)	17	bbl $\rightarrow$ m <sup>3</sup>	20
${}^{\wedge}\text{MOD}$	96	$\mu_0$ (C)	92	ABS	17	BC?	20
	100	$\mu_B$ (C)	92	ac <sub>us</sub> $\rightarrow$ m <sup>2</sup>	17	BEEP	21
M	99	$\mu_e$ (C)	92	ac $\rightarrow$ m <sup>2</sup>	17	BeginP	21
x	99	$\mu_e/\mu_B$ (C)	92	ACC (V)	105	BestF	21
+	96	$\mu_n$ (C)	92	ACOS	17	Binom	22
+/-	96	$\mu_p$ (C)	92	ADM (V)	105	Binom <sup>-1</sup>	22
$\pm\infty$ ?	96	$\mu_u$ (C)	92	ADV	17	Binom:	22
x	96	$\blacksquare$ #	104	AGM	17	Binome	22
$\times\text{MOD}$	96	$\blacksquare$ ADV	102	AGRAPH	17	Binomp	22
$\sqrt{x}$	101	$\blacksquare$ CHAR	102	ALL	17	BITS	22
$\sqrt[3]{x}$	16	$\blacksquare$ DLAY	102	ALLSCI (S)	112	B <sub>n</sub> *	22
$\sqrt[5]{y}$	85	$\blacksquare$ LCD	102	ALP.IN (S)	113	B <sub>n</sub>	22
$\sqrt[4]{}$	101	$\blacksquare$ MODE	102	ALPHA (S)	111	BS?	22
$\int$	101	$\blacksquare$ PROG	102	$a_{\text{Moon}}$ (C)	18	Btu $\rightarrow$ J	22
$\int f$ (M)	101	$\blacksquare$ r	103	AND	18	c (C)	22
$\int f dx$ (M)	101	$\blacksquare$ REGS	103	ANGLES (M)	18	C (V)	105

c <sub>1</sub> (C)	22	CPXS (M)	27	DSZ	31	FB	35
c <sub>2</sub> (C)	22	CROSS	28	e (C)	32	FBR	35
cal→J	22	ct→kg	28	E:	35	FC?	35
CARRY (S)	111	cwt→kg	28	e <sub>E</sub> (C)	32	FC?C	35
CASE	23	CX→RE	28	EIGVAL	32	FC?F	35
CATALOG	23	D (V)	105	EIGVEC	32	FC?S	35
Cauch <sup>-1</sup>	24	D.MS	31	END	32	FCNS (M)	35
Cauch	24	D.MS→	32	ENDP	33	F <sub>e</sub> (x)	35
Cauch:	24	D.MS→D	32	ENG	33	FF	35
Cauch <sub>e</sub>	24	D.MY	32	ENORM	33	FIB	36
CauchF	24	D→D.MS	32	ENTERA	33	FILL	36
Cauch <sub>p</sub>	24	D→J	32	ENTRY?	33	FIN (M)	36
CB	24	D→R	32	EQ.DEL	33	FIX	36
CEIL	24	DATE	28	EQ.EDI	33	FLAGS (M)	36
CF	24	DATE→	29	EQ.NEW	33	FLASH (M)	36
CHARS (M)	24	DATES (M)	28	EQN (M)	33	FLASH?	36
CLALL	24	DAY	29	erf	34	FLOOR	36
CLCVAR	25	dB→fr	29	erfc	34	fm.→m	36
CLFALL	25	dB→pr	29	ERR	34	FP	36
CLK (M)	25	DBL/	29	EVEN?	34	F <sub>p</sub> (x)	35
CLLCD	25	DBLx	29	EXITALL	34	FP?	36
CLMENU	25	DBLR	29	EXP (M)	34	fr→dB	36
CLP	25	DEC	29	ExpF	34	FRACT (S)	110
CLPALL	25	DECIM. (S)	112	Expon <sup>-1</sup>	34	FS?	36
CLR (M)	25	DECOMP	30	Expon	34	FS?C	37
CLREGS	25	DEG	30	Expon:	34	FS?F	37
CLSTK	25	DEG→	30	Expon <sub>e</sub>	34	FS?S	37
CLX	26	DENANY (S)	110	Expon <sub>p</sub>	34	ft.→m	37
CLΣ	26	DENFIX (S)	111	EXPT	34	ft <sub>us</sub> →m	37
CNST (M)	26	DENMAX	30	e <sup>x</sup>	34	FV (V)	106
COMB	26	DENMAX (V)		e <sup>x</sup> -1	35	fz <sub>UK</sub> →m <sup>3</sup>	37
CONJ	26	105		F	35	fz <sub>us</sub> →m <sup>3</sup>	37
CONST	26	DET	30	F <sub>δ</sub>	37	G (C)	38
CONVG	26	DIGITS (M)	30	F <sub>α</sub>	37	g <sub>⊕</sub>	40
CORR	27	DMY (S)	110	f' (M)	37	G <sub>0</sub> (C)	38
cos	27	DOT	30	f'' (M)	37	GAP	38
cosh	27	DROP	31	f''(x)	37	GaussF	38
COV	27	DROPy	31	F&p:	37	G <sub>C</sub> (C)	38
CPX (M)	27	DSE	31	F <sup>-1</sup> (p)	35	GCD	38
CPX?	28	DSL	31	f'(x)	37	g <sub>d</sub>	38
CPXj (S)	110	DSP (M)	30	F(x)	35	g <sub>d</sub> <sup>-1</sup>	38
CPXRES (S)	110	DSTACK	31	F:	37	g <sub>e</sub> (C)	38

Geom <sup>-1</sup>	39	INDEX	42	L.R.	50	m <sub>⊕</sub>	56
Geom	39	INFO (M)	42	LASTx	46	m <sub>⊕</sub>	56
Geom:	39	INPUT	42	lb. $\rightarrow$ kg	46	m <sub>p</sub> (C)	53
Geom <sub>e</sub>	39	INT?	42	lbf $\rightarrow$ N	46	M.DELR	53
Geom <sub>p</sub>	39	INTING (S)	113	LBL	46	M.DIM	53
gl <sub>us</sub> $\rightarrow$ m <sup>3</sup>	39	INTS (M)	42	LBL?	46	M.DIM?	53
gl <sub>uk</sub> $\rightarrow$ m <sup>3</sup>	39	INVRT	42	LCM	46	M.DY	53
GM <sub>⊕</sub>	39	IP	43	LEAD.0 (S)	111	M.EDI	54
GRAD	39	ISE	43	LEAP?	47	M.EDIN	54
GRAD $\rightarrow$	39	ISG	43	LgNrm	47	M.EDIT (M)	54
GRAMOD (V)		ISZ	43	LgNrm <sup>-1</sup>	47	M.GET	54
	106	I <sub>xyz</sub>	43	LgNrm:	47	M.GOTO	54
GROW (S)	112	I $\Gamma_p$	43	LgNrm <sub>e</sub>	47	M.GROW	54
GTO	39	I $\Gamma_q$	43	LgNrm <sub>p</sub>	47	M.INSR	54
GTO.	40	J-	44	LinF	47	M.LU	55
$\bar{x}_H$	84	J (V)	106	LJ	47	M.NEW	55
h (C)	40	J/G	44	L <sub>max</sub>	47	M.OLD	55
$\hbar$ (C)	41	J+	44	L <sub>m</sub>	47	M.PUT	55
ha $\rightarrow$ m <sup>2</sup>	40	J $\rightarrow$ Btu	44	LN	47	M.R $\Rightarrow$ R	55
H <sub>n</sub>	40	J $\rightarrow$ cal	44	LN(1+x)	48	M.SIMQ (M)	55
H <sub>nP</sub>	40	J $\rightarrow$ D	44	LN $\beta$	48	M.SQR?	55
hp <sub>uk</sub> $\rightarrow$ W	40	J $\rightarrow$ Wh	44	LNF	48	M.WRAP	55
hp <sub>E</sub> $\rightarrow$ W	40	J <sub>y</sub> (x)	44	LOAD	48	m:	55
hp <sub>M</sub> $\rightarrow$ W	40	k (C)	44	LOADP	48	m $\rightarrow$ au	56
Hyper	41	K (V)	106	LOADR	48	m $\rightarrow$ fm.	56
Hyper <sup>-1</sup>	41	KEY	44	LOADSS	48	m $\rightarrow$ ft <sub>us</sub>	56
Hyper:	41	KEY?	45	LOADΣ	48	m $\rightarrow$ ft.	56
Hyper <sub>e</sub>	41	KEYG	45	LocR	48	m $\rightarrow$ in.	56
Hyper <sub>p</sub>	41	KEYX	45	LocR?	49	m $\rightarrow$ ly	56
HypF	41	kg $\rightarrow$ ct	45	LOG <sub>10</sub>	49	m $\rightarrow$ mi.	56
I-	43	kg $\rightarrow$ cwt	45	LOG <sub>2</sub>	49	m $\rightarrow$ nmi.	56
I (V)	106	kg $\rightarrow$ lb.	45	LogF	49	m $\rightarrow$ pc	56
i%/a (V)	106	kg $\rightarrow$ oz	45	Logis <sup>-1</sup>	49	m $\rightarrow$ pt.	56
I/O (M)	43	kg $\rightarrow$ s.t	45	Logis	49	m $\rightarrow$ yd.	56
I+	43	kg $\rightarrow$ scw	45	Logis:	49	m <sup>2</sup> $\rightarrow$ ac	50
IDIV	41	kg $\rightarrow$ sto	45	Logis <sub>e</sub>	49	m <sup>2</sup> $\rightarrow$ ac <sub>us</sub>	50
IDIVR	41	kg $\rightarrow$ ton	45	Logis <sub>p</sub>	49	m <sup>2</sup> $\rightarrow$ ha	50
IGNIER (S)	113	kg $\rightarrow$ trz	45	LOG <sub>x,y</sub>	49	m <sup>3</sup> $\rightarrow$ bbl	50
iHg $\rightarrow$ Pa	41	K <sub>j</sub> (C)	45	LOOP (M)	49	m <sup>3</sup> $\rightarrow$ fz <sub>us</sub>	50
Im	41	KTYP?	46	LOWBAT (S)	112	m <sup>3</sup> $\rightarrow$ fz <sub>uk</sub>	50
in. $\rightarrow$ m	42	L (V)	106	l <sub>PL</sub> (C)	49	m <sup>3</sup> $\rightarrow$ gl <sub>uk</sub>	50
INC	42	L.INTS (M)	49	ly $\rightarrow$ m	49	m <sup>3</sup> $\rightarrow$ gl <sub>us</sub>	50

MANT	50	NBin	56	PGMSLV	60	RCL-	64
MASKL	51	NBin <sup>-1</sup>	56	PIXEL	60	RCL /	64
MASKR	51	NBin:	57	PLOT	60	RCL+	64
Mat_A (V)	107	NBin <sub>e</sub>	56	PMT (V)	107	RCLx	64
Mat_B (V)	107	NBin <sub>p</sub>	56	P <sub>n</sub>	60	RCL†	64
Mat_X	51	NEIGHB	57	POINT	60	RCL‡	64
Mat_X (V)	107	NEXTP	57	Poiss <sup>-1</sup>	60	RCLCFG	63
MATR?	51	nmi. $\rightarrow$ m	57	Poiss	60	RCLEL	63
MATRS (M)	51	NOP	57	Poiss:	60	RCLIJ	63
MATX (M)	51	NOR	57	Poisse	60	R-CLR	69
max	51	Norml	57	Poissp	60	RCLS	63
MDY (S)	110	Norml <sup>-1</sup>	57	PopLR	60	R-COPY	69
m <sub>e</sub> (C)	51	Norml:	58	PowerF	61	RDP	64
MEM?	51	Normle	57	pr $\rightarrow$ dB	61	Re	64
MENU	51	Normlp	57	PRCL	61	r <sub>e</sub> (C)	64
MENUS (M)	51	NOT	58	PRIME?	61	RE $\rightarrow$ CX	65
mi. $\rightarrow$ m	52	NPER (V)	107	PRINT (S)	111	Re $\Rightarrow$ Im	65
min	52	NUM.IN (S)	113	PROB (M)	61	REAL?	64
MIRROR	52	n $\Sigma$	58	PROG (M)	61	REALDF (V)	108
M <sub>Moon</sub> (C)	52	ODD?	58	PROGS (M)	61	REALS (M)	64
m <sub>n</sub> (C)	52	OFF	58	PROPFR (S)	110	RECTN (S)	110
m <sub>n</sub> /m <sub>p</sub> (C)	52	OR	58	PRTACT (S)	113	RECV	64
MOD	52	OrthoF	58	psi $\rightarrow$ Pa	61	REGS (V)	108
MODE (M)	52	ORTHOG (M)	58	PSTO	61	RESET	65
MONTH	52	OVERFL (S)	111	pt. $\rightarrow$ m	62	RJ	65
m <sub>p</sub> (C)	52	oz $\rightarrow$ kg	58	PUTK	62	R <sub>K</sub> (C)	65
m <sub>p</sub> /m <sub>e</sub> (C)	52	P.FN (M)	62	PV (V)	107	RL	66
m <sub>PL</sub> (C)	52	P.FN2 (M)	62	QUIET (S)	112	RLC	66
MSG	52	P:	62	R <sub>∞</sub> (C)	70	RM	66
m <sub>u</sub> (C)	53	P <sub>0</sub> (C)	59	R <sub>⊕</sub> (C)	70	RM?	67
m <sub>u</sub> c <sup>2</sup> (C)	53	Pa $\rightarrow$ atm	59	R (C)	62	RMD	67
MULTx (S)	112	Pa $\rightarrow$ bar	59	R <sub>⊖</sub> (C)	70	R <sub>Moon</sub> (C)	67
MULπ	53	Pa $\rightarrow$ iHg	59	R†	70	χ <sub>RMS</sub>	85
MULπ $\rightarrow$	53	Pa $\rightarrow$ psi	59	R $\rightarrow$ D	70	RNORM	67
MVAR	53	Pa $\rightarrow$ tor	59	R $\downarrow$	70	RootF	67
MyMenu	53	ParabF	59	RAD	62	ROUND	67
Myα (M)	53	PARTS (M)	59	RAD $\rightarrow$	62	ROUNDI	67
N $\rightarrow$ lbf	58	PAUSE	59	RAM (M)	62	RR	67
N <sub>A</sub>	56	pc $\rightarrow$ m	59	RAN#	63	RRC	68
NaN (C)	56	PER/a (V)	107	RANI#	62	RSD	68
NaN?	56	PERM	59	RBR	63	R-SORT	69
NAND	56	PGMINT	60	RCL	63	RSUM	68

R-SWAP	70	SLOW (S)	112	SYSTEM	78	$V_m$ (C)	82
RTN	68	SLVQ	74	$t^{-1}(p)$	79	VMDISP (S)	113
RTN+1	68	$s_m$	75	$t(x)$	79	$W^{-1}$	83
RUNIO (S)	111	SMODE?	75	$t:$	80	$W \rightarrow h_{PUK}$	83
RUNTIM (S)	111	$s_{mw}$	75	$t \gtrless$	80	$W \rightarrow h_{PE}$	83
s	70	SOLVE	75	$T_0$	78	$W \rightarrow h_{PM}$	83
S.INTS (M)	78	Solver (M)	75	$\tan$	78	WDAY	82
s.t $\rightarrow$ kg	78	SPCRES (S)	112	$\tanh$	78	Weibl	82
s $\rightarrow$ year	78	SPEC?	76	TDISP	79	Weibl $^{-1}$	82
Sa (C)	70	SR	76	TDIM (S)	109	Weibl:	82
SAVE	70	SSIZE (S)	112	$t_e(x)$	79	Weibl $_e$	82
SB	71	SSIZE?	76	TEST (M)	79	Weibl $_p$	82
Sb (C)	71	ST.A (V)	108	TICKS	79	Wh $\rightarrow$ J	83
SCI	71	ST.B (V)	108	TIME	79	WHO?	83
scw $\rightarrow$ kg	71	ST.C (V)	108	TIMER	79	$W_m$	83
SDIGS?	71	ST.D (V)	108	TIMES (M)	79	$W_p$	83
SDL	71	ST.X (V)	108	$T_n$	79	WSIZE	83
SDR	71	ST.Z (V)	108	ton $\rightarrow$ kg	80	WSIZE?	83
Se $^2$ (C)	71	ST.T (V)	108	TONE	79	$x < ?$	87
Se' $^2$ (C)	72	ST.Y (V)	108	TOP?	80	$x = ?$	86
SEED	71	STAT (M)	76	tor $\rightarrow$ Pa	80	$x \neq ?$	86
SEND	71	STATUS	76	$T_p$ (C)	80	$x = -0?$	86
SETCHN	71	STK (M)	76	$t_p(x)$	79	$x = +0?$	86
SETDAT	72	STO	76	$t_{PL}$ (C)	80	$x > ?$	87
SETEUR	72	STO-	77	TRACE (S)	111	$x \approx ?$	87
SETIND	72	STO/	77	TRANS	80	$x \leq ?$	87
SETJPN	72	STO+	77	TRI (M)	80	$x \geq ?$	87
SETSIG	72	STOx	77	trz $\rightarrow$ kg	80	$x!$	86
SETTIM	72	STO†	77	TVM (M)	80	X.FN (M)	85
SETUK	72	sto $\rightarrow$ kg	77	U $\rightarrow$ (M)	81	$x:$	86
SETUSA	72	STO‡	77	ULP?	80	$x \rightarrow$ DATE	86
SF	72	STOCFG	76	$U_n$	81	$x \rightarrow a$	86
Sf $^{-1}$ (C)	72	STOEL	76	UNITV	81	$x \gtrless$	86
SHOW	73	STOIJ	76	UNSIGN	81	$x \gtrless y$	86
SIGN	73	STOP	76	USER (S)	111	$x^2$	84
SIGNMT	73	STOS	77	V:	82	$x^3$	84
SIM_EQ	73	STRI?	77	$V_4$	82	XEQ	84
sin	73	STRING (M)	77	VAR (M)	81	$xIN$	85
sinc	73	SUM	77	VARMNU	81	XNOR	85
sinh	73	$s_w$	78	VARS (M)	81	XOR	85
SKIP	74	$s_{xy}$	78	VERS?	81	$xOUT$	85
SL	74	SYS.FL (M)	78	VIEW	82	$\hat{y}$	87

Y.MD	88	αSL	89	π (C)	92	Σx <sup>2</sup>	94
y <sup>z</sup>	88	αSR	89	Π <sub>n</sub>	92	Σx <sup>2</sup> /y	94
yd.→m	87	β(x,y)	90	σ	93	Σx <sup>2</sup> y	94
YEAR	87	γ (C)	90	Σ-	94	Σx <sup>3</sup>	94
year→s	87	Γ(x)	90	Σ1/x	93	Σx <sup>4</sup>	94
YMD (S)	110	γ <sub>EM</sub> (C)	90	Σ1/x <sup>2</sup>	93	Σxlny	94
y <sup>x</sup>	87	γ <sub>P</sub> (C)	90	Σ1/y	93	Σxy	94
z <sup>z</sup>	88	γ <sub>xy</sub>	90	Σ1/y <sup>2</sup>	93	Σy	94
Z <sub>0</sub> (C)	88	Γ <sub>xy</sub>	90	Σ+	94	Σy <sup>2</sup>	94
α (C)	88	Δ%	91	σ <sub>B</sub> (C)	93	Σylnx	94
α· (M)	89	δx (L)	90	Σln <sup>2</sup> x	93	Φ (C)	95
α.FN (M)	89	Δv <sub>cs</sub> (C)	90	Σln <sup>2</sup> y	93	Φ <sub>0</sub> (C)	95
α→x	89	ε	91	Σlnx	93	χ <sup>2</sup> (x)	95
αCAP (S)	111	ε <sub>0</sub> (C)	91	Σlnxy	93	χ <sup>2</sup> :	95
αINTL (M)	88	ε <sub>m</sub>	91	Σlny	93	χ <sup>2</sup> <sub>e</sub> (x)	95
αLENG?	88	ε <sub>p</sub>	91	Σlny/x	93	χ <sup>2</sup> <sub>p</sub> (x)	95
αMATH (M)	88	ζ(x)	91	Σ <sub>n</sub>	93	ω (C)	95
αPOS?	89	λ <sub>c</sub> (C)	92	σ <sub>w</sub>	93		
αRL	89	λ <sub>cn</sub> (C)	92	Σx	94		
αRR	89	λ <sub>cp</sub> (C)	92	Σx/y	94		

The same items sorted as they are in your WP 43S:

°C→°F	16	ADM (V)	104	ASL.BLK (S)	112	BeginP	21
°F→°C	16	ADV	17	ASR	19	BestF	21
½ (C)	16	AGM	17	ASSIGN	19	Binom	22
1/x	16	AGRAPH	17	ATAN	19	Binom <sub>e</sub>	22
10 <sup>x</sup>	16	ALL	17	atm→Pa	20	Binom <sub>p</sub>	22
1COMPL	16	ALLSCI (S)	111	AUTOFF (S)	112	Binom <sup>-1</sup>	22
2COMPL	16	ALPHA (S)	110	AUTXEQ (S)	112	Binom:	22
2 <sup>x</sup>	16	ALP.IN (S)	112	au→m	20	BITS	22
3√x	16	a <sub>Moon</sub> (C)	18	A:	20	B <sub>n</sub>	22
a (C)	17	AND	18	a <sub>⊕</sub> (C)	20	B <sub>n</sub> *	22
A (V)	104	ANGLES (M)	18	B (V)	104	BS?	22
a <sub>0</sub> (C)	17	arccos	18	BACK	20	Btu→J	22
ABS	17	arcosh	18	bar→Pa	20	c (C)	22
ac <sub>us</sub> →m <sup>2</sup>	17	arcsin	18	BATT?	20	C (V)	104
ac→m <sup>2</sup>	17	arctan	19	bbl→m <sup>3</sup>	20	c <sub>1</sub> (C)	22
ACC (V)	104	artanh	19	BC?	20	c <sub>2</sub> (C)	22
ACOS	17	ASIN	19	BEEP	21	cal→J	22

CARRY (S)	110	cwt $\rightarrow$ kg	28	EIGVEC	32	FLASH (M)	36
CASE	23	CX $\rightarrow$ RE	28	END	32	FLASH?	36
CATALOG	23	D (V)	104	ENDP	33	FLOOR	36
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Cauch <sub>e</sub>	24	DATE	28	ENORM	33	FP	36
CauchF	24	DATES (M)	28	ENTER $\uparrow$	33	F <sub>p</sub> (x)	35
Cauch <sub>p</sub>	24	DATE $\rightarrow$	29	ENTRY?	33	FP?	36
Cauch $^{-1}$	24	DAY	29	EQN (M)	33	FRACT (S)	109
Cauch:	24	DBLR	29	EQ.DEL	33	fr $\rightarrow$ dB	36
CB	24	DBL $\times$	29	EQ.EDI	33	FS?	36
CEIL	24	DBL/	29	EQ.NEW	33	FS?C	37
CF	24	dB $\rightarrow$ fr	29	erf	34	FS?F	37
CHARS (M)	24	dB $\rightarrow$ pr	29	erfc	34	FS?S	37
CLALL	24	DEC	29	ERR	34	ft. $\rightarrow$ m	37
CLCVAR	25	DECIM. (S)	111	EVEN?	34	ft <sub>us</sub> $\rightarrow$ m	37
CLFALL	25	DECOMP	30	e $^x$	34	FV (V)	105
CLK (M)	25	DEG	30	EXITALL	34	fz <sub>uk</sub> $\rightarrow$ m <sup>3</sup>	37
CLLCD	25	DEG $\rightarrow$	30	EXP (M)	34	fz <sub>us</sub> $\rightarrow$ m <sup>3</sup>	37
CLMENU	25	DENANY (S)	109	ExpF	34	F <sub>α</sub>	37
CLP	25	DENFIX (S)	110	Expon	34	F <sub>δ</sub>	37
CLPALL	25	DENMAX	30	Expone	34	F(x)	35
CLR (M)	25	DENMAX (V)	104	Expon <sub>p</sub>	34	F <sup>-1</sup> (p)	35
CLREGS	25	DET	30	Expon $^{-1}$	34	F:	37
CLSTK	25	DIGITS (M)	30	Expon:	34	f' (M)	37
CLX	26	DMY (S)	109	EXPT	34	f'(x)	37
CLΣ	26	DOT	30	e $^{x-1}$	35	f'' (M)	37
CNST (M)	26	DROP	31	E:	35	f''(x)	37
COMB	26	DROPy	31	F	35	F&p:	37
CONJ	26	DSE	31	FB	35	G (C)	38
CONST	26	DSL	31	FBR	35	G <sub>0</sub> (C)	38
CONVG	26	DSP (M)	30	FC?	35	GAP	38
CORR	27	DSTACK	31	FC?C	35	GaussF	38
cos	27	DSZ	31	FC?F	35	G <sub>c</sub> (C)	38
cosh	27	D.MS	31	FC?S	35	GCD	38
COV	27	D.MS $\rightarrow$	32	FCNS (M)	35	g <sub>d</sub>	38
CPX (M)	27	D.MY	32	F <sub>e</sub> (x)	35	g <sub>d</sub> $^{-1}$	38
CPXj (S)	109	D $\rightarrow$ D.MS	32	FF	35	g <sub>e</sub> (C)	38
CPXRES (S)	109	D $\rightarrow$ J	32	FIB	36	Geom	39
CPXS (M)	27	D $\rightarrow$ R	32	FILL	36	Geom <sub>e</sub>	39
CPX?	28	e (C)	32	FIN (M)	36	Geom <sub>p</sub>	39
CROSS	28	e <sub>E</sub> (C)	32	FIX	36	Geom $^{-1}$	39
ct $\rightarrow$ kg	28	EIGVAL	32	FLAGS (M)	36	Geom:	39

gl <sub>UK</sub> →m <sup>3</sup>	39	ISZ	43	LEAP?	47	m <sup>3</sup> →gl <sub>UK</sub>	50
gl <sub>US</sub> →m <sup>3</sup>	39	I <sub>xyz</sub>	43	LgNrm	47	m <sup>3</sup> →gl <sub>US</sub>	50
GM <sub>⊕</sub>	39	IΓ <sub>p</sub>	43	LgNrm <sub>e</sub>	47	MANT	50
GRAD	39	IΓ <sub>q</sub>	43	LgNrm <sub>p</sub>	47	MASKL	51
GRAD→	39	I+	43	LgNrm <sup>-1</sup>	47	MASKR	51
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GTO	39	i%/a (V)	105	LJ	47	MATX (M)	51
GTO.	40	J (V)	105	L <sub>m</sub>	47	Mat_A (V)	106
g <sub>⊕</sub>	40	J <sub>y</sub> (x)	44	L <sub>ma</sub>	47	Mat_B (V)	106
h (C)	40	J+	44	LN	47	Mat_X	51
h̄ (C)	41	J-	44	LNβ	48	Mat_X (V)	106
ha→m <sup>2</sup>	40	J/G	44	LNF	48	max	51
H <sub>n</sub>	40	J→Btu	44	LN(1+x)	48	MDY (S)	109
H <sub>nP</sub>	40	J→cal	44	LOAD	48	m <sub>e</sub> (C)	51
hp <sub>E</sub> →W	40	J→D	44	LOADP	48	MEM?	51
hp <sub>M</sub> →W	40	J→Wh	44	LOADR	48	MENU	51
hp <sub>UK</sub> →W	40	k (C)	44	LOADSS	48	MENUS (M)	51
Hyper	41	K (V)	105	LOADΣ	48	min	52
Hyper <sub>e</sub>	41	KEY	44	LocR	48	MIRROR	52
Hyper <sub>p</sub>	41	KEYG	45	LocR?	49	mi.→m	52
Hyper <sup>-1</sup>	41	KEYX	45	LOG <sub>10</sub>	49	M <sub>Moon</sub> (C)	52
Hyper:	41	KEY?	45	LOG <sub>2</sub>	49	m <sub>n</sub> (C)	52
HypF	41	kg→ct	45	LogF	49	m <sub>n</sub> /m <sub>p</sub> (C)	52
I (V)	105	kg→cwt	45	Logis	49	MOD	52
IDIV	41	kg→lb.	45	Logise	49	MODE (M)	52
IDIVR	41	kg→oz	45	Logisp	49	MONTH	52
IGN1ER (S)	112	kg→scw	45	Logis <sup>-1</sup>	49	m <sub>p</sub> (C)	52
iHg→Pa	41	kg→sto	45	Logis:	49	m <sub>p</sub> /m <sub>e</sub> (C)	52
Im	41	kg→s.t	45	LOG <sub>xy</sub>	49	MSG	52
in.→m	42	kg→ton	45	LOOP (M)	49	m <sub>u</sub> (C)	53
INC	42	kg→trz	45	LOWBAT (S)	111	m <sub>u</sub> c <sup>2</sup> (C)	53
INDEX	42	K <sub>j</sub> (C)	45	l <sub>PL</sub> (C)	49	MULTx (S)	111
INFO (M)	42	KTYP?	46	ly→m	49	MULπ	53
INPUT	42	L (V)	105	L.INTS (M)	49	MULπ→	53
INT?	42	LASTx	46	L.R.	50	MVAR	53
INTING (S)	112	lbf→N	46	m <sup>2</sup> →ac	50	MyMenu	53
INTS (M)	42	LBL	46	m <sup>2</sup> →acus	50	Myα (M)	53
INVRT	42	LBL?	46	m <sup>2</sup> →ha	50	m <sub>p</sub> (C)	53
IP	43	lb.→kg	46	m <sup>3</sup> →bbl	50	M.DELR	53
ISE	43	LCM	46	m <sup>3</sup> →fz <sub>us</sub>	50	M.DIM	53
ISG	43	LEAD.0 (S)	110	m <sup>3</sup> →fz <sub>uk</sub>	50		

M.DIM?	53	nmi. $\rightarrow$ m	57	Poiss $^{-1}$	60	r <sub>e</sub> (C)	64
M.DY	53	NOP	57	Poiss:	60	REAL?	64
M.EDI	54	NOR	57	PopLR	60	REALDF (V)	107
M.EDIN	54	Norml	57	PowerF	61	REALS (M)	64
M.EDIT (M)	54	Normle	57	PRCL	61	RECTN (S)	109
M.GET	54	Normlp	57	PRIME?	61	RECV	64
M.GOTO	54	Norml $^{-1}$	57	PRINT (S)	110	REGS (V)	107
M.GROW	54	Norml:	58	PROB (M)	61	RESET	65
M.INSR	54	NOT	58	PROG (M)	61	RE $\Rightarrow$ CX	65
M.LU	55	NPER (V)	106	PROGS (M)	61	Re $\gtrless$ Im	65
M.NEW	55	NUM.IN (S)	112	PROPFR (S)	109	RJ	65
M.OLD	55	n $\Sigma$	58	PRTACT (S)	112	R <sub>K</sub> (C)	65
M.PUT	55	N $\rightarrow$ lbf	58	pr $\rightarrow$ dB	61	RL	66
M.R $\gg$ R	55	ODD?	58	psi $\rightarrow$ Pa	61	RLC	66
M.SIMQ (M)	55	OFF	58	PSTO	61	RM	66
M.SQR?	55	OR	58	pt. $\rightarrow$ m	61	RMD	67
M.WRAP	55	OrthoF	58	PUTK	62	R <sub>Moon</sub> (C)	67
m:	55	ORTHOG (M)	58	PV (V)	106	RM?	67
m $\rightarrow$ au	56	OVERFL (S)	110	P.FN (M)	62	RNORM	67
m $\rightarrow$ fm.	56	oz $\rightarrow$ kg	58	P.FN2 (M)	62	RootF	67
m $\rightarrow$ ft <sub>us</sub>	56	P <sub>0</sub> (C)	59	P:	62	ROUND	67
m $\rightarrow$ ft.	56	ParabF	59	QUIET (S)	111	ROUNDI	67
m $\rightarrow$ in.	56	PARTS (M)	59	R (C)	62	RR	67
m $\rightarrow$ ly	56	PAUSE	59	RAD	62	RRC	68
m $\rightarrow$ mi.	56	Pa $\rightarrow$ atm	59	RAD $\rightarrow$	62	RSD	68
m $\rightarrow$ nmi.	56	Pa $\rightarrow$ bar	59	RAM (M)	62	RSUM	68
m $\rightarrow$ pc	56	Pa $\rightarrow$ iHg	59	RANI#	62	RTN	68
m $\rightarrow$ pt.	56	Pa $\rightarrow$ psi	59	RAN#	62	RTN+1	68
m $\rightarrow$ yd.	56	Pa $\rightarrow$ tor	59	RBR	63	RUNIO (S)	110
m <sub>⊕</sub>	56	pc $\rightarrow$ m	59	RCL	63	RUNTIM (S)	110
m <sub>⊖</sub>	56	PERM	59	RCLCFG	63	R-CLR	69
N <sub>A</sub>	56	PER/a (V)	106	RCLEL	63	R-COPY	69
NaN (C)	56	PGMINT	60	RCLIJ	63	R-SORT	69
NAND	56	PGMSLV	60	RCLS	63	R-SWAP	70
NaN?	56	PIXEL	60	RCL+	64	R <sub>∞</sub> (C)	70
NBin	56	PLOT	60	RCL-	64	R <sub>⊕</sub> (C)	70
NBin <sub>e</sub>	56	PMT (V)	106	RCLx	64	R <sub>⊖</sub> (C)	70
NBin <sub>p</sub>	56	P <sub>n</sub>	60	RCL/	64	R $\uparrow$	70
NBin $^{-1}$	56	POINT	60	RCL $\uparrow$	64	R $\rightarrow$ D	70
NBin:	57	Poiss	60	RCL $\downarrow$	64	R $\downarrow$	70
NEIGHB	57	Poiss <sub>e</sub>	60	RDP	64	s	70
NEXTP	57	Poiss <sub>p</sub>	60	Re	64	Sa (C)	70

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SDL 71	STOCFG 76	TONE 79	WSIZE? 83
SDR 71	STOEL 76	ton $\rightarrow$ kg 80	W $^{-1}$ 83
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Se' <sup>2</sup> (C) 72	STOP 76	tor $\rightarrow$ Pa 80	W $\rightarrow$ hp <sub>E</sub> 83
SEED 71	STOS 77	T <sub>p</sub> (C) 80	W $\rightarrow$ hp <sub>M</sub> 83
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SETEUR 72	STO/ 77	TRANS 80	x $^3$ 84
SETIND 72	sto $\rightarrow$ kg 77	TRI (M) 80	XEQ 84
SETJPN 72	STO $\downarrow$ 77	trz $\rightarrow$ kg 80	$\bar{x}_G$ 84
SETSIG 72	STO $\uparrow$ 77	TVM (M) 80	$\bar{x}_H$ 84
SETTIM 72	STRING (M) 77	t(x) 79	xIN 84
SETUK 72	STRI? 77	t $^{-1}$ (p) 79	XNOR 84
SETUSA 72	ST.A (V) 107	t: 80	XOR 84
SF 72	ST.B (V) 107	t $\gtrless$ 80	xOUT 85
Sf $^{-1}$ (C) 72	ST.C (V) 107	ULP? 80	$\bar{x}_{RMS}$ 85
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SIGN 73	ST.X (V) 107	UNITY 81	$\bar{y}$ 85
SIGNMT 73	ST.Z (V) 107	UNSIGN 81	x! 85
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SPEC? 76	TDM (S) 108	Weibl <sub>p</sub> 82	x = -0? 86
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YEAR	87	$\lambda_{cp}$ (C)	91	$\Sigma +$	93	$\nabla$	98
year $\rightarrow$ s	87	$\lambda_{cp}$ (C)	91	$\Sigma -$	93	$ M $	98
YMD (S)	109	$\mu_0$ (C)	91	$\Phi$ (C)	94	$ x $	98
$y^x$	87	$\mu_B$ (C)	91	$\Phi_0$ (C)	94	$  $	99
Y.MD	87	$\mu_e$ (C)	91	$\chi^2_e(x)$	94	%	99
$y \hat{x}$	87	$\mu_e/\mu_B$ (C)	91	$\chi^2_p(x)$	94	%MRR	99
$Z_0$ (C)	87	$\mu_n$ (C)	91	$\chi^2(x)$	94	%T	99
$z \hat{x}$	87	$\mu_p$ (C)	91	$\chi^2:$	94	% $\Sigma$	99
$\alpha$ (C)	88	$\mu_u$ (C)	91	$\omega$ (C)	94	%+MG	99
$\alpha CAP$ (S)	110	$\mu_p$ (C)	91	$(\chi^2)^{-1}$	94	$\sqrt{x}$	100
$\alpha INTL$ (M)	88	$\pi$ (C)	91	$(-1)^x$	94	$\int$	100
$\alpha LENGTH?$	88	$\Pi_n$	91	$[M]^T$	94	$\int f(M)$	100
$\alpha MATH$ (M)	88	$\sigma$	92	$[M]^{-1}$	94	$\int f dx(M)$	100
$\alpha POS?$	88	$\Sigma 1/x$	92	$+ 95$		$\infty$ (C)	100
$\alpha RL$	88	$\Sigma 1/x^2$	92	$+/- 95$		$\nabla 100$	
$\alpha RR$	88	$\Sigma 1/y$	92	$\pm \infty? 95$		$\nabla \rightarrow (M)$	101
$\alpha SL$	88	$\Sigma 1/y^2$	92	$- 95$		$\blacksquare ADV$	101
$\alpha SR$	89	$\sigma_B$ (C)	92	$-\infty 95$		$\blacksquare CHAR$	101
$\alpha \cdot (M)$	89	$\Sigma \ln^2 x$	92	$\times 95$		$\blacksquare DLAY$	101
$\alpha FN$ (M)	89	$\Sigma \ln^2 y$	92	$\times MOD 95$		$\blacksquare LCD$	101
A... $\Omega$ (M)	89	$\Sigma \ln x$	92	$/ 95$		$\blacksquare MODE$	101
$\alpha \rightarrow x$	89	$\Sigma \ln xy$	92	$\wedge MOD 95$		$\blacksquare PROG$	101
$\beta(x,y)$	89	$\Sigma \ln y$	92	$\rightarrow (c) 96$		$\blacksquare r$	102
$\gamma$ (C)	89	$\Sigma \ln y/x$	92	$\rightarrow DATE 96$		$\blacksquare REGS$	102
$\Gamma(x)$	90	$\Sigma_n$	92	$\rightarrow DEG 96$		$\blacksquare STK$	102
$\gamma_{EM}$ (C)	89	$\sigma_w$	92	$\rightarrow D.MS 96$		$\blacksquare TAB$	102
$\gamma_p$ (C)	89	$\Sigma x$	93	$\rightarrow GRAD 96$		$\blacksquare USER$	102
$\gamma_{xy}$	89	$\Sigma x^2$	93	$\rightarrow HR 96$		$\blacksquare WIDTH$	103
$\Gamma_{xy}$	89	$\Sigma x^2 y$	93	$\rightarrow H.MS 96$		$\blacksquare \Sigma$	103
$\delta x$ (L)	90	$\Sigma x^2/y$	93	$\rightarrow INT 96$		$\blacksquare \#$	103
$\Delta v_{Cs}$ (C)	90	$\Sigma x^3$	93	$\rightarrow MUL\pi 96$		#	103
$\Delta \%$	90	$\Sigma x^4$	93	$\rightarrow POL 96$		#B	103
$\varepsilon$	90	$\Sigma x \ln y$	93	$\rightarrow RAD 97$		#DEC (V)	108
$\varepsilon_0$ (C)	90	$\Sigma xy$	93	$\rightarrow REAL 97$			
$\varepsilon_m$	90	$\Sigma x/y$	93	$\rightarrow REC 97$			
$\varepsilon_p$	91	$\Sigma y$	93	$\nabla \lim (V)$	108		
$\zeta(x)$	91	$\Sigma y^2$	93				

## 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 (<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>).</b> 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 SERRw 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> . <b>Changed keyboard layout</b> .
0.6	22.8.17	Merged the Applications and Owner's Manual. Changed the input order of complex number parts on Pauli's request. <b>Changed keyboard layout introducing D.MS, SST, BST, and % while removing ÿ, RAN#, 'FRC, and 'CFIT.</b> 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.
0.7	2.4.18	<b>Changed keyboard layout. Replaced the labels BST by <math>\triangle</math>, SST by <math>\blacksquare\triangledown</math>, and UNDO by <math>\square</math>; added some alpha input mode reminders on the keyboard.</b> Added AGRAPH, CLLCD, EQ.xxx, HYP, J/G, M.GOTO, ORTHOF, PIXEL, POINT, TDISP, and USER. Moved the background considerations out of <i>ReM App. D</i> . Introduced K as alpha register for alphanumeric constants in programs. Removed fraction data type. Extended items from 6 to 7 characters to match HP-42S. Specified

Date	Release notes
	<i>data types more precisely in 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 <u>SUMS</u> in <u>STAT</u> . Renamed the trigonometric and hyperbolic functions according to mathematical standards, and $\blacksquare\text{CHR}$ to $\blacksquare\text{CHAR}$ . 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	Changed keyboard layout: introduced <u>TRG</u> containing trigonometric functions, removed <u>HYP</u> into <u>EXP</u> and $\blacksquare\pi$ to g-shifted $\blacksquare\theta$ , 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. 7.5.18 20.9.18 Corrected errors and inconsistencies. Added one more example. Moved the key response table into an appendix.
0.9	Removed <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 <i>DP</i> numbers and FBR for browsing our two fonts. Split a chapter. Expanded some titles. Added the overlay drawing. Modified functionalities of <u>EXIT</u> and $\blacksquare\frac{1}{x}$ to match <i>HP-42S</i> . Added a chapter about curve fitting. Modified functionalities of <u>ENTER↑</u> and $\blacksquare\int$ . Expanded <i>App. K</i> . Renamed DOUBLE to $\rightarrow\text{DP}$ . Added $\rightarrow\text{SP}$ and conversions of <i>quarts</i> . Rearranged X.FN. Replaced <u>USR</u> by <u>UM</u> . <b>Changed keyboard moving</b> <u>UM</u> , $\blacksquare\text{x}$ , and <u>TRI</u> . Moved $\blacksquare$ to $\blacksquare f$ / $\blacksquare R/S$ . 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. 3.1.19
0.10	Returned <i>angle data type</i> and $\alpha\text{SR}$ . Added IDIVR and VANGLE. Refined FP, IP, IMPFRC, PROFRC, SDIGS?, $\rightarrow\text{DP}$ , $\rightarrow\text{HR}$ , $\rightarrow\text{INT}$ , $\rightarrow\text{REAL}$ , $\rightarrow\text{SP}$ , explanation of ALL, the summary of integer functions, and handling of long alpha strings. Modified contents of <u>CPX</u> , <u>MATX</u> , and $\alpha\bullet$ . 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. <b>Removed <math>\blacksquare</math> from the keyboard</b> . Renamed $X_u$ to $X_e$ for the distributions. 3.3.19

Date	Release notes
0.11 8.5.19	Changed keyboard making <b>CC</b> primary and user mode shifted, removing $x^2$ , $\chi^2$ , 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> , <u>SHOW</u> , <u>STAT</u> , <u>U<math>\rightarrow</math></u> , <u>aMATH</u> , the division matrix, data type conversions, and the <i>Quick Reference Guide</i> . Added conversions of barrels, carats, and fathoms. 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, <u>CLR</u> , and the functions of $\Delta$ and $\nabla$ . Put <u>SUMS</u> instead of <u>RMD</u> 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> , <u>RTN</u> , <u>SHOW</u> , <u>STAT</u> , and <u>a.FN</u> . Rearranged <u>A...<math>\Omega</math></u> and Sect. 2 of the OM.
0.12 16.10.19	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 <b>CC</b> . Refined exiting short integer input. Expanded App. D. Specified maximum size of long integers. Changed keyboard adding $\downarrow$ , moving <u>CPX</u> , <u>FIN</u> , <u>RBR</u> , <u>R<math>\uparrow</math></u> , and <u>SHOW</u> , removing $\%$ . Renamed VANGLE to V $\downarrow$ . Modified <u>CPX</u> , <u>MATX</u> , <u>TRI</u> , and <u>X.FN</u> . Rearranged Section 1 of the OM. Added some internal data types to App. B; reduced the range of long integer results and DP real inputs to $10^{-999}$ . Defined the domains of $e^x-1$ , IDIVR, $\ln(1+x)$ , MOD, and RMD according to the HP-42S; modified PLOT and $\Sigma+$ . Refined the Addressing Tables. Added a data type matrix for IDIVR. Refined the Special Results in App. B.
0.13 30.11.19	Expanded the alpha keyboard and App. I. Modified <u>CPX</u> , <u>INTS</u> , <u>MODE</u> , <u>PROB</u> , <u>STK</u> , <u>TEST</u> , <u>a•</u> , <u>SHOW</u> , and <u>STATUS</u> . Refined the sorting order of items, ALL, CX $\rightarrow$ RE, MEM?, RE $\rightarrow$ CX, RBR, RM, SLVQ, and <u>U<math>\rightarrow</math></u> . Started filling App. F and G. Refined App. 2. Added a long integer example, CPXR?, LZ?, $\Delta v_{CS}$ , conversions of hectares, and a proposal for system status information.
0.14 7.3.20	Introduced system flags for status information. Split I/O. Added <u>CATALOG'SYS.FL</u> , <u>PRINT</u> , <u>PROG</u> , <u>RANI#</u> , <u>VAR</u> , auxiliary constants, some predefined variables, and an index in App. I. Changed keyboard swapping <u>MODE</u> and <u>FLAGS</u> , <u>U<math>\rightarrow</math></u> and <u><math>\downarrow</math><math>\rightarrow</math></u> , moving <u>CPX</u> , <u>FILL</u> , <u>RBR</u> , <u>R<math>\uparrow</math></u> , <u>USER</u> , <u>a.FN</u> , <u>aINTL</u> , <u><math>\sqrt{x}</math></u> , and <u><math>\square</math></u> , displaying <u>PRINT</u> , <u>RMD</u> , <u>STATUS</u> , $x^2$ , and ' $\cdot$ ', and removing

Date	Release notes
	<p><b>c/d</b>, <b>bx</b>, →SP, and →DP. Renamed <u>DISP</u> to <u>DSP</u> and <u>SUMS</u> to <u>Σ</u>, changed <b>g</b> to <b>g</b>. Refined the addressing tables and catalog access, <b>a b/c</b>, <u>ADV</u>, <u>BATT?</u>, <u>BITS</u>, <u>CATALOG'CHARS</u> and <u>'MENUS</u>, CLALL, CLFALL, <u>CPX</u>, <u>EXP</u>, GAP, <u>INTS</u>, I/O, <u>MODE</u>, NEIGHB, <u>PARTS</u>, PRIME?, <u>P.FN</u>, SHOW, <u>STAT</u>, STK, <u>X.FN</u>, <u>gINTL</u>, and <u>ao</u>. Deleted all 16-digit (i.e. SP) data types as well as <u>A...Z</u> and the commands CLK12, CLK24, CPXi, CPXj, CPXRES, CPXR?, DBL?, DENANY, DENFAC, DENFIX, ENGOVR, FAST, IMPFRC, LZOFF, LZON, LZ?, MULTx, MULT-, POLAR, PROFRC, QUIET, RDX., RDX,, REALRE, RECT, SCIOVR, SLOW, SSIZE4, SSIZE8, →DP, and →SP. Corrected.</p>

DRAFT



# 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 **x $\leftrightarrow$  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**  **$\alpha$**  **XYZ** **ENTER↑**. Variable names shall be unique,  $\leq 7$  characters long, and contain  $\geq 1$  letter.

**Flags:** There are 112 global *user flags*, and some 35 named *system flags*.

**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 free memory that is no longer needed.

## DATA TYPES

**Long integers** are the simplest type of data. Any number you enter without using **.**, **E**, **CC**, or **#** 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  $1.23-i\times 4.56$  in rectangular mode (SF RECTN and press **1.23 [CC] 4.56 [+/-] [ENTER]**) or its magnitude and phase like  $-7.89 \angle 120^\circ$  in polar mode (CF RECTN and press **7.89 [+/-] [CC] 120 [ENTER]**).

**Angles:** Any real number input trailed by **.d.ms** is interpreted as an *angle* in *sexagesimal degrees*. Angles may be entered as well in *decimal degrees*, *radians*, *multiples of  $\pi$* , or *gradians*. 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 decimals of *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.mmyyyy for D.MY or mm.ddyyyy for M.DY).

**Matrices:** see pp. vii f.

**Short integers:** Any purely 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 **@**. 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 **+**, **-**, **x**, **.**, 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

MODE	SYSTEM		RM		SETSIG	DENMAX	
	SF	DEG	RAD	GRAD	MULπ	CF	

- SF, CF Set (or clear) a flag.
- DEG Selects *degrees* as angular display mode (*ADM*).
- RAD Selects *radians* as *ADM*.
- GRAD Selects *gradians*, a.k.a. *gon*, as *ADM*.
- MULπ Selects *multiples of π* as *ADM*.
- RM Sets rounding mode.
- SETSIG Sets calculator precision (1 ... 34 significant digits).
- DENMAX Sets the maximum denominator for calculating with fractions.
- SYSTEM Returns the calculator to the *DMCP* system for updating.

## DISPLAY FORMATS

DSP	GAP	CHINA	EUROPE	INDIA	JAPAN	UK	USA	DSTACK
	SDL	SDR				RDP	RSD	
	FIX	SCI	ENG	ALL	ROUNDI	ROUND		

- FIX Fixed number of decimals.
- SCI, ENG Scientific (or engineering) notation.
- ALL Displays all digits required as far as possible.
- ROUND Rounds a *time*, real, or complex *x* to current display format.
- ROUNDI Rounds to next integer.
- RDP Rounds *x* to *n* decimal places (1 ... 99, think of FIX)
- RSD Rounds *x* to *n* significant digits (1 ... 34, think of SCI).
- SDL, SDR Shifts digits left (right) by *n* decimal positions.
- CHINA, EUROPE, INDIA, JAPAN, UK, USA Set local display preferences.
- GAP Selects a digit group gap inserted after every *n* digits.
- DSTACK Sets the number of *stack registers* displayed (1 ... 4).

## 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] PROG** 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 **[ $\equiv$ V]** (or **[ $\nabla$ ]** 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]  $\alpha$  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 **[ $\rightarrow$ ]**. E.g. to display the contents of the variable or *register* specified in **R12**, key in **[VIEW] [ $\rightarrow$ ] 12**. This works with *stack registers* as well.

## CLEARING AND DELETING

CLR	CLall					RESET	
	CLREGS	CLPall	CLFall			CLLCD	CLSTK
	CLΣ	CLP	CF	CLMENU	CLCVAR	CLX	

- 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      (use  or  moves it to next step  
 deletes the *current program step* entirely.

## 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 (cf. p. iv).

**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 binary test step is executed, the program step immediately following said step is executed if the test result is “true”; if the result is “false”, the step following the test step 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 ccccccc being the current counter value, fff 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. xf) 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**  $\alpha$  **name** **ENTER↑** for a matrix in a variable. If the variable already exists, DIM re-dimensions it.

**To edit the matrix in X**, use **[MATX] EDIT**.

**To edit 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  $(A)\vec{X} = \vec{B}$ :

- 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**.
- Press **[Mat A]**; fill the matrix; press **EXIT**.
- Press **[Mat B]**; fill the matrix; press **EXIT**.
- Press **[Mat X]** to compute the solution matrix.

## PROBABILITY

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

Binom:	d	Binomial d.	( $i = p_0$ = gross probability of a success, $j = n$ = sample size)
Cauch:	c	Cauchy-Lorentz (a.k.a. Breit-Wigner) d.	( $i$ = location, $j$ = shape)
Expon:	c	Exponential d.	( $i$ = rate)
F:	c	Fisher's F d.	( $i$ = degrees of freedom 1 ( $dof_1$ ), $j$ = $dof_2$ )
Geom:	d	Geometric d.	( $i = p_0$ )
Hyper:	d	Hyperbolic d.	( $i = p_0$ , $j = n$ , $k$ = batch size)
LgNrm:	c	Log-normal d.	( $i = \mu$ , $j = \sigma$ )
Logis:	c	Logistic d.	( $i = \mu$ , $j$ = scale parameter)
NBin:	d	Negative Binomial d.	( $i = p_0$ , $j = n$ )
Norml:	c	(General) normal d.	( $i = \mu$ , $j = \sigma$ )
Poiss:	d	Poisson d.	( $i = n p_0$ = Poisson parameter)
t:	c	Student's t d.	( $i$ = dof)
Weibl:	c	Weibull d.	( $i$ = shape, $j$ = characteristic lifetime)
$\chi^2$ :	c	Chi-square d.	( $i$ = 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 **UNDO** (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	
		$\bar{x}_{RMS}$					
		$\bar{x}_H$	cov				
	L.R.	r	$s_{xy}$	$\hat{x}$	$\hat{y}$	$x^2$	
STAT	CLΣ	$\bar{x}_G$	$\varepsilon$	$\varepsilon_p$	$\varepsilon_m$	PLOT	
	$\Sigma^-$	$\bar{x}_w$	$s_w$	$s_w$	$s_{mw}$	SUM	
	$\Sigma^+$	$\bar{x}$	s	s	$s_m$	$x^2$	

$\bar{x}$ , s,  $\sigma$ ,  $s_m$  Arithmetic mean value, sample standard deviation (*SD*), population *SD*, standard error (a.k.a. *SD* 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 (*SF*), population *SF*, *SF* of the mean.

$\bar{x}_H$ ,  $\bar{x}_{RMS}$  Harmonic and quadratic mean values.

SUM Returns  $\Sigma x$  and  $\Sigma y$ .

PLOT See the *ReM*.

L.R. Computes the parameters  $a_0$  and  $a_1$  (and  $a_2$ , if applicable) of the fit model selected (see below).

r	Returns the correlation coefficient.
S <sub>xy</sub> , cov	Return the sample or population covariance.
$\hat{x}, \hat{y}$	Return the forecast for x or y according to the fit model selected.
LinF	Linear fit model: $y = a_0 + a_1x$ .
ExpF	Exponential fit model: $\ln(y) = \ln(a_0) + a_1x$ 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, & deriving equations.

**[ADV]** is for programmed summing, multiplying, solving, integrating, & deriving.

### Interactive Operations on Equations



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

ADV	PGMSLV	f''(x)				
SOLVE	SLVQ	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**.

**f1d 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 **[fdx]**. 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 ( $\downarrow LIM$ ), the upper limit ( $\uparrow LIM$ ), and the accuracy factor (ACC).
5. Press **[** 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**.

## OPERATIONS ON SHORT INTEGERS

	1COMPL	2COMPL	UNSIGN	SIGNMT		WSIZE	
LJ					RJ	<th></th>	
SL	RL	RLC	RRC	RR	SR		
SB	BS?	#B	FB	BC?	CB		
NAND	NOR	XNOR		MIRROR	ASR		
AND	OR	XOR	NOT	MASKL	MASKR		

AND, OR, XOR, NAND, NOR, XNOR Boole's binary operators.

NOT Inverts every bit in **X**.

MASKL, MASKR Create masks of  $x$  bits on the left (or right) side.

MIRROR Reflects all bits.

ASR  $n$  Arithmetic shift  $x$  right by  $n$  places.

SB, FB, or CB  $n$  Sets, flips, or clears bit # $n$  in  $x$ .

BS?, BC? Checks if bit # $n$  in  $x$  is set (or clear).

#B Returns the number of bits set in  $x$ .

SL, SR  $n$  Shift  $x$  left (or right) by  $n$  places.

RL, RR $n$	Rotate $x$ left (or right) by $n$ places.
RLC, RRC $n$	Rotate $x$ left (or right) by $n$ places through Carry.
LJ, RJ	Adjust the bits set in $x$ to the left (or right).
1COMPL, 2COMPL	1's (2's) complement mode.
UNSIGN	Unsigned mode.
SIGNMT	Sign-and-mantissa mode.
WSIZE	Sets the word size (1 ... 64 bits).

INTS	1COMPL	2COMPL	UNSIGN	SIGNMT		WSIZE	GCD
	DBL /	DBLR	DBL $\times$	$\wedge$ MOD	CEIL		
	IDIV	RMD	MOD	$\times$ MOD	FLOOR	LCM	
	A	B	C	D	E	F	

A ... F	Digits for short integers of bases >10.
IDIV	$\mathbb{R} \mathbb{Z}$ Integer divide – works for real numbers ( $\mathbb{R}$ ) and long integers ( $\mathbb{Z}$ ) as well.
RMD, MOD	$\mathbb{R} \mathbb{Z}$ Remainder and modulo.
$\times$ MOD	$\mathbb{R} \mathbb{Z}$ Returns $(z \cdot y) \bmod x$ .
$\wedge$ MOD	$\mathbb{R} \mathbb{Z}$ Returns $(z^y) \bmod x$ .
FLOOR	$\mathbb{R}$ Returns the greatest integer $\leq x$ .
CEIL	$\mathbb{R}$ Returns the smallest integer $\geq x$ .
LCM	$\mathbb{Z}$ Returns the least common multiple of $x$ and $y$ .
GCD	$\mathbb{Z}$ 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.

a.FN	FBR			αLENG?	αPOS?		
		x→α	αRL	αRR	αSL	αSR	α→x

- $x \rightarrow \alpha \ s$  Converts a code  $x$  to the corresponding character and appends it to the string in  $s$ .
- $\alpha RL, \alpha RR \ s$  Rotates the string in  $s$  by  $x$  characters to the left (or right).
- $\alpha SL, \alpha SR \ s$  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.
- $\alpha LENG? \ s$  Pushes the length of the string in  $s$  on the stack.
- $\alpha POS? \ s$  Returns the position where substring  $x$  begins in the string in  $s$ .
- FBR Displays all characters defined in both fonts.

DRAFT

## BACKGROUND CONSIDERATIONS AND FACTS

This section is for recording and explaining some of the boundary conditions considered and the settings chosen for the *WP 43S* in the course of this project. It is not necessary for operating the *WP 43S* but may foster understanding.

### Accessing Items

The hardware offers 43 keys for some 750 *items*. Subtract six for the *softkeys*. Space for primary functions is quickly occupied. These functions are mostly set. For the remaining set, secondary functions compete with *menus*.

Obvious primary functions are **0** ... **9**, **.**, **ENTER↑**, **x $\geq$ y**, **±L**, **E**, **⬅**, **+**, **-**, **×**, **/**, **STO**, **RCL**, **XEQ**, **R/S**, **▲** and **▼**, **EXIT**, **f** and **g**, taking 29 key tops. So eight locations are left. Once you want to deal with complex numbers seriously, you need a primary **CC**.

Other functions may be debated: **R↓**, **1/x**, **y<sup>x</sup>**, **x<sup>2</sup>**, **fx**, **e<sup>x</sup>**, **In**, **10<sup>x</sup>**, **Ig**, **sin**, **cos**, and **tan** are most popular – twelve candidates for seven key tops left. Either **x<sup>2</sup>** or **fx** shall be primary (we chose **x<sup>2</sup>**); and we can ditch **10<sup>x</sup>** and **Ig** when we have **e<sup>x</sup>** and **In**. So **R↓**, **1/x**, **y<sup>x</sup>**, **sin**, **cos**, and **tan** compete for the remaining four key tops. We chose the first three and put the latter three (and their inverses) under one primary *menu* key: **TRI**; thus, you can access each of **sin**, **cos**, **tan**, **arcsin**, **arccos**, and **arctan** with two keystrokes maximum.

The losing candidates **fx**, **10<sup>x</sup>**, and **Ig** shall become secondary functions. But is it better having them as shifted keyboard functions or unshifted *softkeys*? No definite answer can be given here since it depends on the time the respective *menu* will stay on screen. For these particular functions, we made all three **g**-shifted and put **fx** also in the unshifted row of **EXP**.

The *WP 43S* features 33 *menus* on its keyboard. Of these, CATALOG, CNST, U→, and the three alpha *menus* must be separated since they

follow special rules. Each of the remaining 27 menus offers six unshifted locations for its most popular items. Selecting these can be easy (like in STK, ADV, LOOP, or TRI) or more difficult (like in P.FN or X.FN).

Besides  $\sqrt{x}$ , only **SF**, **CF**, **|x|**, and **4** are also featured as shifted keyboard functions **SF**, **CF**, **|x|**, and **4**. Accessing **|x|** or **4** needs two keystrokes while **|x|** and **4** require four maximum (and two if the menu is open). Also **SF** and **CF** need two keystrokes but **SF** and **CF** require three maximum (and only one if FLAGS is open already). In consequence, **|x|** and **4** are actually not needed but left in CPX and PARTS since sufficient space is available there.

## Alpha Register

For long I thought we could do without a dedicated *alpha register* since each and every *register* is capable holding an alpha string. 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 real numbers’. 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*). They 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 depending on *integer sign modes* and bases selected. *Radians*, however, did not fit into this concept due to the necessity for high precision storage of  $\pi$  for modulo calculations and reduction of 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  $2\pi$  suffice to warrant 16 digits accuracy of respective function results for the number range of *single precision* reals.<sup>83</sup> *WP 43S* uses 1065 digits for  $2\pi$  to warrant 34 digits accuracy of respective function results within  $\pm 10^{999}$ .

## Backward Compatibility

Compatibility to *WP 34S* and *HP-42S* was kept for many years in a way that programs written for both calculators could run on the *WP 43S* as well (except matrix operations and some flag allocations). It became difficult with the full implementation of the *data type* concept and was eventually abandoned officially when introducing named *system flags* with v0.14.

## 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

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<sup>83</sup> See <https://forum.swissmicros.com/viewtopic.php?f=2&t=350#p4349> .

numbers – following *ISO 80000-1* for an unambiguous numeric display. This font is generally used for numeric output of the *WP 43S*. It is also employed for echoing numeric input unless too long. It can be used for echoing command input as well – screen space suffices.

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 fraction numerators. 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. xix ff).

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 a few exceptions: see e.g. the multiplication dot at  $00B7_{16}$  and the root symbols in row  $2210_{16}$ .

Characters with codes  $< 0020_{16}$  are for control purposes; some of them ( $4_{10}$ ,  $10_{10}$ ,  $27_{10}$ ) may be useful for printer control (e.g. of an *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 at right with their hex addresses and their widths). Using them, any spacing is feasible.

	Character code	px
Standard space	$20_{16}$	10
m space	$2003_{16}$	12
m/3 space	$2004_{16}$	4
m/4 space	$2005_{16}$	3
m/6 space	$2006_{16}$	2
Figure space	$2007_{16}$	8
Punctuation sp.	$2008_{16}$	4
Hair space	$200A_{16}$	1

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, Slovenčina, Slovensky, Srpski, Suomi, Svenska, Tagalog, Tatarça, Türkçe, Türkmençe, Vlaams, Wallon, 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.

Turn to the OM for examples where these characters are used.<sup>84</sup> See here some sample strings in either font, approximately to a common realistic scale:

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

## Complex Infinities

Since infinities are counted as numeric data being part of the real number range (see p. 172), also complex infinities are part of the complex number plane the WP 43S operates on. Coming from rectangular notation, there are eight ‘complex infinities’ possible only:

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<sup>84</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.

$\text{Re}(z)$	$\text{Im}(z)$	$r(z)$	$\varphi(z)$	
$-\infty$	$-\infty$	$\infty$	$-135^\circ$	$-\frac{3\pi}{4}$
0	$-\infty$	$\infty$	$-90^\circ$	$-\frac{\pi}{2}$
$\infty$	$-\infty$	$\infty$	$-45^\circ$	$-\frac{\pi}{4}$
$\infty$	0	$\infty$	$0^\circ$	0
$\infty$	$\infty$	$\infty$	$45^\circ$	$\frac{\pi}{4}$
0	$\infty$	$\infty$	$90^\circ$	$\frac{\pi}{2}$
$-\infty$	$\infty$	$\infty$	$135^\circ$	$\frac{3\pi}{4}$
$-\infty$	0	$\infty$	$180^\circ$	$\pi$

Note the phase is counted counterclockwise, starting with  $\varphi = 0$  at positive real axis.

Calculating with infinities, any finite numbers may be neglected in comparison; so for  $|x| \neq \infty$  any inputs like e.g.  $x + i \times \infty$  may be replaced by  $0 + i \times \infty$ , easing calculations significantly. Actually, you will have to deal with the eight cases listed above only.<sup>85</sup>

## Complex Notation and Storage

Like with angles or short integers, there are different ways a complex number can be written: either in Cartesian or polar notation, the latter with all kinds of angular units. As long as you stay away from infinities, any notation will do (cf. previous chapter).

For reasons of mathematical tradition, rectangular notation is found most frequently. We used it for storing complex numbers in the

<sup>85</sup> Following an article of HP about the HP-71, complex infinities should be treated in polar notation (see <http://hparchive.com/Journals/HPJ-1984-07.pdf>, p. 27, left column for the reasons).

WP 34S. Thus, it is used for the WP 43S as well, but care must be taken at complex infinities as explained in previous chapter.

## Display Limits

Due to the character sizes and their design (cf. pp. xvii f), 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 hardly be readable. With 3-digit separators (*startup default*), 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>86</sup>

With SHOW, any real number can be displayed with 34-digits precision in a single row:

2020-01-06 17:28 CL<sub>E</sub>4<sup>r</sup> /max 64:2 A S<sub>L</sub>  
-1.428 571 428 571 428 571 428 571 428 571 429 $\times 10^{-235}$   
  
10 000 001  
10 000 064 000 201 600 416 640 635 376 762 451 950 $\times 10^{411}$   
-1.428 571 428 571 429 $\times 10^{-235}$

Some *temporary information* may limit output precision, though without limiting its use for real-world applications. E.g. for linear regression, up

<sup>86</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.

to 8 digits are viable allowing for 2-digit exponents in SCI or ENG and up to 12 digits in FIX:

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

**Complex numbers** in Cartesian notation require  $1 + 15 + 12 + 15 + 1 = 44$  px for  $+jx$  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:

$$\begin{aligned} & -6.234\ 5 \times 10^{-925} + i \times 6.234\ 5 \times 10^{-925} \\ & -6.234\ 56 \cdot 10^{-925} + i \cdot 6.234\ 56 \cdot 10^{-925} \end{aligned}$$

With SHOW, any complex number can be displayed with 34 digits precision:

2020-01-06 17:15 CL<sub>4</sub><sup>r</sup> /max 64:2 A  $\bar{4}$  S  
-8.403 361 344 537 815 126 050 420 168 067 229 $\times 10^{-126}$   
-i $\times$ 5.882 352 941 176 470 588 235 294 117 647 059 $\times 10^{-158}$

$$-8.403 \times 10^{-126} - i \times 5.882 \times 10^{-158} \quad -1. \times 10^{-33}$$

Complex numbers in **polar notation** need  $4 + 16 + 4 = 24$  px for  $\frac{4}{4}$  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:

$$-4.234\ 567\ 8 \angle -0.234\ 567\ 8\pi$$

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  $-200^\circ$  to  $+200^\circ$  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*:

$$-4.234\ 5 \times 10^{-925} \angle -120.234\ 5^\circ$$

For *radians* or *multiples of  $\pi$* , however, 5 decimals are displayable always at least:

$$-4.234\ 56 \times 10^{-925} \angle -0.234\ 56\pi$$

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 the usual large digits:

-123 456 789 012 345 678 901 ,

taking  $(1 + 15 + 21 \times 16 + 6 \times 8 = 400 \text{ px})$ . Larger *long integers* 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* may be 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 $\times 10^{21}$  .

With SHOW, one *long integer* may take up to 7 rows meaning 294 digits.  $\text{Long integers} \geq 10^{294}$  shall be trailed by an exponent again taking  $9 + 13 + 3 \times 8 = 46 \text{ px}$  in worst case; thus, display precision may be reduced to 288 digits minimum then:

2020-01-06 17:20 CL4r /max 64:2 A Ȑ S  
100 000 320 000 496 000 496 000 359 600 201 376 090 619 2  
33 658 570 518 302 804 880 645 122 529 024 502 579 287 47  
3 736 471 435 656 572 278 010 804 465 722 767 143 563 473  
736 225 792 852 902 448 645 122 428 048 801 051 830 033  
658 560 906 192 020 137 600 359 600 004 960 000 049 600 0  
00 320 000 001

2020-01-06 17:22 CL4r /max 64:2 A Ȑ S  
10 000 064 000 201 600 416 640 635 376 762 451 949 744 30  
1 216 634 616 812 205 996 593 289 175 611 024 560 167 423  
597 795 591 072 087 154 275 016 633 545 248 630 060 887  
595 709 345 161 126 819 915 383 185 691 423 735 290 107 2  
59 571 090 772 323 598 587 085 564 911 661 593 733 567 97  
4 201 161 434 343 572 772 188 085 733 555 689 437 511 105  
995 105 806 963 778 061 809 682 674 493 540 378 $\times 10^{156}$

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:

1111 1100 0000 1111 0000 1111 1100 0000 1111 1100 0000 1111 1100 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	21 <i>bits</i>	25 <i>bits</i>	44 <i>bits</i>	64 <i>bits</i>
3	31 <i>bits</i>	38 <i>bits</i>		
4	38 <i>bits</i>	44 <i>bits</i>		
5	46 <i>bits</i>	55 <i>bits</i>		

Base ▼	Allowable size of digits for display			
	large	narrow	small	special
6	51 bits	62 bits	64 bits	
7	56 bits			
8	57 bits	64 bits		
> 8	64 bits			

One row of four arbitrary **real matrix elements** (with absolute values  $< 10^{100}$ ) takes 399 px in small font, SCI 3:

$$\lceil -6,609 \cdot 10^{-19} \quad -6,609 \cdot 10^{-19} \quad -1,609 \cdot 10^{-19} \quad -1,609 \cdot 10^{-19} \rceil$$

using multiplication dots. Else you will lose one decimal. A slightly different notation allows for SCI 4:

$$\lceil -6.609 \cdot 2E^{-19} \quad -6.609 \cdot 2E^{-19} \quad -1.609 \cdot 2E^{-19} \quad -1.609 \cdot 2E^{-19} \rceil$$

Matrices with more than four columns will need ellipses added on one or both sides:

$$\lceil \dots \quad -6,609 \cdot 2 \cdot 10^{-19} \quad -6,609 \cdot 2 \cdot 10^{-19} \quad -1,609 \cdot 2 \cdot 10^{-19} \quad \dots \rceil .$$

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

$$\lceil \dots \quad -6.609 \cdot 226+i \cdot 6.609 \cdot 226 \quad -1.609 \cdot 226+i \cdot 1.609 \cdot 226 \quad \dots \rceil$$

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 RE4π /3 546f 64:u0 A ☰①↑↓□□□
```

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 already. 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*, or
  - c) up to 7 rows of numeric output of *SHOW*, and
- 69 px maximum for the menu section.

2017-05-08 23:49
-12 345 67
-9.234 56
-5.678 901
010 1100 0
ABCDEF   B
B
C

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. xvii f). 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→, extra-large labels may appear (cf. p. 135): 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. p. xvii) 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?)
- With SHOW, also pure numeric output may require more than one row – the small font will be used there as well. Cf. pp. 73 and xxiv.

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.

## Layouting

Based on our experience gained with the *WP 34S* and following a poll on the forum of the *Museum of HP Calculators* about general preferences for the placement of the four arithmetic operators on an undefined portrait *RPN* calculator (see <https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234505>), I published the basic concept and a first keyboard layout for the *WP 43S* on said forum in November 2012 (see <https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234685>). The picture at left shows the last layout before said post.

Everything thereafter was and is just refinement and careful tuning



of the basic idea. It even survived an hardware change – we were waiting for *Eric Smith's* and *Richard Ottosen's Reptiles* (see the HPCC meetings until 2015) still when *Michael* mailed me the concept of his and *David's DM42* in March 2016. Actually, the *DM42* development overtook the *WP 43S* – it was launched in the market late in spring 2017 while the *Pauli* and me were looking for willing software engineers and actual support still in vain.

## 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.

## Number Range

A number range up to  $10^{99}$  is sufficient for almost all real-world problems – else common scientific calculators would feature a larger numeric range generally. So we can conclude that the real number range (see p. 168) suffices by far for solving what has to be solved. For sake of consistency, maximum numbers of different *data types* should match. I.e. the maximum absolute value allowed for a long integer should be approximately equal to the respective values for a real and a complex number.

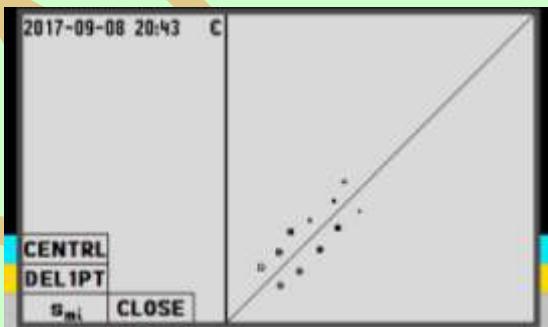
Note the number range determines the precision required for calculating accurately (see *Precision and Accuracy* on p. xxxiv).

## 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 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 sketch (to scale) for general screen layout and various data point symbols for checking visibility.

CLLCD was 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 axis and line can also be created using AGRAPH and PIXEL.

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, cf. GRAMOD on p. 106):

<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  $45^\circ$  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 in this almost quadratic drawing area then, using the commands AGRAPH, CENTRL, CLLCD, CLOSE, PIXEL, PLOT, POINT, and  $s_{mi}$ .

## Precision and Accuracy

As mentioned above 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 a real number deviates from the truth by more than  $3 \times 10^{-35}$ . During calculations, such errors accumulate as elaborated e.g. in footnote 64.

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  $9^\circ$ , you can nevertheless get 28-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, the *WP 43S* works with 39 digits internally and rounds the results to 34 digits as well. *SLVQ* calculates using 72 digits internally.

Luckily, real-world problems are usually far less precisely defined than the internal precision of the *WP 43S*. Compare the set of physical and astronomical constants provided (see pp. 135ff).

## Prefixes

Prefixes  and  passed without any discussion for over six years until 2019-06. Alternatively, prefixes  and  could have been chosen but their typography leaves less freedom for label placing.

## Sorting in Detail

There is no international standard for sorting characters; we had to invent our own order. Sorting of *items*, variable *names*, alphanumeric strings, *system flags*, etc. on the *WP 43S* works as listed below, top down and left to right.

Note that sorting is a two-step procedure: step 1 sorts the alphanumeric strings under consideration just according to column 1 of this table, comparing them; if two strings are rated equal in this aspect, step 2 takes the columns following into account:<sup>87</sup>

0020	2003	2004	...	2007	2008	200a
0030	220e	00b0	02070	02080		
0031	2027	½ 00bd	¼ 00bc	1 00b9	1 2071	1 2081
						1 2460
0032	00b2	2082	2461			
0033	00b3	2083	2462	3✓ 221b		
0034	2074	2084	2463			
0035	2075	2085	2464			
0036	2076	2086	2465			
0037	2077	2087	2466			
0038	2078	2088	2467			
0039	2079	2089	2468			
2491	2469					
246a						
246b						
246c						
246d						
246e						
246f						

<sup>87</sup> Applying this algorithm, a section of CATALOG'FCNS looks like e.g. **s, SAVE, SB, SCI, SCIOVR, scw→kg, ..., SLVQ, s<sub>m</sub>, SMODE?, s<sub>mw</sub>, SOLVE, ...**

The 4-digit number trailing each character in the table is its hexadecimal *Unicode*. Characters printed on grey background are inaccessible for users; those printed on darker grey are not used at all so far.

Sorting is illustrated for the small font here. It holds also for the large font as far as characters are applicable.

<b>A</b> 0041	<b>a</b> 0061	<b>ä</b> 00aa	<b>A</b> 24b6	<b>a</b> 2090	<b>a</b> 249c	
	<b>À</b> 00c0	<b>à</b> 00e0	<b>Á</b> 00c1	<b>á</b> 00e1	<b>Á</b> 00c2	<b>â</b> 00e2
	<b>Ã</b> 00c3	<b>ã</b> 00e3	<b>Ä</b> 00c4	<b>ä</b> 00e4	<b>Ä</b> 00c5	<b>â</b> 00e5
	<b>Æ</b> 00c6	<b>æ</b> 00e6	<b>Ā</b> 0100	<b>ā</b> 0101	<b>Ā</b> 0102	<b>ă</b> 0103
					<b>Ą</b> 0104	<b>ą</b> 0105
<b>B</b> 0042	<b>b</b> 0062	<b>B</b> 24b7	<b>b</b> 249d			
<b>C</b> 0043	<b>c</b> 0063	<b>c</b> 24b8	<b>c</b> 249e	<b>Ç</b> 00c7	<b>ç</b> 00e7	
	<b>Ć</b> 0106	<b>ć</b> 0107	<b>Ć</b> 010c	<b>ć</b> 010d	<b>Ć</b> 2102	<b>ć</b> 2201
<b>D</b> 0044	<b>d</b> 0064	<b>d</b> 24b9	<b>d</b> 249f	<b>Đ</b> 00d0	<b>đ</b> 00f0	
			<b>Đ</b> 010e	<b>d'</b> 010f	<b>Đ</b> 0110	<b>đ</b> 0111
<b>E</b> 0045	<b>e</b> 0065	<b>E</b> 24ba	<b>e</b> 2091	<b>e</b> 24a0	<b>È</b> 00c8	<b>è</b> 00e8
	<b>É</b> 00c9	<b>é</b> 00e9	<b>Ê</b> 00ca	<b>ê</b> 00ea	<b>Ë</b> 00cb	<b>ë</b> 00eb
	<b>Ē</b> 0112	<b>ē</b> 0113	<b>Ē</b> 0114	<b>ě</b> 0115	<b>Ē</b> 0116	<b>ě</b> 0117
	<b>Ę</b> 0118	<b>ę</b> 0119	<b>Ě</b> 011a	<b>ě</b> 011b	<b>Ę</b> 2073	
<b>F</b> 0046	<b>f</b> 0066	<b>f</b> 24a1	<b>f</b> 24bb			
<b>G</b> 0047	<b>g</b> 0067	<b>g</b> 24a2	<b>g</b> 24bc	<b>Ğ</b> 011e	<b>ğ</b> 011f	
<b>H</b> 0048	<b>h</b> 0068	<b>h</b> 210e	<b>h</b> 24a3	<b>ჼ</b> 24bd	<b>ჼ</b> 2095	
					<b>ჼ</b> 0127	<b>ჼ</b> 210f
<b>I</b> 0049	<b>i</b> 0069	<b>I</b> 24be	<b>i</b> 24a4	<b>İ</b> 00cc	<b>İ</b> 00ec	
	<b>Í</b> 00cd	<b>í</b> 00ed	<b>Í</b> 00ce	<b>í</b> 00ee	<b>İ</b> 00cf	<b>ï</b> 00ef
	<b>Ī</b> 012a	<b>ī</b> 012b	<b>Ī</b> 012c	<b>ī</b> 012d	<b>İ</b> 012e	<b>ï</b> 012f
					<b>İ</b> 0130	<b>ı</b> 0131
<b>J</b> 004a	<b>j</b> 006a	<b>J</b> 24bf	<b>j</b> 24a5			
<b>K</b> 004b	<b>k</b> 006b	<b>K</b> 24c0	<b>k</b> 24a6	<b>k</b> 2096		
<b>L</b> 004c	<b>l</b> 006c	<b>L</b> 24c1	<b>l</b> 24a7	<b>l</b> 2097	<b>Ľ</b> 0139	<b>ľ</b> 013a
			<b>Ľ</b> 013d	<b>ľ</b> 013e	<b>Ľ</b> 0141	<b>ľ</b> 0142
<b>M</b> 004d	<b>m</b> 006d	<b>M</b> 24c2	<b>m</b> 24a8	<b>m</b> 2098		
<b>N</b> 004e	<b>n</b> 006e	<b>N</b> 24c3	<b>n</b> 24a9	<b>n</b> 2099	<b>Ń</b> 00d1	<b>ń</b> 00f1
	<b>Ń</b> 0143	<b>ń</b> 0144	<b>Ń</b> 0147	<b>ń</b> 0148	<b>Ń</b> 2115	

<b>O</b> 004f	o 006f	ø 00ba	ö 00a9	ó 24c4	ö 24aa	ø 2092
	ò 00d2	ò 00f2	Ó 00d3	ó 00f3	ò 00d4	ò 00f4
	õ 00d5	õ 00f5	Ö 00d6	ö 00f6	õ 00d8	ø 00f8
	õ 014c	õ 014d	Õ 014e	õ 014f	Œ 0152	œ 0153
<b>P</b> 0050	p 0070	p 24c5	p 24ab	p 209a		
<b>Q</b> 0051	q 0071	q 24c6	q 24ac	Q 211a		
<b>R</b> 0052	r 0072	r 24ad	r 24c7	Ŕ 0154	ŕ 0155	Ŕ 0158
					ř 0159	Ŕ 211d
<b>S</b> 0053	s 0073	s 24c8	s 24ae	s 209b	Ś 015a	ś 015b
	ſ 015e	ſ 015f	Š 0160	ſ 0161	þ 00df	
<b>T</b> 0054	t 0074	t 24af	t 22a4	t 24c9	t 209c	
			ṭ 0162	ṭ 0163	ෂ 0164	ෂ 0165
<b>U</b> 0055	u 0075	u 24ca	u 24b0	u 1d64	Ù 00d9	ù 00f9
	ú 00da	ú 00fa	Ú 00db	ú 00fb	Ü 00dc	ü 00fc
	ő 0168	ő 0169	Ő 016a	ő 016b	Ǚ 016c	ǚ 016d
			Ӯ 016e	Ӯ 016f	ӿ 0172	ӿ 0173
<b>V</b> 0056	v 0076	v 24cb	v 24b1			
<b>W</b> 0057	w 0077	w 24cc	w 24b2	Ŵ 0174	ŵ 0175	
<b>X</b> 0058	x 0078	x 1d61	x 24cd	x 24b3	x 2093	
			Ӯ 0379	Ӯ 0378	Ӯ 037f	Ӯ 221c
<b>Y</b> 0059	y 0079	y 24ce	y 24b4	Ŷ 00dd	ÿ 00fd	
	ÿ 0176	ÿ 0177	Ŷ 0178	ÿ 00ff	ÿ 0233	ÿ 0232
<b>Z</b> 005a	z 007a	z 24cf	z 24b5	Ž 0179	ž 017a	ž 017b
			ڇ 017c	ڇ 017d	ڇ 017e	ڇ 2124
<b>A</b> 0391	α 03b1	α 2065	ά 03ac			
<b>B</b> 0392	β 03b2					
<b>Γ</b> 0393	γ 03b3					
<b>Δ</b> 0394	δ 03b4	δ 2066				
<b>E</b> 0395	ε 03b5	é 03ad				

<b>Z</b>	0396	<b>ζ</b>	03b6						
<b>H</b>	0397	<b>η</b>	03b7	<b>ń</b>	03ae				
<b>Θ</b>	0398	<b>ϑ</b>	03b8						
<b>I</b>	0399	<b>ι</b>	03b9	<b>í</b>	03af	<b>ī</b>	03aa	<b>ī</b>	03ca
<b>K</b>	039a	<b>κ</b>	03ba						
<b>Λ</b>	039b	<b>λ</b>	03bb						
<b>M</b>	039c	<b>μ</b>	03bc	<b>μ</b>	00b5	<b>μ</b>	2067		
<b>N</b>	039d	<b>ν</b>	03bd						
<b>Ξ</b>	039e	<b>ξ</b>	03be						
<b>Ω</b>	039f	<b>ο</b>	03bf	<b>ó</b>	03cc				
<b>Π</b>	03a0	<b>Π</b>	220f	<b>π</b>	03c0				
<b>P</b>	03a1	<b>ρ</b>	03c1						
<b>Σ</b>	03a3	<b>σ</b>	03c3	<b>ς</b>	03c2				
<b>Τ</b>	03a4	<b>τ</b>	03c4						
<b>Υ</b>	03a5	<b>υ</b>	03c5	<b>ύ</b>	03cd	<b>΍</b>	03ab	<b>ύ</b>	03cb
<b>Φ</b>	03a6	<b>φ</b>	03c6						
<b>Χ</b>	03a7	<b>χ</b>	03c7						
<b>Ψ</b>	03a8	<b>ψ</b>	03c8						
<b>Ω</b>	03a9	<b>ω</b>	03c9	<b>ώ</b>	03ce				
(	0028	)	0029						
[	005b	Γ	23a1		23a2		23a3		
]	005d	]	005d		23a4		23a5		23a6
{	007b	}	007d						
+	002b	+	207a	+	208a	±	00b1		
-	002d	-	207b	-1	2072	-	208b	±	2213
×	00d7	·	00b7	•	2219	◦	2218	*	002a
/	002f	\	005c					*	208f
^	005e								

,	002c	,	2429				
.	002e	.	2428	...	2026		
!	0021	!	00a1				
?	003f	?	00bf				
:	003a	:	2236	÷	00f7		
;	003b						
'	0027	'	2018	'	2019	,	201a
"	0022	"	201c	"	201d	,,	201e
@	0040						
-	005f	-	2427				
~	007e						
→	2192	→	21c0				
←	2190	←	21cd				
↑	2191	↑	21e7	△	21c9	↑	242b
↓	2193	↓	21e9	▽	21cb		
↗	21c4						
↖	2195						
☰	21cc						
¬	00ac						
▲	2227	▼	2228	▼	22bb	▲	22bc
&	0026						
	007c		2223		2224		2225
«	226a	<	003c	≤	2264	≡	2261
		≈	2248	≥	2258	≥	2259
						=	2254
						=	003d
						≈	2243
						≥	2265
						>	003e
							»
							226b
%	0025	\$	0024	€	20ac	¢	00a2
✓	221a	✗	221d				
♾	221e	♾	209e	♾	209f		
ʃ	222b	ʃ	222c	ʃ	222e	ʃ	222f

⌚	2299	⌚	229a	⌚	2068								
⊕	2295	⊕	2069										
↳	221f	↳	22a5										
↶	2220	↶	2221										
↑	2308	↑	2309										
↳	230a	↳	230b										
☒	2399	☒	231b	⌚	231a	⌚	242a	⌚	242c	⌚	242f		
#	0023												
UK	242d	US	242e										
▼	2200	▼	2202	Ǝ	2203	♯	2204	♾	2205	▲	2206	▼	2207
		Ǝ	2208	♯	2209	Ǝ	220b	♯	220c	♾	2229	U	222a
↳	2422	↙	2423	↙	2425	↙	2426						
✓	2713												

## Stack Size

At a very early stage of this project (2013), *stack size* was discussed. 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). In this context 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. At the bottom line, eight *stack registers* turn out being sufficient for solving any real-world mathematical, scientific, or engineering problem (cf. Section 1 of the OM and also the field experience with WP 34S and WP 31S since 2011).

After all, we decided sticking to *RPN* as implemented on the WP 34S and WP 31S. It covers everything needed most easily. 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*,  $\Sigma+$ , and  $\Sigma-$  disable *automatic stack lift*, all other functions enable it. But compare *INPUT* on p. 42.

## Structured Programming

In 2013, I suggested the following control structures:

- IF ... THEN ... ELSE ... END,
- FOR ... FROM ... TO ... END,
- REPEAT ... UNTIL, and
- 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; and
- WHILE ... DO BEGIN ... END;

We refrained from implementing such commands since we had doubts about the sensibility of mixing keystroke programming and structured programming features.

## UNDO

In 2013, UNDO was planned as it works in *HP-48*, recalling just 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 before executing last command. It turned out that such a complete

UNDO was viable on the WP 43S, too, so we implemented it for better user experience.

DRAFT