



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

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The pictures on p. 154 and bottom of p. 155 were kindly supplied by SwissMicros as well as the drawing on p. 216, the picture on p. 214 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*

DRAFT

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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*

## 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. specific 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).

*ASL* = automatic stack lift (see Section 1 of the OM).

*BCD* = binary coded decimal.

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

*DT* = data type (see *Appendix B*).

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

*GP* = general purpose.

*HP* = *Hewlett-Packard*.

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

*LCD* = liquid crystal display.

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

*OH* = Owner's Handbook.

*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.

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

*SRS* = subroutine return stack (see *App. B* on pp. 158ff).

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

Some more abbreviations may be used and explained locally.

## **SECTION 1: INDEX OF ITEMS (10)**

All the *items* provided on your WP 43S (more than 850) are listed below with their *names* (as they are displayed and printed in routines) in column 1 and in column 2 the keystrokes necessary to call them. Most *items* shall be picked from *menus* (see pp. 112ff). For such *items*, we list the keys calling the respective *menu*, the *prefix* of the respective row (if applicable), and the label as shown therein; we are confident you will find the corresponding *softkey*. *Items* stored in CONST are listed with their *names* only since they are sorted alphabetically and will be explained in detail in a separate chapter below.

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 printed on the bezel or displayed in *menus*, featuring less or more characters than its *name* (see some unit conversions, for example). These labels are not required to be unique.<sup>1</sup>

On your WP 43S, sorting (e.g. of *names*) works in the following order:<sup>2</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 *HP* 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

<sup>1</sup> Actually, there are two separate sets of *items*: set 1 contains commands, constants, *menus*, global program labels, and reserved symbols; set 2 is for *registers*, *system flags* and variables. The *name* of each *item* must be unique in its set.

<sup>2</sup> Characters printed on grey background are inaccessible for users for the time being. The entire sorting table covering all characters is printed in an appendix.

specified otherwise. Also for functions inspired by other vintage calculators as mentioned in the index below, their manuals may contain helpful additional information.

Some 300 functions featured in your *WP 43S* are new compared to *HP's RPN* pocket calculators. Operations carrying familiar *names* but deviating in their functionality from previous *HP RPN* calculators or the *WP 34S* are marked light red.<sup>3</sup>

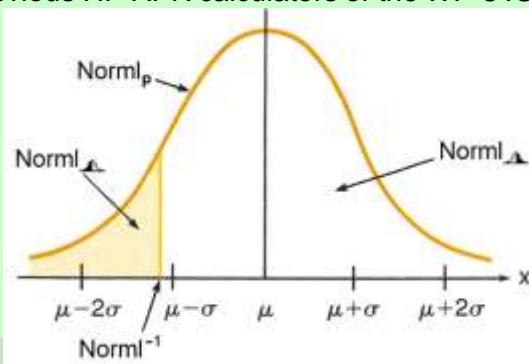
Operations working with the accumulated statistical data are marked light blue. For probability distributions, the naming rules are as pictured here for the *normal distribution* (cf. the OM).

Operations whose results are reflected in the *status bar* are printed on grey in the first column. Commands asking for your confirmation are printed red. Those printed red or orange cannot be undone or reverted by UNDO.

All operations may be also entered in *PEM* unless marked violet – on the other hand, the majority of functions contained in P.FN and TEST carry most use in *PEM*.

For the vast majority of operations, their remarks in the table start with a number representing:

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



<sup>3</sup> We did neither compare the *RPL* calculators nor the *HP Prime*. They are exceeding the realm of shirt pocket calculators.

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>

Operation or function **parameters** will be taken from the lowest *stack register(s)* unless mentioned explicitly in column 2 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**.

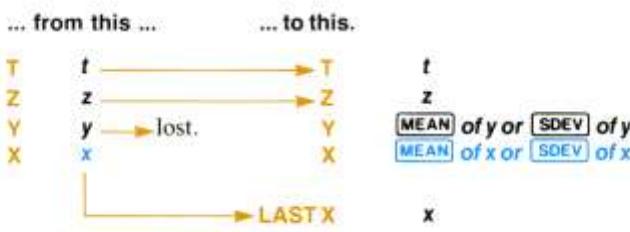
1. **n** represents an arbitrary integer number which must be keyed in directly, while
  - n** represents such a number which may be specified indirectly via a *register* or variable as well (as shown in the addressing tables in *Section 1* of the *OM*); and
  - n** stands for the respective number itself;

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

---

<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 *WP 43S* we stick to the paradigm as implemented on the *Voyagers* in this matter (as we did for *WP 34S* and *31S* before).

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. **labl** represents an arbitrary program label which must be keyed in directly or picked from a *menu*, while  
**labl** represents such a label which may be specified indirectly (as shown in the addressing table in *Section 3* of the OM); and  
**labl** 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 → X** and it will take its parameter from **X** instead – like a good old traditional *RPN* command.

The *data types* a particular function operates on are listed in { } under “remarks” if there are any restrictions – cf. *App. B* on pp. 158ff. Many bit and integer functions make only sense operating on *short integers* (*DT 10*). Other functions typically work with more *DTs*. Functions stating *DTs 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 *DTs* differing from their input, the output types are listed as well.<sup>5</sup>

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

Some functions operating on *long integers* will return either such integers or *reals*, depending on the input value. E.g.  $\sqrt[3]{x}$  will return 3 for an input of 27, i.e. for a proper

ASL is enabled after each command except the following:

1. After CLX, ENTER $\uparrow$ ,  $\Sigma+$ , and  $\Sigma-$  it is disabled (cf. Sect. 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>6</sup>
2. The following (neutral) commands leave stack lift status as is: xxx

Below, the functions checked already are highlighted green, those which don'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 yet isn't highlighted at all. This applies to the respective *DTs*.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	  etc.	(1) {2}; {1} → {2} Convert temperatures. See pp. 137ff.
$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$		
$10^x$		(1) {1, 2, 3, 8*, 9*, 10} Returns $10^x$ , the inverse of $\lg(x)$ .
<b>1COMPL</b>	 	(0) Sets 1's complement mode for operations on <i>short integers</i> . See Section 2 of the OM.

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. See the OM, Section 2, *Integers: Summary of Functions*.

<sup>6</sup> Some reasoning why ASL is disabled for these four:

- a) CLX is for clearing **X** to make room for a corrected value. This new value shall overwrite  $x$  – an extra zero on the stack makes no sense.
- b) ENTER $\uparrow$  is a *stack lift* manually initiated by the user. An additional ASL immediately after this command makes no sense.
- c)  $\Sigma+$  and  $\Sigma-$  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.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$1/x$	$\text{1/x}$	(1) {2, 3, 5, 8*, 9*}; {1} → {2} Inverts the number $x$ or all elements of the matrix $x$ . Take $[M]^{-1}$ for inverting the matrix instead (see p. 89).
2COMPL	$f \text{BITS} \blacktriangleright \text{2COMPL}$ $g \text{INTS} \blacktriangleleft \text{2COMPL}$	(0) Sets 2's complement mode for operations on <i>short integers</i> . See Section 2 of the OM.
$2^x$	$g \text{EXP} \text{ 2}^x$	(1) {1, 2, 3, 8*, 9*, 10} Returns $2^x$ , the inverse of $\text{lb}(x)$ .
$\sqrt[3]{x}$	$g \text{EXP} f \sqrt[3]{x}$	(1) {1, 2, 3, 8*, 9*, 10}; {1} → {2} Returns the cube root of $x$ . See the DT tables in Section 2 of the OM for more.
ABS	$f \text{CATALOG} \text{ FCNS ABS}$	Points to $ x $ on p. 92. Maintained for backward compatibility only.
ACOS	$f \text{CATALOG} \text{ FCNS ACOS}$	Points to arccos on p. 18.
$\text{ac} \rightarrow m^2$	$f \text{U} \rightarrow f \text{ A: acre} \rightarrow m^2$	(1) {2}; {1} → {2}
$\text{ac}_{\text{US}} \rightarrow m^2$	$f \text{U} \rightarrow f \text{ A: acre}_{\text{US}} \rightarrow m^2$	Convert areas. See pp. 137ff.
ADV	$f \text{ADV}$	Menu. See p. 119.
AGM	$g \text{X.FN} \text{ AGM}$	(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. 254 for more.
AGRAPH	$g \text{P.FN} \text{ P.FN2}$ $g \text{AGRAPH s}$	(0) Alpha graphics. Displays a graphics image. Each character in the source $s$ specifies an 8-dot-1-column pattern. The X- and Y-registers specify the pixel location of the bottom left point of this block (valid inputs are $1 \leq x \leq 400$ and $1 \leq y \leq 232$ ). So one row (8 px high) starting in column 1 needs up to 400 characters (in various sources) to specify – the more blank space is found in this row the less characters are required for describing it. – Cf. HP-42S OM, pp. 135 – 140, and HP-42S Programming Examples & Techniques, pp. 195 – 223.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
ALL	<b>g</b> <b>DISP</b> <b>ALL</b> <b>n</b>	(0) Sets the numeric display format to show all decimals of <i>real</i> or <i>complex numbers</i> whenever displayable (without trailing decimal zeros). ALL 0 works almost like ALL in HP-42S. For $x \geq 10^{16}$ (or earlier for <i>complex numbers</i> ), display will switch to SCI or ENG (depending on ALLENG) with maximum displayable precision using the large font. 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. 60.
AND	<b>f</b> <b>BITS</b> <b>AND</b>	(2) {10} Works bitwise as in HP-16C (see OM, Sect. 2).
		(2) {1, 2} → {1} Works as in HP-28S, i.e. $x$ and $y$ are interpreted before executing this operation. Zero is ‘false’; any other <i>real number</i> or <i>long integer</i> is ‘true’.
ANGLES	<b>f</b> <b>CATALOG</b> <b>VARS</b> <b>ANGLES</b>	Submenu of tagged angular variables defined at execution time. See pp. 113f.
arccos	<b>TRI</b> <b>arccos</b>	(1) {3, 8*, 9*}; {1, 2} → {4}; Returns the tagged angle $\text{arccos}(x)$ . <sup>7</sup>
arcosh	<b>g</b> <b>EXP</b> <b>g</b> <b>arcosh</b>	(1) {2, 3, 8*, 9*}
	<b>TRI</b> <b>g</b> <b>arcosh</b>	Returns $\text{arcosh}(x)$ .
arcsin	<b>TRI</b> <b>arcsin</b>	(1) {3, 8*, 9*}; {1, 2} → {4}; Returns the tagged angle $\text{arcsin}(x)$ . <sup>8</sup>

<sup>7</sup> Precisely, ARCCOS returns the principal value of  $\text{arccos}(x)$ , i.e. a *real* part  $\in [0, \pi]$  in  $4^r$ , or  $\in [0, 1]$  in  $4\pi$ , or  $\in [0^\circ, 180^\circ]$  in  $4^\theta$  or  $4^\alpha$ , or  $\in [0^\theta, 200^\theta]$  in  $4^\theta$ . Cf. ISO/IEC 9899.

<sup>8</sup> Precisely, ARCSIN returns the principal value of  $\text{arcsin}(x)$ , i.e. a *real* part  $\in [-\pi/2, \pi/2]$  in  $4^r$ , or  $\in [-0.5, 0.5]$  in  $4\pi$ , or  $\in [-90^\circ, 90^\circ]$  in  $4^\theta$  or  $4^\alpha$ , or  $\in [-100^\theta, 100^\theta]$  in  $4^\theta$ . 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>9</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 <b>n</b> ( $\leq 63$ ) consecutive ASR commands in HP-16C, corresponding to a division of $x$ by $2^n$ . ASR <b>0</b> executes as NOP, but loads <b>L</b> . See SR and Section 2 of the OM.
ASSIGN	<b>f ASN item, location</b>	(0) Assigns an <i>item</i> (like a function, menu, label, or character) to a specific location on the keyboard or in a <i>menu</i> . See the OM, Sect. 6.
ATAN	<b>f CATALOG FCNS ATAN</b>	Points to ARCTAN above. Maintained for backward compatibility only.
atm→Pa	<b>f U→ F&amp;p: atm→Pa</b>	(1) {2}; {1} → {2}
au→m	<b>f U→ x: au→m</b>	Convert pressures and distances. See pp. 137ff.
A:	<b>f U→ f A:</b>	Submenu. See p. 137.

<sup>9</sup> Precisely, ARCTAN returns the principal value of  $\text{arctan}(x)$ , i.e. a *real* part  $\in [-\pi/2, \pi/2]$  in **4r**, for example (cf. ASIN), if SPCRES is set. Else the result interval for ATAN becomes  $(-\pi/2, \pi/2)$  in **4r**, for example. Cf. ISO/IEC 9899.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
BACK	 	(0) Jumps $n$ steps backwards ( $0 \leq n \leq 255$ ) in a program. E.g. BACK 1 goes to the previous program step. If BACK attempts to cross an END, an error is thrown. Reaching step 000 stops program execution and lights . See also 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&p: bar→Pa	(1) {2}; {1} → {2} Converts pressures. See pp. 137ff.
BATT?	 	(-1) {} → {2} Measures the battery voltage in the range between 1.9 V and 3.4 V and returns this value. Measurement resolution is 1mV. Voltages < 2.5 V are considered low, voltages < 2.0 V may lead to your WP 34S turning off automatically.
bbl→m <sup>3</sup>	  	(1) {2}; {1} → {2} Converts volumes. See pp. 137ff.
BC?	 	(-1) {10} Tests if the specified bit in $x$ is clear.
BEEP	 	(0) Sounds a sequence of four tones. See also TONE.
BeginP	 	(0) Sets “Begin” mode in TVM: payments occur at the beginning of each period. Typical for savings plans and leasing. Compare ENDP.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>BestF</b>	<b>f</b> <b>STAT</b> <b>▼</b> <b>BestF</b> <b>n</b>	<p>(0) Instructs your <i>WP 43S</i> 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 <b>BEST</b> in <i>HP-42S</i>).</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 leads to <math>n = 64 + 128 + 256 = 448</math>. Hence, call <b>BESTF 448</b> to look for the best-fitting 2-parameter model.</p> <p>Note ORTHOF is not part of the set of models under investigation. See pp. 230ff for more.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>BestF?</b>	<b>g INFO</b> <b>▼ BestF?</b>	(-1) {} → {1} Returns the ‘best’ curve fit model for the current statistical data by picking the one with maximum <i>correlation</i> out of the models allowed, encoded as an integer according to the list at BESTF.
<b>Binom<sub>p</sub></b>	<b>g PROB</b> <b>g Binom:</b> <b>Binom<sub>p</sub></b> etc.	(1) {2}; {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. 221 for more.
<b>Binom<sub>▲</sub></b>		
<b>Binom<sub>-1</sub></b>		Binom <sup>-1</sup> returns the maximum number of successes <b>m</b> for a given probability <b>p</b> in <b>X</b> , <b>p<sub>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>	<i>Submenu</i> . See p. 122.
<b>BITS</b>	<b>f BITS</b>	<i>Menu</i> . See p. 116.
<b>B<sub>n</sub></b>	<b>g X.FN</b> <b>B<sub>n</sub></b>	(1) {1, 2}
<b>B<sub>n</sub>*</b>	<b>g X.FN</b> <b>B<sub>n</sub>*</b>	B <sub>n</sub> and B <sub>n</sub> * return the Bernoulli number for an integer <b>n &gt; 0</b> given in <b>X</b> , working with different definitions (see both formulas on p. 219).
<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. 137ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
cal→J	f U→ E: cal→J	(1) {2}; {1} → {2} Converts energies. See pp. 137ff.
CASE	g P.FN P.FN2 g CASE s	(0) Works like SKIP but takes the number of steps to skip from s. <b>Example:</b> Assume a program section:  <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>Executing 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	f CATALOG	Catalog of everything. See pp. 113ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CauchF	f STAT ▼ f CauchF	(0) Selects the <i>Cauchy</i> (a.k.a. <i>Lorentz</i> ) peak fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 230ff for more.
Cauch <sub>p</sub>	g PROB f Cauch: Cauch <sub>p</sub>	(1) {2}; {1} → {2}
Cauch <sub>x</sub>	etc.	Cauchy-Lorentz (a.k.a. <i>Lorentz</i> or <i>Breit-Wigner</i> ) distribution with the location $x_0$ specified in <b>I</b> and the shape $\gamma$ in <b>J</b> . See p. 224 for more.
Cauch <sup>-1</sup>		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> .
Cauch:	g PROB f Cauch:	Submenu. See p. 122.
CB	f BITS g CB n	(1) {10} Clears the specified bit in $x$ , i.e. sets it to 0.
CEIL	g INTS g CEIL	(1) {8*}; {1, 2} → {1} Returns the smallest integer $\geq x$ . Compare FLOOR.
CF	g FLAGS CF n g MODE CF n g CLR CF n	(0) Clears the flag specified, i.e. sets it to 0.
CHARS	f CATALOG CHARS	Submenu of characters. See pp. 113ff.
chī→m	f U→ x: ▼ g chī→m	(1) {2}; {1} → {2} Converts distances. See pp. 137ff.
CLALL	g CLR g CLall	(0) Clears all registers, numbered user flags, variables, and programs in RAM. Modes will stay as they are. See also CLCVAR, CLFALL, CLPALL, CLREGS, CLSTK, and RESET.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>CLCVAR</b>	<b>g CLR CLCVAR</b>	(0) Clears all variables used in the <i>current program</i> , i.e. sets all such <i>real</i> , <i>complex</i> and <i>integer</i> variables to zero, 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 <i>text strings</i> to zero length, and all the elements of all matrix variables used to <b>0</b> .
<b>CLFALL</b>	<b>g FLAGS g CLFall</b>	(0) Clears (after confirmation unless in <i>PEM</i> ) all numbered global and local <i>user flags</i> (cf. CF). Lettered flags are not cleared since they may coincide with <i>system flags</i> .
	<b>g CLR f CLFall</b>	
<b>CLK</b>	<b>g CLK</b>	<b>Menu.</b> See p. 112.
<b>CLLCD</b>	<b>g CLR f CLLCD</b>	(0) Clears all pixels $\geq x$ and $\geq y$ on the screen.
<b>CLMENU</b>	<b>g CLR CLMENU</b>	(0) Clears all <i>menu key</i> definitions for the programmable <i>menu</i> . See MENU.
	<b>g P.FN P.FN2 ...</b>	
<b>CLP</b>	<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.
<b>CLPALL</b>	<b>g CLR f CLPall</b>	(0) Clears <u>all</u> programs in <i>RAM</i> . Cf. CLP.
<b>CLR</b>	<b>g CLR</b>	<b>Menu.</b> See p. 119.
<b>CLREGS</b>	<b>g CLR f CLREGS</b>	(0) Clears (after confirmation unless in <i>PEM</i> ) all global and local <i>GP registers</i> allocated (see also LOC.R), i.e. sets all these registers to <b>0</b> . The contents of the <i>stack</i> and <b>L</b> are kept.
<b>CLSTK</b>	<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>	
<b>CLX</b>	<b>g CLR CLX</b>	(1) Clears <i>stack register X</i> , disabling ASL. Cf. CLREGS and CLSTK.
	<b>« (for closed x)</b>	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CLΣ	<b>g CLR CLΣ</b>	(0) Clears the statistical summation <i>registers</i> and releases the memory allocated for them (see p. 162).
	<b>f STAT g CLΣ</b>	
CNST	<b>g P.FN</b> <b>f CNST n</b>	(-1) {} → {2} Returns the constant stored at position <i>n</i> in CONST (see below and pp. 127ff). Allows for indirectly addressing these constants, also beyond $\infty$ .
COMB	<b>g PROB C<sub>yx</sub></b>	(2) {1} Returns the number of possible <u>subsets</u> of <i>x</i> items taken out of a set of <i>y</i> items (i.e. choose <i>x</i> out of <i>y</i> ). No item occurs more than once in a subset, and <u>different orders</u> of the same <i>x</i> items are <u>not counted</u> separately. Compare PERM.
		(2) {2, 3} See pp. 219f for the formula.
CONJ	<b>g CPX conj</b>	(1) {3, 9*} Returns the <i>complex conjugate</i> of <i>x</i> .
CONST	<b>f CONST</b>	Menu. Cf. CNST above and see pp. 127ff.
CONVG?	<b>g TEST</b> <b>g CONVG? r</b>	(0) {2} Checks for convergence by comparing <i>x</i> and <i>y</i> as determined by the lowest five bits of <i>r</i> .  a) The very lowest 2 bits set the tolerance limit: $0 = 10^{-14}, \quad 1 = 10^{-24}, \quad 2 = 10^{-32}$ .  b) The next two bits determine the comparison mode using the tolerance limit set: $0 = \text{compare the numbers } x \text{ and } y \text{ relatively,}$ $1 = \text{compare them absolutely.}$

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		c) The top bit tells how special numbers will be treated: 0 = NaN and $\pm\infty$ are considered converged, 1 = they are not considered converged. Now, $r = a + 4b + 16c$ .
CORR	[f] STAT ▲ r	(-1) { } → {2} Returns the <i>coefficient of correlation</i> for the current statistical data and curve fit model. See pp. 230ff for more.
cos	[TRI] cos	(1) {2, 3, 8*, 9*}; {1, 4} → {2} Returns the cosine of the angle in X (takes x as tagged, else assumes the current ADM; see Section 2 of the OM for details).
cosh	[g] EXP [g] cosh	(1) {2, 3, 8*, 9*}
	[TRI] [g] cosh	Returns the hyperbolic cosine of x.
COV	[f] STAT ▲ cov	(-1) { } → {2} Returns the <i>population covariance</i> for the two data sets {x} and {y} entered via $\Sigma+$ , depending on the curve fit model selected. See $s_{xy}$ for the <i>sample covariance</i> and pp. 230ff for more.
CPX	[g] CPX	Menu. See p. 119.
CPXS	[f] CATALOG VARS CPXS	Submenu of complex variables defined at execution time. See pp. 113f.
CPX?	[g] TEST ▲ CPX?	(0) Checks if x is <i>complex</i> . Returns true if X contains data of type 3 or 9 with nonzero <i>imaginary</i> part.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
CROSS	<b>f</b> [MATX] <b>f</b> cross	(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 it does for <i>complex numbers</i> .
	<b>g</b> [CPX] cross	(2) {3} → {2} When two <i>complex numbers</i> are crossed, your WP 43S simply returns a <i>real number</i> that is equal to the signed <i>magnitude</i> of the resulting moment vector. See an example in the OM.
ct→kg	<b>f</b> [U→] m: <b>f</b> carat → kg	(1) {2}; {1} → {2}
cùn→m	<b>f</b> [U→] x: ▾ <b>g</b> cùn→m	Convert masses and distances. See pp. 137ff.
cwt→kg	<b>f</b> [U→] m: cwt→kg	
CX→RE	<b>CC</b> (works in run mode only)	(-1) {3} → {2}; {9} → {8} Cuts a closed <i>complex object</i> <i>x</i> , putting either <ul style="list-style-type: none"> <li>• (for <b>L</b>) its <i>real part</i> in <b>Y</b> and its <i>imaginary part</i> in <b>X</b> or</li> <li>• (for <b>Ø</b>) its <i>magnitude</i> in <b>Y</b> and <i>phase</i> in <b>X</b>.</li> </ul>
	<b>g</b> [CPX] <b>f</b> CX→RE	
DATE	<b>g</b> [CLK] DATE	(-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 Section 2 of the OM).
DATES	<b>f</b> [CATALOG] VARS <b>f</b> DATES	Submenu of <i>date variables</i> defined at execution time. See pp. 113f.
DATE→	<b>g</b> [CLK] DATE→	(-2) {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 pushes its three components as integers on the stack. Reversible by →DATE.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DAY		(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	  etc.	{10} Double word length commands for remainder, multiplication and division (see the HP-16C OH, Sect. 4, pp. 52ff).
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	▲ dB → field ratio	(1) {2}; {1} → {2}
dB→pr	▲ dB → power ratio	Convert ratios. See pp. 137ff.
DEC	 	(0) {1, 2, 10} Decrements $r$ by 1. Does not load <b>L</b> even for target address <b>X</b> .
DECOMP	 DECOMP	(-1) {1, 2} → {1} Decomposes $x$ (after converting it to an improper fraction, if applicable), returning a stack [ <i>denominator</i> ( $x$ ), <i>numerator</i> ( $x$ ), ...]. This works with maximum precision always, regardless of the settings of DENMAX, DENFIX, and DENANY. <b>Example:</b> For $x = 2.25$ , DECOMP returns $x = 4$ and $y = 9$ .
DEG		(0) Sets the ADM to decimal degrees.
DEG→		(1) {1, 2, 4} → {4} Converts angles as described on p. 145.
DELITM		(0) Deletes a user-defined item from memory. See the OM, Section 6.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DENMAX	<b>g MODE</b> <b>f DENMAX</b>	(1) Works like /c on HP-35S, but the maximum legal denominator is 9 999. For $x < 1$ or $x > 9\,999$ , DENMAX will be set to 9 999. For $x = 1$ , the current DENMAX setting is recalled, replacing x.
DET	<b>f CAT. FCNS DET</b>	Points to  M  explained on p. 92. Maintained for backward compatibility only.
DIGITS	<b>f CAT. f DIGITS</b>	Submenu of digits defined. See pp. 113ff.
DISP	<b>g DISP</b>	Menu. See p. 119.
DOT	<b>g CPX dot</b>	(2) {3} → {2} Returns $Re(x) Re(y) + Im(x) Im(y)$
	<b>f MATX</b> <b>f dot</b>	(2) {8} → {2}; {9} → {3} Requires two matrices in $x$ and $y$ and returns their dot (scalar) product. The dot product is defined as the sum of the products of the corresponding elements in both matrices. Note both matrices must be of matching size; else DOT will throw an error. See the OM, Section 2.
DROP	<b>g DROP↓</b>	Drops $x$ ... from the stack. See Section 1 of the OM for details.
DROPy	<b>g STK DROPy</b>	Drops $y$
DSE	<b>f LOOP</b> <b>DSE r</b>	(0) {1, 2, 10} Given $r = ccccc.ffffii$ , DSE decrements $r$ by ii, skipping next program step if then $cccccc \leq ffff$ (cf. the rear side of your WP 43S). If $r$ features no fractional part then $ffff$ is 0. If $ii = 0$ , $cccccc$ will be decremented by 1. DSE does not load L even for target address X. Note that neither $ffff$ nor $ii$ can be negative, and DSE makes sense with $cccccc > 0$ only. In run mode, DSE returns true for $cccccc > ffff$ and false for $cccccc \leq ffff$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
DSL	 	(0) {1, 2, 10} Works like DSE but skips if $cccc < fff$ .
DSTACK	 	(0) Sets the maximum number of <i>stack registers</i> displayed. For an input of 1, only $x$ will be shown directly above the <i>menu section</i> ; for 2, $x$ and $y$ will be displayed; maximum input is 4.  Expanded views of e.g. matrices and dual- or multi-level returns like SUM will work as described in the OM regardless of the DSTACK parameter set. In any case, command input will be echoed directly below the <i>status bar</i> .  This command is for old-school calculator users who feel distracted by a multitude of <i>stack registers</i> displayed changing simultaneously while only the lowest ones are really relevant.
DSZ	DSZ $s$	(0) {1, 2, 10} Decrement $s$ by 1 and skips the next step if $-1 < s < +1$ thereafter. Does not load <b>L</b> even for target address <b>X</b> . Known from HP-29C, HP-67, and HP-16C.
D.MS	 (for closed input)	(0) Sets the ADM to <i>sexagesimal degrees</i> .
D.MS→		(1) {1, 2, 4} → {4}
D.MS→D		Convert angles as described on p. 145.
D.MY		(0) Sets the format dd.mm.yyyy for <i>dates</i> .
D→D.MS		(1) {1, 2, 4} → {4} Converts angles as described on p. 145.
D→J		(1) {2, 6} → {1} Assumes $x$ 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> according to the J/G setting. Please see p. 42.

Item	Keystrokes	Remarks (see pp. 12ff for general information)	
D→R	<b>g L→ g D→R</b>	(1) {1, 2, 4} → {4} Converts angles as described on p. 145.	
EIGVAL	<b>f MATX ▲ g EIGVAL</b>	(-1) {8, 9} Evaluates the matrix $x$ and pushes a matrix containing its eigenvalues on the stack.	See the OM, Sect. 2.
EIGVEC	<b>f MATX ▲ g EIGVEC</b>	(-1) {8, 9} Evaluates the matrix $x$ and pushes a matrix containing its eigenvectors on the stack.	
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. Cannot be skipped by a test. 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 DISP 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 $X$ . This norm is defined as the square root of the sum of squares of all matrix elements. For a vector, ENORM returns its length. Compare $ x $ on p. 92.	
ENTER↑	<b>ENTER↑</b>	(-1) Separates two entries in input. Copies $x$ into $Y$ , disabling ASL. See p. 109 and the OM, Sect. 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 A/M, or</li> <li>any command is accepted for entry (be it via <b>ENTER↑</b>, a function key, or <b>R/S</b> with a partial command line).</li> </ul> Useful in routines, e.g. after PAUSE.	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
EQN	<b>g EQN</b>	<b>Menu.</b> See p. 120.
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}
erfc		Returns the error function or its complement. See pp. 254ff for more.
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. 179ff for the error codes. Compare MSG.
EVEN?	<b>g TEST f EVEN?</b>	(0) Checks if $x$ is integer (see INT?) and even.
$e^x$	<b>e<sup>x</sup></b>	(1) {2, 3, 8*, 9*, 10}; {1} → {2} Returns $e^x$ , the inverse of $\ln(x)$ . Note $e^{i\pi} = -1$ . See the DT tables in Sect. 2 of the OM for more.
EXITALL	<b>g P.FN P.FN2 EXITall</b>	(0) Exits all menus.
EXP	<b>g EXP</b>	<b>Menu.</b> See p. 120.
ExpF	<b>f STAT</b> <b>▼ ExpF</b>	(0) Selects the exponential curve fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 230ff for more.
Expon <sub>p</sub>	<b>g PROB</b> <b>f Expon:</b> <b>Expon<sub>p</sub></b> etc.	(1) {2}; {1} → {2}
Expon <sub>λ</sub>		<i>Exponential distribution</i> with the rate $\lambda$ in <b>J</b> . See pp. 221ff for more.
Expon <sub>λ</sub>		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> .
Expon:	<b>g PROB</b> <b>f Expon:</b>	<b>Submenu.</b> See p. 122.

See Section 4 of  
the OM.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
EXPT	f PARTS EXPT	(1) {1, 2} → {1} Returns the exponent $h$ of the number $x = m \cdot 10^h$ displayed. Compare MANT.
$e^x - 1$	g EXP f $e^x - 1$	(1) {2, 8*} For $x \approx 0$ , this returns a more accurate result for the fractional part than $e^x$ does.
E:	f U→ E:	_submenu. See p. 135.
FB	f BITS g FB n	(1) {10} Inverts ('flips') the specified bit in $x$ .
FBR	g a.FN g FBR	(0) Font browser. Shows all characters designed for your WP 43S.
FCNS	f CAT. FCNS	_submenu of all functions. See pp. 113ff.
FC?	g FLAGS FC? n	(0) Tests if the specified flag is clear.
FC?C	g FLAGS f FC?C n	(0) Tests if the specified flag is clear. Clears, flips, or sets this flag after testing, respectively. etc.
FC?F	g FLAGS f FC?F n	
FC?S	g FLAGS f FC?S n	
fēn→m	f U→ x: ▽ g fēn→m	(1) {2}; {1} → {2} Converts distances. See pp. 137ff.
FF	g FLAGS FF n	(0) Flips the flag specified.
FIB	g X.FN f FIB	(1) {1} Returns the Fibonacci number (4791 is maximum input).  (1) {2, 3} Returns the extended Fibonacci number.  See pp. 219f.
FILL	f FILL	Fills the whole stack with $x$ .
FIN	g FIN	Menu. See p. 120.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>FIX</b>	<b>g DISP FIX <i>n</i></b>	(0) Sets fixed point display format (see the OM, Section 2).
<b>FLAGS</b>	<b>g FLAGS</b>	<b>Menu.</b> See p. 120.
<b>FLASH</b>	<b>f CAT. PROGS FLASH</b>	<i>Submenu</i> of global labels defined in FM at execution time. See pp. 113f.
<b>FLASH?</b>	<b>g INFO f FLASH?</b>	(-1) {} → {1} Returns the number of free bytes in FM.
<b>FLOOR</b>	<b>g INTS g FLOOR</b>	(1) {8*} {1, 2} → {1} Returns the greatest integer ≤ <i>x</i> . Cf. CEIL.
<b>fm.→m</b>	<b>f U→ x: ▲ fathom → m</b>	(1) {2, 11; {1} → {2}} Converts distances. See pp. 137ff.
<b>FP</b>	<b>f PARTS FP</b> <b>f # F</b> (for closed input)	(1) {1, 2, 8*, 10} Returns the fractional part of <i>x</i> . Compare IP.
<b>FP?</b>	<b>g TEST f FP?</b>	(0) Tests <i>x</i> for having a fractional part ≠ 0.
<b>F<sub>p</sub>(x)</b>	<b>g PROB F: F<sub>p</sub>(x)</b>	etc.  <i>Fisher's F distribution.</i> $F_{\Delta}(x)$ equals $Q(F)$ on HP-21S. The degrees of freedom shall be specified in <b>I</b> and <b>J</b> . See pp. 221ff for more.
<b>F<sub>Δ</sub>(x)</b>		
<b>F<sub>Δ</sub>(x)</b>		
<b>F<sup>-1</sup>(p)</b>		
<b>fr→dB</b>	<b>f U→ ▲ field ratio → dB</b>	(1) {2}; {1} → {2} Converts ratios. See pp. 137ff.
<b>FS?</b>	<b>g FLAGS FS? <i>n</i></b>	(0) Tests if the specified flag is set.
<b>FS?C</b>	<b>g FLAGS f FS?C <i>n</i></b>	etc.  (0) Tests if the specified flag is set. Clears, flips, or sets this flag after testing, respectively.
<b>FS?F</b>		
<b>FS?S</b>		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$ft \rightarrow m$		(1) (2); {1} → {2} Convert distances and volumes. See pp. 137ff.
$ft_{us} \rightarrow m$		
$fz_{uk} \rightarrow m^3$		
$fz_{us} \rightarrow m^3$		
F:		Submenu. See p. 122.
f'		Submenus for calculating the 1 <sup>st</sup> or 2 <sup>nd</sup> derivative of a given equation. See the OM (Section 4) for more.
f''		
f'(x)		{1, 2} → {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>ATTENTION:</b> $f'(x)$ and $f''(x)$ fill all stack registers with $x$ before calling the routine specified.
F&p:		Submenu. See p. 137.
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, no group separators will be displayed in any number at all. See Section 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. 230ff for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
GCD	<b>g INTS g GCD</b>	(2) {1; 10} Returns the Greatest Common Divisor of $x$ and $y$ . <sup>10</sup> This will always be positive.
$g_d$	<b>g X.FN f g_d</b> etc.	(1) {2, 3}; {1} → {2} Returns the Gudermannian function or its inverse. See p. 255 for details.
$\text{Geom}_p$	<b>g PROB</b> <b>g Geom:</b> Geom <sub>p</sub> etc.	(1) {2}; {1} → {2}
$\text{Geom}_{\Delta}$		<i>Geometric distribution:</i> The CDF returns the probability for a 1 <sup>st</sup> success after $m = x$ Bernoulli experiments. The probability $p_o$ for a success in each such experiment must be specified in <b>J</b> . See pp. 221ff for more.
$\text{Geom}_{\Delta}$		
$\text{Geom}^{-1}$		$\text{Geom}^{-1}$ returns the number of failures $f$ before 1 <sup>st</sup> success for given probabilities $p$ in <b>X</b> , $p_o$ in <b>J</b> .
<b>Geom:</b>	<b>g PROB f Geom:</b>	Submenu. See p. 122.
$\text{gl}_{\text{UK}} \rightarrow m^3$	<b>f U→</b> <b>f V: gl_{UK} → m<sup>3</sup></b> etc.	(1) {2}; {1} → {2}
$\text{gl}_{\text{US}} \rightarrow m^3$		Convert volumes. See pp. 137ff.
<b>GRAD</b>	<b>g MODE GRAD</b>	(0) Sets the ADM to <i>grades</i> (a.k.a. <i>gradians</i> or <i>gon</i> ).
<b>GRAD→</b>	<b>g L→ f GRAD→</b>	(1) {1, 2, 4} → {4} Converts angles as described on p. 145.
<b>GTO</b>	<b>f GTO <u>label</u></b>	(0) In <i>PEM</i> , inserts an unconditional branch to <i>label</i> . Else positions the program pointer to <i>label</i> .

<sup>10</sup>  $\text{GCD}(x, y) = \left| \frac{x}{\text{LCM}(x, y)} \right|$ . See also LCM.

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

Item	Keystrokes	Remarks (see pp. 12ff for general information)
GTO.	<b>f GTO</b> <b>nnn</b>	to local label <b>n</b> (specify $\leq 2$ digits).
	<b>f GTO</b> <b>label</b>	to step <b>nnn</b> – specify $\geq 3$ digits until becoming definite in <i>current pgm</i> .
	<b>f GTO</b> <b>.▲</b>	to the global label specified (shall be picked from <b>PROG</b> ).
	(0) Positions the program pointer ...	directly <u>after previous END</u> , i.e. to the top of <i>current program</i> (see Sect. 3 of the OM); if being there already, jumps to the top of previous program.
	<b>f GTO</b> <b>.▼</b>	directly <u>after next END</u> , i.e. to the top of next program.
	<b>f GTO</b> <b>..</b>	to the end of used program memory in <b>RAM</b> , i.e. right to the final END.
ha $\rightarrow$ m <sup>2</sup>	<b>f U→</b> <b>f A:</b> ha $\rightarrow$ m <sup>2</sup>	(1) {2}; {1} $\rightarrow$ {2} Converts areas. See pp. 137ff.
H <sub>n</sub>	<b>g X.FN</b> Orthog H <sub>n</sub>	(2) {2}; {1} $\rightarrow$ {2}
H <sub>np</sub>	... Orthog <b>f H<sub>np</sub></b>	<i>Hermite polynomials</i> for probability (H <sub>n</sub> ) and physics (H <sub>np</sub> ). See p. 249 for details.
hp <sub>E</sub> $\rightarrow$ W	<b>f U→</b> <b>P:</b> hp <sub>E</sub> $\rightarrow$ W etc.	(1) {2}; {1} $\rightarrow$ {2} Convert powers. See pp. 137ff.
hp <sub>M</sub> $\rightarrow$ W		
hp <sub>UK</sub> $\rightarrow$ W		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Hyper <sub>p</sub>	<b>g PROB</b> <b>g Hyper:</b> Hyper <sub>p</sub> etc.	(1) {2}; {1} → {2} <i>Hypergeometric 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> , the sample size <b>n</b> in <b>J</b> , and the batch size <b>n<sub>o</sub></b> in <b>K</b> . See pp. 221ff for the formula and the OM, Sect. 2, for an example.
Hyper <sub>-1</sub>		Hyper <sup>-1</sup> returns the maximum number of successes <b>m</b> for a given probability <b>p</b> in <b>X</b> , <b>p<sub>o</sub></b> in <b>I</b> , <b>n</b> in <b>J</b> , and <b>n<sub>o</sub></b> in <b>K</b> .
Hyper:	<b>g PROB</b> <b>g Hyper:</b>	Submenu. See p. 122.
HypF	<b>f STAT</b> <b>f HypF</b>	(0) Selects the hyperbolic fit model. Relevant for CORR, COV, L.R., s <sub>XY</sub> , $\hat{x}$ , and $\hat{y}$ . See pp. 230ff for more.
IDIV	<b>g INTS</b> <b>f IDIV</b>	(2) {1, 10}; {2} → {1} Integer division, working like <b>/</b> + <b>[IP]</b> . <sup>11</sup>
IDIVR	<b>f CATALOG</b> FCNS IDIVR	{1, 2, 10} Like IDIV but returns also the remainder in <b>Y</b> . <sup>11</sup>
iHg→Pa	<b>f U→</b> F&p: <b>f in.Hg → Pa</b>	(1) {2}; {1} → {2} Converts pressures. See pp. 137ff.
Im	<b>g CPX</b> <b>f Im</b> <b>f PARTS</b> <b>g Im</b>	(1) {2, 3} → {2}; {9} → {8}; Returns the imaginary part of <b>x</b> . Compare RE.
INC	<b>f LOOP</b> <b>f INC r</b>	(0) {1, 2, 10} Increments <b>r</b> by 1. Does not load <b>L</b> even for target address <b>X</b> .

<sup>11</sup> See the OM, Section 2, for the DTs of quotient and remainder, if applicable.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
INDEX	<b>f</b> [MATX] <b>f</b> INDEX <i>name</i>	(1) Indexes a named matrix. You can also index a matrix by editing it (see M.EDIT or M.EDIN). After exiting the <i>Matrix Editor</i> , the matrix is no longer indexed.  See also <i>Matrix Utility Functions</i> in the HP-42S Owner's Manual, pp. 223ff.
INFO	<b>g</b> [INFO]	Menu. See p. 120.
INPUT	<b>g</b> [P.FN] INPUT <i>r</i>	Works in programs only: Recalls the content of the source specified into X, displays the name of the source along with <i>r</i> , and halts program execution, allowing you to enter or calculate a value; pressing <b>R/S</b> then stores <i>x</i> into said destination and continues program execution – pressing <b>EXIT</b> instead cancels INPUT, so <b>R/S</b> thereafter will continue with the source content as it was.  If you use an input variable <i>name</i> undefined at execution time, INPUT automatically creates the variable with an initial value of zero.
INTS	<b>g</b> [INTS]	Menu. See p. 120.
INT?	<b>g</b> [TEST] <b>f</b> INT?	(0) Tests <i>x</i> for being an integer, i.e. having a fractional part equal to zero. Cf. FP?.
INVRT	<b>f</b> [CAT] FCNS INVRT	Works like $[M]^{-1}$ on p. 92. Maintained for backward compatibility only.
in. $\rightarrow$ m	<b>f</b> [U $\rightarrow$ ] <i>x</i> : <b>g</b> in. $\rightarrow$ m	(1) {2}; {1} $\rightarrow$ {2}  Converts distances. See pp. 137ff.
IP	<b>f</b> [PARTS] IP	(1) {1, 8*}; {2, 10} $\rightarrow$ {1}
	<b>f</b> [#] <input type="checkbox"/> (for closed input)	Returns the integer part of <i>x</i> . Cf. FP.

Item	Keystrokes	Remarks (see pp. 12ff for general information)												
ISE	<b>f</b> <b>LOOP</b> ISE <b>s</b>	(0) {1, 2, 10} Given $cccccc.ffffii$ in the source <b>s</b> , ISE increments <b>s</b> by $ii$ , skipping next program step if $cccccc \geq ffff$ then (cf. the rear side of your WP 43S and DSE on p. 30). If <b>s</b> has no fractional part then $ffff = 0$ 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 $ffff$ nor $ii$ can be negative, but $cccccc$ can.												
ISG	<b>f</b> <b>LOOP</b> ISG <b>s</b>	(0) {1, 2, 10} Works like ISE but skips if $cccccc > ffff$ .												
ISM?	<b>g</b> <b>INFO</b> ISM?	(-1) {} → {1} Returns the <i>integer sign mode</i> set for <i>short integers</i> : <table style="margin-left: 200px;"><tr><td>true</td><td>2</td><td>for 2's complement,</td></tr><tr><td>true</td><td>1</td><td>for 1's complement,</td></tr><tr><td>false</td><td>0</td><td>for unsigned, or</td></tr><tr><td>true</td><td>-1</td><td>for sign &amp; mantissa mode.</td></tr></table>	true	2	for 2's complement,	true	1	for 1's complement,	false	0	for unsigned, or	true	-1	for sign & mantissa mode.
true	2	for 2's complement,												
true	1	for 1's complement,												
false	0	for unsigned, or												
true	-1	for sign & mantissa mode.												
ISZ	<b>f</b> <b>LOOP</b> ISZ <b>s</b>	(0) {1, 2, 10} Increments <b>s</b> by 1, skipping next program step if $-1 < s < +1$ thereafter. ISZ does not load <b>L</b> even for target address <b>X</b> . Known from HP-29C, HP-67, and HP-16C.												
$I_{xyz}$	<b>g</b> <b>X.FN</b> <b>f</b> $I_{xyz}$	(3) {1, 2} Returns the <i>regularized Beta function</i> . See p. 255.												
$\Gamma_p$	<b>g</b> <b>X.FN</b> <b>f</b> $\Gamma_p$	(2) {1, 2}												
$\Gamma_q$	etc.	Returns the <i>regularized Gamma function</i> (one of two kinds).												

Item	Keystrokes	Remarks (see pp. 12ff for general information)
I+	f MATX ▲ I+	(1) Increments or decrements the row index $i$ of the indexed matrix. See INDEX and also J+, J-, RCLEL, STOEL, RCLIJ, and STOIJ.
I-	f MATX ▲ I-	
I/O	f I/O	Menu. See p. 120.
J <sub>y</sub> (x)	g X.FN g J <sub>y</sub> (x)	(2) {2}; {1} → {2} Returns the <i>Bessel function of first kind</i> and order $y$ . See p. 256 for details.
J+	f MATX ▲ J+	(1) Increments or decrements the column index $j$ of the indexed matrix. If GROW is set and $i$ and $j$ are pointing 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-	f MATX ▲ J-	
J/G	g CLK ▲ f J/G	(0) {2} Takes $x$ specifying the date the <i>Gregorian calendar</i> became valid in the region you are interested in. This shall be entered as a real number formatted according to the <i>date display mode</i> set (D.MY, M.DY, or Y.MD) reflecting the crucial <i>Gregorian date</i> .
J/G?	g INFO ▲ J/G?	(-1) {} → {6} Returns the current setting of J/G (see there).
J→Btu	f U- E: J→Btu	(1) {2}; {1} → {2}
J→cal	etc.	Convert energies. See pp. 137ff.
J→D	g CLK f J→D	(1) {1} → {6} Takes $x$ as a <i>Julian day number</i> <sup>12</sup> and converts it to a common <i>date</i> according to J/G (see above) and the date format selected.

<sup>12</sup> Translator's note: *Julian day number* translates to «jour Julien» in French and to “Julianisches Datum” or “Julianische Tageszahl” in German. See the corresponding articles in Wikipedia for more information about these counting numbers. Note a Julian day number differs from a Julian (calendar) date.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
J→Wh		(1) {2}; {1} → {2} Converts energies. See pp. 137ff.
KEY		See KEYG and KEYX below.
KEYG	 KEYG key#, <u>labl</u>	Specifies 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  KEY key# GT0 <i>labl</i> or  KEY key# XEQ <i>labl</i> , respectively. Key numbers go from 1 to 18 with 1 corresponding to <b>F1</b> , 9 to  , and 14 to  , for example.
KEY?	 	(0) Tests if a key was pressed while a routine was running or paused. If no key was pressed in that interval then the next program step after KEY? will be executed; else it will be skipped and the code of said key will be stored in <i>r</i> . Key codes reflect the rows and columns on the keyboard (see the OM, Section 3; cf. GETKEY on HP-42S).
kg→ct		(1) {2}; {1} → {2} Convert masses. See pp. 137ff.
kg→cwt	 etc.	
kg→lb.		
kg→oz		
kg→scw		
kg→sto		
kg→s.t		
kg→ton		
kg→trz		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
KTYP?	<b>g [INFO] KTYP? <i>r</i></b>	<p>(-1) {} → {1}</p> <p>Assumes a key code in the address specified (cf. 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>Helps in user interaction with routines (see the OM, Section 3)..</p>
LASTx	<b>RCL L</b>	(-1) See Sect. 1 of the OM. This command will be recorded as RCL L in routines.
lbf <sup>t</sup> →Nm	<b>f [U→] ▶ lbf·ft → Nm</b>	(1) {2}; {1} → {2}
lbf→N	<b>f [U→] F&amp;p: lbf→N</b>	Convert torques and forces. See pp. 137ff.
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. <sup>t</sup> →kg	<b>f [U→] m: lb.<sup>t</sup>→kg</b>	(1) {2}; {1} → {2}
Converts masses. See pp. 137ff.		
LCM	<b>g [INTS] f LCM</b>	(2) {1; 10}
Returns the Least Common Multiple of x and y. <sup>13</sup>		This will always be positive.

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<sup>13</sup>  $\text{LCM}(x, y) = \left| \frac{x y}{\text{GCD}(x, y)} \right|$ . Cf. GCD.

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

Item	Keystrokes	Remarks (see pp. 12ff for general information)
LEAP?	 	(0) {2, 6} Assumes $x$ containing a date in the format selected (or a <i>real number</i> in corresponding format), extracts the year, and tests for a leap year.
LgNrm <sub>p</sub>	 	(1) {2}; {1} → {2}
LgNrm <sub>△</sub>	etc.	<i>Log-normal distribution</i> with $\mu = \ln \bar{x}_g$ specified in <b>I</b> and $\sigma = \ln \varepsilon$ in <b>J</b> . See $\bar{x}_g$ and $\varepsilon$ below and pp. 221ff for more.
LgNrm <sub>▲</sub>		
LgNrm <sup>-1</sup>		LgNrm <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> .
LgNrm:	 	Submenu. See p. 122.
LinF	 	(0) Selects the linear fit model. Relevant for CORR, COV, L.R., s <sub>XY</sub> , $\hat{x}$ , and $\hat{y}$ . See pp. 221ff for more.
i→m	   	(1) {2}; {1} → {2} Converts distances. See pp. 137ff.
LJ	 	(10) Left justifies a bit pattern within its word size as in <i>HP-16C</i> : The stack will lift, placing the left-justified word in <b>Y</b> and the count of bit-shifts necessary to left justify the word in <b>X</b> .  <b>Example</b> for word size 8: 1 0110 <sub>2</sub> LJ returns $x = 3$ and $y = 1011\ 0000_2$
L <sub>m</sub>	 	(2) {2}; {1} → {2}
L <sub>mα</sub>	etc.	Laguerre polynomials and Laguerre's generalized polynomials. See pp. 236f for more.
LN		(1) {2, 3, 8*, 9*, 10}; {1} → {2} Returns the natural logarithm of $x$ . See the DT tables in Section 2 of the OM for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\text{LN}\beta$		(2) {2, 3}; {1} → {2} Returns the natural logarithm of <i>Euler's Beta function</i> (see p. 85).
$\text{LN}\Gamma$		(1) {2, 3}; {1} → {2}
		Returns the natural logarithm of $\Gamma(x)$ (see p. 85). Allows also for calculating really great factorials (see an example in the <i>OM</i> ).
$\text{LN}(1+x)$		(1) {2, 8*} For $x \approx 0$ , this function returns a more accurate result for the fractional part than $\ln(x)$ does.
<b>LOAD</b>		Restores the entire backup from the file in the <i>FAT system</i> in <i>FM</i> whereto it was written by <b>SAVE</b> . <b>LOAD</b> calls <b>LOADP</b> , <b>LOADR</b> , <b>LOADV</b> , <b>LOADΣ</b> , <b>LOADSS</b> , recalls the lettered <i>registers</i> (incl. the <i>stack!</i> ), and signals <b>Backup restored</b> . <sup>14</sup>
<b>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>14</sup>
<b>LOADR</b>		(0) Recalls the numbered <i>GP registers</i> from backup (incl. the <i>local registers</i> allocated). Lettered <i>registers</i> will not be recalled. <sup>14</sup> The number of registers copied is the minimum of the registers held in the backup and allocated in <i>RAM</i> at execution time.

<sup>14</sup> **LOAD** and **LOADP** are not programmable. See **SAVE** on p. 73 and *App. B* (pp. 166ff).

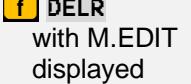
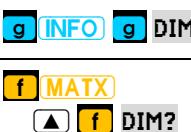
Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>LOADSS</b>	 LOADSS	(0) Recovers the system state from backup, <sup>14</sup> meaning the entire calculator <i>configuration</i> (user assignments, system variables and <i>flags</i> as covered by RESET – see p. 62) plus all global <i>user flags</i> .
<b>LOADV</b>	 LOADV	(0) Recalls the user-defined variables from backup. <sup>14</sup>
<b>LOADΣ</b>	 LOADΣ	(0) Recovers the statistical summation <i>registers</i> from backup. Throws an error if there is none. <sup>14</sup>
<b>LocR</b>	 	(0) Allocates <i>n local registers</i> ( $\leq 99$ ) and 16 <i>local flags</i> for the <i>current routine</i> . The new <i>registers</i> and <i>flags</i> are cleared. Any subsequent LOC R in the same routine, if applicable, will set the amount of local <i>registers</i> to the new number. Cf. the OM, Sect. 3.
<b>LocR?</b>	 	(-1) { } $\rightarrow$ {1} Returns the number of <i>local registers</i> currently allocated for the <i>current routine</i> .
<b>LOG<sub>10</sub></b>		(1) {1, 2, 3, 8*, 9*, 10} ((1) $\rightarrow$ {2}) Returns the logarithm of <i>x</i> for base 10. <sup>15</sup>
<b>LOG<sub>2</sub></b>	 lb x	(1) {1, 2, 3, 8*, 9*, 10} ((1) $\rightarrow$ {2}) Returns the logarithm of <i>x</i> for base 2. <sup>15</sup>
<b>LogF</b>	 	(0) Selects the logarithmic curve fit model. Relevant for CORR, COV, L.R., s <sub>XY</sub> , $\hat{x}$ , and $\hat{y}$ . See pp. 221ff for more.

<sup>15</sup> See the DT tables in Section 2 of the OM for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>Logis<sub>p</sub></b>	<b>g [PROB]</b> <b>f Logis:</b> <b>Logis<sub>p</sub></b> etc.	(1) {2}; {1} → {2} <i>Logistic distribution with <math>\mu</math> given in I and s in J.</i> See pp. 221ff for details.
<b>Logis<sub>a</sub></b>		
<b>Logis<sub>a</sub></b>		
<b>Logis<sup>-1</sup></b>		
<b>Logis:</b>	<b>g [PROB]</b> <b>f Logis:</b>	<b>Submenu.</b> See p. 122.
<b>LOG<sub>x,y</sub></b>	<b>g [EXP]</b> <b>log<sub>x,y</sub></b>	(2) {1, 2, 3, 8*, 9*, 10}; ({1} → {2}) Returns the logarithm of y for the base number x. See the DT tables in Sect. 2 of the OM for more.
<b>LOOP</b>	<b>f [LOOP]</b>	<b>Menu.</b> See p. 121.
<b>L.INTS</b>	<b>f [CATALOG]</b> <b>VARS</b> <b>L.INTS</b>	<b>Submenu of long integer variables defined at execution time.</b> See pp. 113ff.
<b>L.R.</b>	<b>f [STAT]</b> <b>▲ L.R.</b>	(-2) or (-3) {} → {2} Pushes the parameters <b>a<sub>2</sub></b> (in Z), <b>a<sub>1</sub></b> (in Y), and <b>a<sub>0</sub></b> (in X) of the fit curve through the data points accumulated in the statistical summation <i>registers</i> on the <i>stack</i> , according to the curve fit model selected (see LINF, ORTHOF, EXPF, POWERF, LOGF, HYPF, ROOTF, PARABF, CAUCHF, GAUSSF). For a straight line, <b>a<sub>0</sub></b> is its y-intercept and <b>a<sub>1</sub></b> is its slope. See pp. 221ff for more.
<b>l.y.→m</b>	<b>f [U→]</b> <b>x: l.y.→m</b>	(1) {2}; {1} → {2} Converts distances. See pp. 137ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$m^2 \rightarrow ac$	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}
$m^2 \rightarrow ha$	f [U→] f A: $m^2 \rightarrow ha$	Convert areas. See pp. 137ff.
$m^2 \rightarrow m\ddot{u}$	f [U→] f A: f $m^2 \rightarrow m\ddot{u}$	
$m^3 \rightarrow bbl$	f [U→] f V: f $m^3 \rightarrow barrel$	
$m^3 \rightarrow fz_{uk}$	f [U→] f V: f $m^3 \rightarrow fz_{uk}$ etc.	
$m^3 \rightarrow fz_{us}$		(1) {2}; {1} → {2}
$m^3 \rightarrow gl_{uk}$	f [U→] f V: $m^3 \rightarrow gl_{uk}$ etc.	Convert volumes. See pp. 137ff.
$m^3 \rightarrow gl_{us}$		
$m^3 \rightarrow qt.$		
MANT	f [PARTS] MANT	(1) {2}; {1} → {2} Returns the mantissa $m$ of the number $x = m \cdot 10^h$ displayed. Cf. EXPT.
MASKL	f [BITS] MASKL n	(-1) {} → {10}
MASKR	f [BITS] MASKR n	Work like MASKL and MASKR on HP-16C, but with the mask length (or its address) following the command instead of being taken from X. Thus, the mask is pushed on the stack. MASKL 0 and MASKR 0 return 0.  <b>Example:</b> For WSIZE 8, MASKL 3 will return a mask word 1110 0000 <sub>2</sub> . Use it e.g. for extracting the top three bits of an arbitrary byte via AND.
MATRS	f [CATALOG] VARS MATRS	Submenu of matrix variables defined at execution time. See pp. 113f.
MATR?	g TEST ▲ MATR?	(0) Checks if $x$ is a <i>real</i> or <i>complex</i> matrix.
MATX	f [MATX]	Menu. See p. 121.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
Mat_X	f [MATX] SIM EQ Mat X	(-1) Returns the solution vector for a system of linear equations (see the OM, Section 2).
max	g [X.FN] g max	(2) {1, 2, 4, 5, 6, 7, 10} Returns the maximum of $x$ and $y$ .
MEM?	g [INFO] MEM?	(-1) {} → {1} Returns the number of free bytes in RAM (i.e. the pool size), taking into account all registers currently allocated and their current contents.
MENU	g [P.FN] P.FN2 MENU	Displays the programmable menu. See the OM, Sect. 3, and the HP-42S OM, Part 2, Sect. 10, p. 146.
MENUS	f [CAT.] MENUS	Submenu of all menus defined at execution time. See pp. 113ff.
min	g [X.FN] g min	(2) {1, 2, 4, 5, 6, 7, 10} Returns the minimum of $x$ and $y$ .
MIRROR	f [BITS] f MIRROR	(1) {10} Reflects the bit pattern in $x$ (e.g. 0001 0111 <sub>2</sub> would become 1110 1000 <sub>2</sub> for word size 8).
mi.→m	f [U→] x: f mi.→m	(1) {2}; {1} → {2}
mmH>Pa	f [U→] F&p: ▲ mmHg → Pa	Convert distances and pressures. See pp. 137ff.
MOD	g [MOD]	(2) {1, 2, 10}
	g [INTS] f MOD	Returns $y \bmod x$ (modulo, see Section 2 of the OM for examples). Cf. RMD.
MODE	g [MODE]	Menu. See p. 121.
MONTH	g [CLK] f MONTH	(1) {2, 6} → {1} Assumes $x$ containing a date in the format selected (or a real number in corresponding format) and extracts the month.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
MSG		(0) {1, 2} Throws the ( <i>temporary</i> ) error message specified by the integer part of $x$ . Cf. ERR. See App. C on pp. 179ff for the respective error codes.
MUL $\pi$		(0) Sets the ADM to <i>multiples of <math>\pi</math></i> .
MUL $\pi\rightarrow$		(1) {1, 2, 4} → {4} Converts angles as described on p. 145.
$m\ddot{u} \rightarrow m^2$		(1) {2}; {1} → {2} Converts areas. See pp. 137ff.
MVAR		(0) Defines a <i>menu variable</i> . Such variables are required for VARMNU. Works in PEM only. See the OM, Section 3.
MyMenu		User menu. See the OM, Section 6.
My $\alpha$		User menu in AIM.
M.DELR		(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		(0) {1, 2} Creates a new named matrix or re-dimensions an existing matrix to IP(y) rows and IP(x) columns. Cf. DIM in the HP-42S OM, p. 217.
M.DIM?		(8, 9) → {1} Returns the dimensions of the matrix $x$ (rows to $\mathbf{Y}$ , columns to $\mathbf{X}$ ). Note the matrix is saved in $\mathbf{L}$ . Former $y$ goes into $\mathbf{Z}$ , former $z$ into $\mathbf{T}$ , etc.
M.DY		(0) Selects the format mm/dd/yyyy for dates.
M.EDI		(2) {8, 9} Opens $x$ using the <i>Matrix Editor</i> (like MATRIX EDIT in HP-42S). <sup>16</sup> See Section 2 of the OM.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
M.EDIN	 	(2) Opens a named matrix using the <i>Matrix Editor</i> (like MATRIX EDITN in <i>HP-42S</i> ). <sup>16</sup> See Section 2 of the OM.
M.EDIT		<b>Submenu</b> for matrix editing, called by M.EDI and M.EDIN. See p. 121.
M.GET	 	(0) {1, 2} → {8, 9} Gets a sub-matrix with IP(y) rows and IP(x) columns out of the indexed matrix into <b>X</b> . Cf. M.PUT.
M.GOTO		(0) Asks for target row and column and moves to this matrix element.
M.GROW		(0) Allows the indexed matrix to grow automatically (cf. J+ and Section 2 of the OM; cf. also GROW in the <i>HP-42S OM</i> , p. 213.). See M.WRAP.
M.INSR		(0) Inserts a new row of elements containing 0., left of the current cursor position in the matrix.
M.LU	 	(1) <i>WP 34S</i> : Takes a <i>descriptor</i> of a square matrix in <b>X</b> . Transforms ( <b>X</b> ) 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. <i>xxx</i>
M.NEW	NEW	(2) {1, 2} → {8} Creates a new matrix. 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.

<sup>16</sup> EDIT and EDITN disable ASL. In the *HP-42S*, both don't actually disable ASL; they preserve the *stack lift* state – you can observe this if you do ENTER vs. a *stack-lift*-enabling operation (e.g.  $x\downarrow y$ ) just before invoking them. This behavior is not really useful – it is dropped here since *HP-42S* compatibility is not required.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
M.PUT	f MATX g PUTM	(0) {8, 9} Puts the matrix $x$ as is into the indexed matrix. Cf. M.GET.
M.R <sub>x</sub> R	f MATX ▲ f R <sub>x</sub> R	(0) {8, 9} Swaps row $x$ and row $y$ of the indexed matrix.
M.SIMQ		Submenu of MATX, called by SIM_EQ.
M.SQR?	g TEST ▲ f M.SQR?	(0) Returns true if $x$ is a square matrix.
M.WRAP	f WRAP with M.EDIT displayed	(0) Controls the index pointers (see Section 2 of the OM). Cf. M.GROW.
m:	f U <sub>→</sub> m:	Submenu. See p. 123.
m→au	f U <sub>→</sub> x: m→au	(1) {2}; {1} → {2} Convert distances or heights. See pp. 137ff.
m→chī	... ▼ g m→chī etc.	
m→cūn		
m→fēn		
m→fm.	... ▲ m → fathom	
m→ft.	... f m→ft.	
m→ft <sub>us</sub>	... ▲ m → survey foot <sub>us</sub>	
m→in.	... g m→in.	
m→lī	... ▼ m→lī	
m→l.y.	... m→l.y.	
m→mi.	... f m→mi. etc.	
m→nmi.		
m→pc	... m→pc	

Item	Keystrokes	Remarks (see pp. 12ff for general information)
m→pt.	... <b>g</b> m → point	
m→yd.	... <b>g</b> m → yd.	
m→yīn	... <b>▼</b> m → yīn	
m→zhàng	... <b>▼</b> m → zhàng	
NAND	<b>f</b> BITS <b>f</b> NAND	(2) Works in analogy to AND. See p. 18.
NaN?	<b>g</b> TEST <b>▲</b> <b>f</b> NaN?	(0) Returns true if $x$ is Not a Number. For complex $x$ , Re( $x$ ) or Im( $x$ ) must be ±NaN..
NBin <sub>p</sub>	<b>g</b> PROB	(1) {2}; {1} → {2}
NBin <sub>▲</sub>	<b>g</b> NBin: NBin <sub>p</sub>	Negative binomial distribution with the total number of failures $f$ in <b>X</b> , the probability of a success $p_o$ in <b>I</b> , and the number of draws $n$ in <b>J</b> . See pp. 221ff for more information.
NBin <sub>▲</sub>	etc.	
NBin <sup>-1</sup>		
NBin:	<b>g</b> PROB <b>g</b> NBin:	Submenu. See p. 122.
NEIGHB	<b>g</b> INFO	(2) {1}
	<b>f</b> NEIGHB	Returns ... <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>
		(2) {2}
		Returns the nearest machine-representable number to $x$ in the direction towards $y$ in the mode set. For <ul style="list-style-type: none"><li>• ... <math>x &lt; y</math> , it is the machine successor of <math>x</math> ;</li><li>• ... <math>x = y</math> , it is <math>y</math> ;</li><li>• ... <math>x &gt; y</math> , it is the machine predecessor of <math>x</math>.</li></ul>
		NEIGHB may be useful investigating numeric stability (see NEIGHBOR in the HP-71 Math Pac).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>NEXTP</b>	<b>g X.FN</b> <b>g NEXTP</b>	(1) {1, 10}; {2} → {1} Returns the next prime number greater than $ P(x) $ . See also PRIME? on p. 58.
<b>nmi.→m</b>	<b>f [U→] x: f nmi.→m</b>	(1) {2}; {1} → {2}
<b>Nm→lbf·ft</b>	<b>f [U→] ▾ Nm → lbf·ft</b>	Convert distances and torques. See pp. 137ff.
<b>NOP</b>	<b>g P.FN</b> P.FN2 <b>f NOP</b>	'Empty' step (for historical reasons only).
<b>NOR</b>	<b>f BITS</b> <b>f NOR</b>	(2) Works in analogy to AND. See p. 18.
<b>Norml<sub>p</sub></b>	<b>g PROB</b> <b>Norml:</b> Norml <sub>p</sub>	(1) {2}; {1} → {2}
<b>Norml<sub>μ</sub></b>	etc.	Normal distribution with an arbitrary mean $\mu$ given in <b>I</b> and standard deviation $\sigma$ in <b>J</b> . See Section 2 of the OM for an application example and pp. 221ff for more.
<b>Norml<sub>Δ</sub></b>		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> .
<b>Norml<sup>-1</sup></b>		
<b>Norml:</b>	<b>g PROB</b> Norml:	Submenu. See p. 122.
<b>NOT</b>	<b>f BITS</b> NOT	(1) {10} Inverts $x$ bit-wise as on HP-16C. (1) {1, 2} → {1} Returns 1 for $x = 0$ , and 0 for $x \neq 0$ .
<b>nΣ</b>	<b>g Σ</b> n	(-1) {} → {1} Recalls the number of accumulated data points.
<b>N→lbf</b>	<b>f [U→]</b> F&p: N→lbf	(1) {2}; {1} → {2} Converts forces. See pp. 137ff.
<b>ODD?</b>	<b>g TEST</b> <b>f ODD?</b>	(0) Checks if $x$ is integer (see INT?) and odd.
<b>OFF</b>	<b>g OFF</b>	(0) Turns your WP 43S off. In PEM, inserts a step to turn it off under program control.
<b>OR</b>	<b>f BITS</b> OR	(2) Works in analogy to AND, see p. 18.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
OrthoF	f [STAT] g OrthoF	(0) Selects the linear orthogonal fit model. Relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 230ff for more.
ORTHOG	g [X.FN] Orthog	Submenu for orthogonal polynomials, see p. 124.
oz→kg	f [U↔] m: oz→kg	(1) {2}; {1} → {2} Converts masses. See pp. 137ff.
ParabF	f [STAT] ▼ f ParabF	(0) Selects the parabolic fit model. Relevant for COV, CORR, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 230ff for more.
PARTS	f PARTS	Menu. See p. 121.
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	Convert pressures. See pp. 137ff.
Pa→bar	... Pa→bar	
Pa→iHg	... f Pa → in.Hg	
Pa→mmH	... f Pa → mmHg	
Pa→psi	... Pa→psi	
Pa→tor	... f Pa → torr	
pc→m	f [U↔] x: pc→m	Converts distances. See pp. 137ff.
PERM	g PROB P <sub>yx</sub>	(2) {1} Returns the number of possible <u>arrangements</u> (a.k.a. <i>permutations</i> ) of $x$ <i>items</i> taken out of a set of $y$ <i>items</i> . No <i>item</i> occurs more than once in an arrangement, and <u>different orders</u> of the same $x$ <i>items</i> are counted separately. Cf. COMB. (2) {2, 3} See pp. 219f 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. See Section 4 of the OM.
PGMSLV	f ADV f PGMSLV <i>label</i>	
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. B-20 for more.
P <sub>n</sub>	g X.FN Orthog P <sub>n</sub>	(1) {2}; {1} → {2} <i>Legendre polynomials.</i> See pp. 236f for more.
POINT	g P.FN P.FN2 g POINT	(1) {1, 2} Turns on a square point (3x3 px ▀) on the screen. The position 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 <sub>p</sub>	g PROB g Poiss: Poiss <sub>p</sub>	(1) {2}; {1} → {2}
Poiss <sub>▲</sub>	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. 221ff for details.
Poiss <sub>▲</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:	g PROB g Poiss:	Submenu. See p. 122.
PopLR	g P.FN g PopLR	(0) Pops the local registers allocated to the <i>current routine</i> (see the OM, Section 3) <u>without returning to the calling routine</u> . See LOCR and RTN.
PowerF	f STAT ▼ PowerF	(0) Selects the power curve fit model. Relevant for CORR, COV, L.R., sXY, $\hat{x}$ , and $\hat{y}$ (see pp. 221ff for more).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
PRCL	<b>g P.FN</b> <b>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</b> <b>f PRIME?</b>	(0) {1, 2, 10}  Checks if $ IP(x) $ is a prime. Returns <b>true</b> for prime and <b>false</b> for composite. For $x > 3.3 \times 10^{24}$ , <b>true</b> means ‘probably prime’ (see p. 168 for more).
PRINT	<b>g PRINT</b>	<b>Menus.</b> See p. 122.
PROB	<b>g PROB</b>	
PROG		<b>Submenu</b> of global labels defined when calling XEQ etc. See Section 3 of the <i>OM</i> .
PROGS	<b>f CAT. PROGS</b>	<b>Submenu</b> of global labels defined at execution time. See pp. 113f.
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. 137ff.
PSTO	<b>g P.FN</b> <b>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 <b>XEQ</b> .
pt.→m	<b>f U→ x:</b> <b>g point → m</b>	(1) {2}; {1} → {2}  Converts print heights. See pp. 137ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>PUTK</b>	 	(0) Assumes a key code in the address specified. Stops program execution, takes said code and puts it in the keyboard buffer resulting in immediate execution of the corresponding call. <b>R/S</b> is required to resume program execution then. May help in user interaction with routines (see the OM, Section 3).
<b>P.FN</b>		<b>Menu.</b> See p. 122.
<b>P.FN2</b>	<b>P.FN2</b>	<b>Submenu.</b> See p. 122.
<b>P:</b>		<b>Submenu.</b> See p. 135.
<b>qt.→m<sup>3</sup></b>	 	(1) {2}; {1} → {2} Converts volumes. See pp. 137ff.
<b>RAD</b>		(0) Sets the <i>ADM</i> to <i>radians</i> .
<b>RAD→</b>		(1) {1, 2, 4} → {4} Converts angles as described on p. 145.
<b>RAM</b>		<b>Submenu</b> of global labels defined at execution time. See pp. 113f.
<b>RANGE</b>	 	(0) {1, 2} Limits the range of displayable <i>real numbers</i> to $\pm 10^{\pm n}$ with $n = \text{IP}(x)$ , $99 \leq n \leq 6145$ . For greater input, $n$ will be set to 6145 (startup default); for less it will be set to 99. RANGE allows for saving screen space for reasonable data.
<b>RANGE?</b>		(-1) {} → {1}
		Returns the current range setting.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RANI#	 	(-1) {} → {1} Returns an integer random number $n$ with $\text{IP}[\min(x,y)] \leq n \leq \text{IP}[\max(x,y)]$ . After executing RANI#, the stack looks like $[n, x, y, \dots]$ , 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.
RAN#	 	(-1) {} → {2} Returns a random number between 0. and 1. See also SEED.
RBR		Calls the register browser – 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 numbers</i> are generally displayed in their format chosen; since it uses the small font all the way, more digits can be shown here in ALL 0 than in a standard numeric row. For <i>reals</i> and ALL 0, RBR display will turn to SCI or ENG at 33 digits in worst case. Extended display precision may be observed for <i>complex numbers</i> as well.
RCL		(-1) Recalls the content of a register or variable and pushes it on the stack.
RCLCFG		(0) Recalls a calculator configuration stored by STO CFG (see the OM, Sections 2 and 6). Cf. also RESET on p. 62.
RCLEL	 <hr/>  <hr/>  with M.EDIT displayed	(-1) {} → {2, 3}  Recalls a copy of the current element $a_{ij}$ of the indexed matrix. Cf. STOEL.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RCLIJ	 	(-2) {} → {1} Recalls the current values of the matrix index pointers into X (= column number) and Y (= row number). If both pointers equal zero, then there is no indexed matrix. Cf. STOIJ.
RCLS	Stack r	Recalls 4 or 8 values from a set of registers starting at address r, and pushes them on the stack. This is the converse command of STOS.
RCL+	r	(1) Recalls a content of a register or variable, executes the operation specified, and puts the result on the stack like a monadic function. <sup>17</sup>
RCL-	r	
RCLx	r	
RCL/	r	
RCL↑	r r	(1) {1, 2, 4, 5, 6, 10} Replaces x with the maximum of r and x. <sup>17</sup>
RCL↓	r r	(1) {1, 2, 4, 5, 6, 10} Replaces x with the minimum of r and x. <sup>17</sup>
RDP	 n	(1) {2, 3, 4, 5, 8*, 9*} Rounds x to n decimal places ( $0 \leq n \leq 99$ , think of FIX format), taking the RM setting into account. See RM and compare RSD.
Re	Re g Re	(1) {2, 3} → {2}; {9} → {8} Returns the real part of x. Cf. IM.
REALS	VARS REALS	Submenu of real variables defined at execution time. See pp. 113f.
REAL?	▲ REAL?	(0) Checks if x is a real number or matrix.

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

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RECV	f I/O f RECV	(0) Prepares your WP 43S for receiving data via serial I/O. See SEND and Section 3 in the OM for more.
REGIST	f CAT. REGIST	Submenu of named registers defined. See pp. 113f.
RESET	g CLR g RESET	Executes CLALL and resets your WP 43S to startup default configuration, i.e. 2COMPL, ALL 0, DEG, DENMAX 0, DSTACK 4, GAP 3, J/G 1752.0914, LinF, LocR 0, RM 0, RSD 34, TDISP 0, WSIZE 64, and Y.MD. In this course, RESET also sets RANGE to 6145, resets the random number generator, sets the flags ASLIFT, DECIM., DENANY, MULTx, PROPFR, TDM24, and clears all other system flags (see pp. 101ff). See said commands and system flags for more.
RE→CX	CC (works in run mode only)	(2) {2} → {3} Composes a complex number out of two reals or integers $x$ and $y$ , setting C and taking either... <ul style="list-style-type: none"><li>• (for L) the real part from Y and imaginary part from X, or</li><li>• (for ⊙) magnitude from Y and phase from X.</li></ul>
	g CPX f RE→CX	(2) {8} → {9} Works in analogy for two real matrices $x$ and $y$ .
Re↔Im	g CPX Re↔Im	(1) {3, 9*} Swaps real and imaginary part of complex objects.
RJ	f BITS ▲ g RJ	[10] Right justifies a bit pattern within its word size, in analogy to LJ (see there). The stack will lift, placing the right-justified word in Y and the count of bit-shifts necessary to justify the word in X. <b>Example:</b> 10 1100 <sub>2</sub> RJ results in $y = 1011_2$ and $x = 2$ .

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RL		(1) {10}  Works like $n$ consecutive RLs on HP-16C, similar to RLn there ( $0 \leq n \leq 63$ ). RL 0 executes as NOP, but loads L. See the OM, Sect. 2, for more.
RLC		(1) {10}  Works like $n$ consecutive RLCs on HP-16C, similar to RLCn there ( $0 \leq n \leq 64$ ). RLC 0 acts as NOP, but loads L. See the OM, Sect. 2, for more.
RM		(0) Sets floating point rounding mode. This rounding mode is used only for RSD or when converting from the extended precision internal format (typically 39 digits) to packed reals. It will <u>not</u> alter the display nor change the behavior of ROUND. The following 7 modes are supported:  0: round half even: $\frac{1}{2}\uparrow$ 0.5 rounds to next even number (default, used in science). 1: round half up: $\frac{1}{2}\uparrow$ 0.5 rounds up ('business-man's rounding' <sup>18</sup> ). 2: round half down: $\frac{1}{2}\downarrow$ 0.5 rounds down. 3: round up: $\leftarrow\rightarrow$ rounds away from 0. 4: round down: $\rightarrow\leftarrow$ rounds towards 0. 5: ceiling: $\lceil x \rceil$ rounds towards $+\infty$ . 6: floor: $\lfloor x \rfloor$ rounds towards $-\infty$ .  The abbreviations printed on grey background are used in STATUS for indicating the respective rounding modes (see Section 5 of the OM).

<sup>18</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	 	(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, Section 2, for examples. Cf. MOD.
RM?		(-1) {} → {1} Returns the floating point rounding mode set. See RM for more.
RNORM	 	(1) {8, 9} Calculates the row norm of the matrix $x$ , i.e. the maximum value (over all rows) of the sums of the absolute values of all elements in a row (like RNRM on HP-42S). For a vector, the row norm is the largest absolute value of any of its elements.
RootF	 	(0) Selects the root fit model; relevant for CORR, COV, L.R., $s_{XY}$ , $\hat{x}$ , and $\hat{y}$ . See pp. 230ff for more.
ROUND		(1) {2, 3, 4, 5, 6, 8*, 9*} Rounds $x$ using the current display format like RND on HP-42S.
ROUNDI		(1) {8*}; {2} → {1} Rounds $x$ to next integer. $\frac{1}{2}$ rounds to 1. Cf. IP.
RR	 	(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.
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.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
RSD	 	(1) {2, 3, 4, 5, 8*, 9*} Rounds $x$ to $n$ significant digits ( $1 \leq n \leq 34$ ), taking the RM setting into account. Think of SCI. Cf. RM and RDP.
RSUM	 	(0) {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 the OM, Section 3). 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. the routine is top level), program execution halts, the program pointer is set to step 0000, and $\overline{F}$ 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, Section 3). If this program is in FM, the pointer is set to step 0000 in RAM, and $\overline{F}$ is lit.
RTN+1	 	(0) Works like RTN but: in a routine executing, RTN+1 moves the program pointer <u>two</u> steps behind the XEQ instruction that called said routine.
R-CLR	 	(0) {2} Interprets $x$ in the form $sss.nnn$ . Clears $nn$ registers starting with address $sss$ .  <b>Example:</b> For $x = 34.567$ , R-CLR will clear R34 through R89.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		<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>P.FN</b>  <b>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, r08, r09</math> will be copied into <b>R45, R46, 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>P.FN</b>  <b>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> <p><b>ATTENTION:</b> For <math>nn = 0</math>, sorting will cover the maximum available as explained with R-CLR.</p>
R-SWAP	 <b>P.FN</b>  <b>R-SWAP</b>	<p>(0) {2}</p> <p>Works like R-COPY but <u>swaps</u> the contents of source and destination <i>registers</i>.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
R→D		(1) {1, 2, 4} → {4} Converts angles as described on p. 145.
R↑		
R↓		Rotates the stack contents one level up or down, respectively. See Section 1 of the OM for details.
s		(-2) {} → {2} Takes the statistical sums accumulated, calculates the <i>sample standard deviations</i> $s_y$ and $s_x$ and pushes them on the stack. See Sect. 2 of the OM for the output format and pp. 230ff for the formula.
SAVE		(0) Saves user program space, registers and system state to a file in the FAT system, and returns Saved. Recall your backup using the different flavors of LOAD.
SB		(1) {10} Sets the specified bit in $x$ .
SCI		(0) Sets scientific display format (see Section 2 of the OM).
scw→kg		(1) {2}; {1} → {2} Converts masses. See pp. 137ff.
SDIGS?		(-1) {} → {1} Returns the number of significant digits set by SETSIG. Also returned by STATUS.
SDL	 etc. or	(1) {1, 2}
SDR	 etc.	Shifts digits left (right) by $n$ decimal positions, equivalent to multiplying (dividing) $x$ by $10^n$ . SDR for long integers ends with zero. Compare SL and SR for binary integers.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SEED	<b>g PROB</b> <b>▲ SEED</b>	(0) {2} Stores a seed for random number generation. For $x \leq 0$ , the seed is taken from the real-time clock.
SEND	<b>f I/O</b> <b>f SEND</b>	(0) Sends all RAM data to the device connected via serial I/O. See RECV and the OM, Section 3 for more.
SETCHN	<b>g DISP</b> <b>▲ CHINA</b>	(0) Sets regional format preferences. <sup>19</sup>
SETDAT	<b>g CLK</b> <b>▲ SETDAT</b>	(0) Sets the date for the real-time clock. <sup>20</sup>
SETEUR	<b>g DISP</b> <b>▲ EUROPE</b>	
SETIND	<b>g DISP</b> <b>▲ INDIA</b>	(0) Set regional format preferences. <sup>19</sup>
SETJPN	<b>g DISP</b> <b>▲ JAPAN</b>	
SETSIG	<b>g MODE</b> <b>f SETSIG</b>	(0) {1} Sets the number of significant digits (1 ... 34) for rounding after each operation. SETSIG 0 sets maximum precision.
SETTIM	<b>g CLK</b> <b>▲ SETTIM</b>	(0) Sets the time for the real-time clock. <sup>20</sup>
SETUK	<b>g DISP</b> <b>▲ UK</b> etc.	(0) Set regional format preferences. <sup>19</sup>
SETUSA		
SF	<b>g FLAGS</b> <b>SF n</b>	
	<b>g MODE</b> <b>SF n</b>	(0) Sets the flag specified.

<sup>19</sup> See Section 2 of the OM about localization of numeric output.

<sup>20</sup> Works on the calculator only – the simulator takes this information from the PC clock.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SHOW	f SHOW	(0) {1, 2, 3, 4, 7} Shows all digits or characters stored in <b>X</b> in top numeric row until next keystroke, using small font. For a <i>complex number</i> , either part of it will take one display row if one row cannot take both parts. For a <i>real, time, or date</i> up to 34, 35, or 36 digits will be shown. For a <i>long integer</i> , up to 296 digits can be shown using up to 7 display rows; for any greater integer, just its most significant 294 digits can be shown, trailed by ellipses. The simulator allows for extracting even longer integers (see App. E).
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 number</i> $x$ (cf. UNITV). Maintained for backward compatibility only.
SIGNMT	f BITS ▼ SIGNMT g INTS ▲ SIGNMT	(0) Sets sign-and-mantissa mode for operations on <i>short integers</i> . See the OM, Sect. 2.
SIM_EQ	f MATX SIM EQ n	(0) Solves a system of $n$ linear equations $(MATA) \cdot \overrightarrow{MATX} = \overrightarrow{MATB}$ . If these matrices are not defined before, they will be created automatically at execution time. See Section 2 of the OM for more.
sin	TRI sin	(1) {2, 3, 8*, 9*}; {1, 4} → {2} Returns the sine of the angle in <b>X</b> (takes $x$ as tagged, else assumes the current ADM; see Section 2 of the OM for details)..

Item	Keystrokes	Remarks (see pp. 12ff for general information)
sinc	[TRI] [f] sinc	(1) {2, 3, 4, 8*, 9*} ... for $x \neq 0$ and 1 for $x = 0$ . Tagged input of data type 4 will be converted in radians before computing. Untagged input is taken as radians. Returns $\sin(x)/x$ ...
sincπ	[TRI] [f] sincπ	(1) {2, 3, 4, 8*, 9*} Returns $\sin(\pi x)/\pi x$ ...
sinh	[TRI] [g] sinh [g] [EXP] [g] sinh	(1) {2, 3, 8*, 9*} Returns the hyperbolic sine of $x$ .
SKIP	[g] [P.FN] P.FN2 [g] SKIP n	(0) Skips $n$ program steps forwards ( $0 \leq n \leq 255$ ). So e.g. SKIP 2 skips over the next two steps, going e.g. from step 123 to step 126. If SKIP attempts to cross an END, an error is thrown. <b>ATTENTION:</b> If you edit a section of your routine crossed by one or more BACK, SKIP, or CASE jumps, this may well result in a need to <b>manually maintain all those statements individually</b> .
SL	[f] [BITS] [▲] [f] SL n	(1) {10} [C] ← ← ← ← ← ← ← ← ← ← 0 Works like $n$ ( $\leq 63$ ) consecutive SLs on HP-16C. SL 0 executes as NOP, but loads L. See Section 2 of the OM for more.
SLVQ	[f] [ADV] SLVQ	(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>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
		In either case and also for <i>complex</i> parameters, SLVQ returns $r$ in <b>Z</b> . Higher <i>stack registers</i> are kept unchanged. <b>L</b> will contain equation parameter <b>c</b> .
<b>s<sub>m</sub></b>	<b>f 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 stack. Output format will be like the one of s (see the OM, Section 2).
<b>s<sub>mw</sub></b>	<b>f STAT</b> <b>f 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 $\bar{x}_w$ .
<b>SNAP</b>	<b>g SNAP</b>	(0) Stores a snapshot of the screen (a.k.a. screenshot) in a <b>BMP</b> file on the calculator's <i>USB</i> flash disk in the /SCREENS directory. The file name comprises date and time of storage. The file can be dealt with on your computer.
<b>SOLVE</b>	<b>f ADV</b> <b>SOLVE</b> <b>var</b>	[2, 3] Solves the equation $f(var) = 0$ , with $f$ calculated by the equation specified (in <i>PEM</i> by PGMSLV). Two initial estimates of the root must be supplied in <b>X</b> and <b>Y</b> when calling SOLVE. It returns $var_{root}$ in <b>X</b> , the second last <b>var</b> -value tested in <b>Y</b> , then $f(var_{root})$ 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.  <b>ATTENTION:</b> SOLVE fills all <i>stack registers</i> with $x$ before calling the routine specified.
<b>Solver</b>	<b>g EQN</b> <b>Solver</b>	Submenu for solving a given equation. See the OM, Section 4, for more.
<b>SPEC?</b>	<b>g TEST</b> <b>▲ f SPEC?</b>	(0) True if $x$ is 'special' (i.e. $±\infty$ or NaN).

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SR	 	(1) {10} 0 → [ ] → C Works like $n$ ( $\leq 63$ ) consecutive SRs on HP-16C. SR 0 executes as NOP, but loads L. Cf. ASR. See Section 2 of the OM for more.
SSIZE?		(-1) {} → {1} Returns the number of <i>stack registers</i> currently allocated, 4 or 8.
STAT		Menu. See p. 123.
STATUS		Displays number of free bytes in RAM, flags set, local registers allocated, and system variables. See the OM, Sect. 5 for more.
STK		Menu. See p. 123.
STO		(0) Stores $x$ into destination. <sup>21</sup>
STOCFG		(0) Stores the current calculator configuration in a variable or <i>register</i> for later use as described in Sections 2 and 6 of the OM. RCLCFG recalls such data. Cf. also RESET on p. 62. <sup>21</sup>
STOEL		(1) {1, 2, 3}
		Stores a copy of $x$ into the indexed matrix at the current element, $a_{ij}$ . Cf. RCLEL. <sup>21</sup>
STOIJ		(1) {1}
		Sets the index pointers to IP( $x$ ) (column number) and IP( $y$ ) (row number). Cf. RCLIJ. <sup>21</sup>
STOP		(0) Stops program execution. May be inserted in programs to wait for input, for example.
STOS		(0) Stores the entire <i>stack</i> in a set of 4 or 8 <i>registers</i> , starting at the destination address specified. Cf. RCLS. <sup>21</sup>

<sup>21</sup> L will not be loaded.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
<b>STO+</b>	<b>STO</b> <b>+</b> <i>r</i>	
<b>STO-</b>	<b>STO</b> <b>-</b> <i>r</i>	(0) Executes the specified operation on <i>r</i> and stores the result (e.g. $r - x$ ) at the address specified. <sup>22</sup>
<b>STOx</b>	<b>STO</b> <b>x</b> <i>r</i>	
<b>STO/</b>	<b>STO</b> <b>/</b> <i>r</i>	
<b>sto→kg</b>	<b>f</b> <b>U→</b> <b>m:</b> <b>f</b> <b>stone</b> → <b>kg</b>	(1) {2}; {1} → {2} Converts masses. See pp. 137ff.
<b>STO↑</b>	<b>STO</b> <b>f</b> <b>Max</b> <i>r</i>	
	<b>STO</b> <b>▲</b> <i>r</i>	(0) {1, 2, 4, 5, 6, 10}
<b>STO↓</b>	<b>STO</b> <b>f</b> <b>Min</b> <i>r</i>	Stores the maximum (or minimum) of <i>r</i> and <i>x</i> in the address specified. <sup>22</sup>
	<b>STO</b> <b>▼</b> <i>r</i>	
<b>STRI?</b>	<b>g</b> <b>TEST</b> <b>g</b> <b>STRI?</b>	(0) True if <i>x</i> is a <i>text string</i> (cf. STR? in HP-42S).
<b>STRING</b>	<b>f</b> <b>CATALOG</b> <b>VARS</b> <b>STRING</b>	Submenu of <i>text string</i> variables defined at execution time. See pp. 113f.
<b>SUM</b>	<b>f</b> <b>STAT</b> <b>SUM</b>	(-2) {} → {2} Recalls the linear sums $\Sigma y$ and $\Sigma x$ . Useful in basic 2D vector algebra. Output labeled in analogy to <i>s</i> .
<b>s<sub>w</sub></b>	<b>f</b> <b>STAT</b> <b>f</b> <b>s<sub>w</sub></b>	(-1) {} → {2} Calculates the <i>standard deviation</i> for weighted data (where the weight <i>y</i> of each data point <i>x</i> was entered via <b>[Σ+]</b> ). See pp. 221ff for the formula.
<b>s<sub>xy</sub></b>	<b>f</b> <b>STAT</b> <b>▲</b> <b>s<sub>xy</sub></b>	(-1) {} → {2} Calculates the <i>sample covariance</i> for the two data sets <i>{x}</i> and <i>{y}</i> entered via <b>[Σ+]</b> , depending on the curve fit model selected. See pp. 230ff for the formula and COV for the <i>population covariance</i> .

<sup>22</sup> Only legal operations according to the *DT* matrices in Section 2 of the OM will work.  
See also the examples given there. **L** will not be loaded.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
SYSTEM	<b>g MODE</b> <b>g SYSTEM</b>	(0) Returns to DMCP. Works on the calculator only (not on the simulator). See App F.
SYS.FL	<b>f CATALOG</b> SYS.FL	Submenu of system flags. See p. 113.
s(a)	<b>f STAT</b> ▲ <b>f s(a)</b>	(-2) {} → {2} Pushes the standard errors $s(a_1)$ (in Y), and $s(a_0)$ (in X) for the parameters of the line fitted through the data points accumulated in the statistical summation registers on the stack. Works for LINF only. See pp. 236f for more.
S.INTS	<b>f CAT.</b> VARS S.INTS	Submenu of short integer variables defined at execution time. See pp. 113f.
s.t→kg	<b>f U→ m:</b> ▲ short ton → t	(1) {2}; {1} → {2}
s→year	<b>f U→ f s→year</b>	Convert masses and times. See pp. 137ff.
tan	<b>TRI tan</b>	(1) {2, 3, 8*, 9*}; {1, 4} → {2} Returns the tangent of the angle in X (takes x as tagged, else assumes the current ADM; see Sect. 2 of the OM for details). Returns "Not a Number" for $x = \pm 90^\circ$ or equivalents if SPCRES is set.
tanh	<b>g EXP g tanh</b> <b>TRI g tanh</b>	(1) {2, 3, 8*, 9*} Returns the hyperbolic tangent of x.
TDISP	<b>g CLK</b> ▲ <b>TDISP n</b>	(0) Sets time display format. TDISP 0 allows for the full time string (pure trailing decimal zeros will not be displayed), TDISP 1 or 2 truncates it to hours : minutes only, TDISP 3 to hours : minutes : seconds, and $n \geq 4$ displays also $n - 3$ digits for decimal fractions of seconds. <b>Example:</b> With TDISP 6, a time string might look like 157:26:38.409

Item	Keystrokes	Remarks (see pp. 12ff for general information)
TEST	<b>g TEST</b>	<b>Menu.</b> See p. 123.
TICKS	<b>g [P.FN] TICKS</b>	<b>(-1 { } → {1})</b> 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>	<b>(-1 { } → {5})</b> Recalls the time from the real-time clock (or the PC clock for the simulator) 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, Section 5 for a detailed description.
TIMES	<b>f CAT. VARS f TIMES</b>	<b>Submenu of time variables defined at execution time.</b> See pp. 113f.
$T_n$	<b>g [X.FN] Orthog T<sub>n</sub></b>	<b>(2 {2}; {1} → {2})</b> <i>Chebyshev polynomials of first kind.</i> See pp. 236f for details.
TONE	<b>f I/O f TONE n</b>	<b>(0)</b> Sounds a tone according to $n$ (= 1 ... 9).
ton→kg	<b>f U→ m: ▲ ton→kg</b>	<b>(1 {2}; {1} → {2})</b> Converts masses. See pp. 137ff.
TOP?	<b>g TEST g TOP?</b>	<b>(0)</b> 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 flag is set and the SRS pointer is clear).</li> </ul>
torr→Pa	<b>f U→ F&amp;p: f torr → Pa</b>	<b>(1 {2}; {1} → {2})</b> Converts pressures. See pp. 137ff.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$t_p(x)$	<b>g [PROB]</b> <b>t:</b> $t_p(x)$ etc.	(1) {2}; {1} → {2} <i>Student's t distribution.</i> The degrees of freedom are stored in <b>I</b> . $t_p(x)$ equals $Q(t)$ on HP-21S. See Sect. 2 of the OM for an application example and pp. 221ff for more mathematical details.
$t_{\Delta}(x)$		
$t_{\Delta}(x)$		
$t^{-1}(p)$		
TRANS	<b>f [CAT.] FCNS TRANS</b>	Works like $[M]^T$ on p. 92. Maintained for backward compatibility only.
TRI	<b>TRI</b>	<i>Menu.</i> See p. 123.
$trz \rightarrow kg$	<b>f [U→] m:</b> <b>f tr.oz → kg</b>	(1) {2}; {1} → {2} Converts masses. See pp. 137ff.
TVM	<b>g [FIN] TVM</b>	<i>Submenu</i> for the <i>Time Value of Money</i> . See Section 5 of the OM.
$t:$	<b>g [PROB] t:</b>	<i>Submenu.</i> See p. 122.
$t \leftrightarrow r$	<b>g [STK] t \leftrightarrow r</b>	Swaps $t$ and $r$ , in analogy to $x \leftrightarrow$
ULP?	<b>g [INFO]</b> <b>f ULP?</b>	(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 (internal) value of $x$ in your WP 43S in the mode set. Thus, <b>1</b> is returned for integers. Indicated in STATUS.
$U_n$	<b>g [X.FN]</b> <b>Orthog</b> <b>U<sub>n</sub></b>	(2) {2}; {1} → {2} <i>Chebyshev polynomials of second kind.</i> See pp. 236f for details.
UNDO	<b>f</b>	Recalls the stack, the summation registers, and the system flags as they were before the last operation executed.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
UNITY	<b>f</b> MATX <b>f</b> UNITY	(1) {8, 9} Returns the unit vector for the matrix $x$ . 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 number</i> with <i>magnitude</i> $ r  = 1$ in direction of $x$ .
UNSIGN	<b>f</b> BITS ▼ UNSIGNED <b>g</b> INTS ▲ UNSIGNED	(0) Sets unsigned mode for mode for operations on <i>short integers</i> . Cf. UNSGN on HP-16C. See Section 2 of the OM.
U→	<b>f</b> U→	Menu. See p. 123.
VAR		Submenu of variables defined at execution time when calling STO, RCL, etc.
VARMNU	<b>g</b> P.FN <b>f</b> VARMNU <i>labl</i>	Creates a variable <i>menu</i> using the MVAR instructions following the global label specified. See the OM, Section 3.
VARS	<b>f</b> CAT. VARS	Submenu of variables defined at execution time. See pp. 113f.
VERS?	<b>g</b> INFO <b>g</b> VERS?	(0) Shows firmware version and build number until next keystroke (see the OM, Section 2).
VIEW	<b>g</b> VIEW <i>r</i>	(0) Shows <i>r</i> until the next key is pressed.  <b>Example:</b> If a variable called Test12 contains -123.45, <b>VIEW</b> <b>Test12</b> <b>ENTER↑</b> will display Test12 = -123.45
V:	<b>f</b> U→ <b>f</b> V:	Submenu. See p. 135.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\text{v}_4$		(2) {8} → {4} Returns the angle between two 2D or 3D vectors $\vartheta = \arccos\left(\frac{\vec{v}_1 \cdot \vec{v}_2}{ \vec{v}_1  \vec{v}_2 }\right)$
WDAY		(1) {2, 6} → {1} Assumes $x$ containing a <i>date</i> in the format selected (or a <i>real number</i> in a corresponding format) and returns the name of the respective day and a corresponding integer (Monday = 1). <sup>23</sup>
Weibl <sub>p</sub>		(1) {2}; {1} → {2}
Weibl <sub>▲</sub>		Weibull distribution with its shape parameter $b$ in I and its characteristic lifetime $T$ in J. See pp. 221ff for details.
Weibl <sub>▲</sub>	etc.	
Weibl <sup>-1</sup>		Weibl <sup>-1</sup> returns the survival time $t_s$ for a given probability $p$ in X, with $b$ in I and $T$ in J.
Weibl:		Submenu. See p. 122.
WHO?		(0) Displays credits to the brave men who made this project work (temporary message).
Wh→J		(1) {2}; {1} → {2} Converts energies. See pp. 137ff.
$W_m$		(1) {2, 3}; {1} → {2}
$W_p$	etc.	$W_p$ returns the principal branch of Lambert's W for given $x \geq -1/e$ . $W_m$ returns its negative branch (works for $x \in \mathbb{R}$ only). $W^{-1}$ returns $x$ for a given $W_p$ ( $\geq -1$ ). See pp. 254ff for more.
$W^{-1}$		

<sup>23</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)
<b>WSIZE</b>	<b>f BITS</b> ▼ WSIZE <b>n</b>	(0) Sets the <i>word size</i> (a.k.a. bit width) for <i>DT 10</i> . Works almost like on <i>HP-16C</i> , but with the parameter $1 \leq n \leq 64$ trailing the command instead of taken from <b>X</b> . WSIZE 0 sets the <i>word size</i> to maximum, i.e. 64 bits.  WSIZE works as it does in <i>WP 34S</i> :  Reducing <i>word size</i> truncates the <i>short integer</i> values in <b>L</b> and in the <i>stack registers</i> . All other memory content stays as is (see <i>App. B</i> on pp. 170f).  Increasing the <i>word size</i> adds significant empty bits to <i>short integer</i> values in <b>L</b> and in the <i>stack registers</i> . All other memory content stays as is.
	<b>g INTS</b> ▲ WSIZE <b>n</b>	
<b>WSIZE?</b>	<b>g INFO</b> <b>g WSIZE?</b>	(-1) {} → {1} Recalls the <i>word size</i> set.
<b>W→hp<sub>E</sub></b>	<b>f U→</b> <b>P:</b> <b>W→hp<sub>E</sub></b> etc.	(1) {} → {2}; {1} → {2}
<b>W→hp<sub>M</sub></b>		Convert powers. See pp. 137ff.
<b>W→hp<sub>UK</sub></b>		
<b>ŷ</b>	<b>f STAT</b> ▲ <b>ŷ</b>	(1) {} → {2} Returns a forecast <b>ŷ</b> for a given <b>y</b> (in <b>X</b> ) according to the curve fit model chosen. See L.R. for more.
<b>ȳ</b>	<b>f STAT</b> <b>ȳ</b>	(-2) {} → {2} Calculates the <i>arithmetic means</i> of the <i>y-</i> and <i>x-</i> data accumulated and pushes them on the <i>stack</i> . See also <b>s</b> , <b>s<sub>m</sub></b> , and <b>σ</b> .
<b>x<sup>2</sup></b>	<b>x<sup>2</sup></b>	(1) {1, 2, 3, 8*, 9*, 10}
<b>x<sup>3</sup></b>	<b>g EXP</b> <b>x<sup>3</sup></b>	Return the square or cube of <b>x</b> , respectively.
<b>XEQ</b>	<b>XEQ</b> <b>label</b>	(0) Executes the function or routine with the label specified. – In <i>PEM</i> , XEQ inserts a call to the subroutine with the label specified.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\bar{x}_G$		(-2) {} → {2} Calculates the <i>geometric means</i> of the y- and x-data accumulated and pushes them on the stack. See pp. 230ff for the formula. Output format will be similar to the one of $\bar{x}$ . See also $\varepsilon$ , $\varepsilon_m$ , and $\varepsilon_p$ .
$\bar{x}_H$		(-2) {} → {2} Calculates the <i>harmonic means</i> of the y- and x-data accumulated and pushes them on the stack.
xIN		with <b>type</b> = 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 SSIZE8). xIN is the recommended way to start an XROM routine. Thereafter, SSIZE8 is clear. Note xIN cannot nest and XROM routines using xIN cannot call user code.
$x_{\max}$	 etc.	(-2) {} → {2} Returns the maximum (or minimum) of the y- and x-data accumulated and pushes them on the stack.
$x_{\min}$	<b>ATTENTION:</b> These extrema will not be updated after $\Sigma-$ (see there).	
XNOR		(2) Work in analogy to AND. See p. 18.
XOR		
xOUT		Cleans and reverts the settings of xIN, taking care of a proper return including the correct setting of I and the stack. Typically, <b>way</b> = xOUT NORMAL . Generally, xOUT shall be the last command of an XROM routine.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\bar{x}_{\text{RMS}}$		(-2) {} → {2} Calculates the <i>quadratic means</i> of the $y$ - and $x$ -data accumulated and pushes them on the <i>stack</i> . Quadratic means are often used in electrical engineering for alternating currents.
$\bar{x}_w$		(-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. 230ff for the formula. See also $s_w$ and $s_{mw}$ .
$\sqrt[x]{y}$		(2) Returns the $x^{\text{th}}$ root of $y$ . For $y < 0$ and CPXRES set, it may return <i>complex numbers</i> . See the <i>DT</i> tables in <i>Section 2</i> of the OM for more.
X.FN		<b>Menu.</b> See p. 124.
$x!$		(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 maximum 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>real numbers</i> .
x:		<b>Submenu.</b> See p. 135.
$x \rightarrow \text{DATE}$		(1) {2} → {6} Interprets the <i>real number</i> $x$ 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</b> <b>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</b> <b>STK</b> $x \leftrightarrow r$	Swaps $x$ and $r$ , in analogy to $x \leftarrow y$ . Will be listed like $x \leftrightarrow J$ , $x \leftrightarrow .12$ , $x \leftrightarrow \rightarrow 12$ , etc. in programs.
$x \leftrightarrow y$	$x \leftrightarrow y$	Swaps the contents of stack registers X and Y.
$x = ?$	<b>g</b> <b>TEST</b> $x = ? r$ etc.	(0) Compare $x$ with $r$ . See $x < ?$ for more.
$x \approx ?$	<b>g</b> <b>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</b> <b>TEST</b> $x < ? r$ etc.	(0) {1, 2, 4, 5, 6, 7, 10} Compare $x$ with $r$ . <i>Text strings</i> are compared according to their sorting order.
$x \leq ?$		
$x \geq ?$		
$x > ?$		
$x = +0?$	<b>g</b> <b>TEST</b> $\Delta$ $x = +0?$ etc.	(0) {1, 2, 10} These two tests are for comparing <i>short integers</i> in modes 1COMPL and SIGNMT, and for <i>real or complex numbers</i> if SPCRES is set. Then e.g. $0./(-7)$ will display $-0$ .
$x = -0?$		

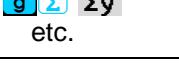
Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\hat{y}$		(1) {2}; {1} → {2} Returns a forecast $y$ (in $X$ ) for a given $x$ according to the curve fit model chosen. See L.R. for more.
$yd \rightarrow m$		(1) {2}; {1} → {2} Converts distances. See pp. 137ff.
YEAR		(1) {2, 6} → {1} Assumes $x$ containing a date in the format selected (or a real number in corresponding format) and extracts the year.
year→s		(1) {2}; {1} → {2}
$yin \rightarrow m$		Convert times and distances. See pp. 137ff.
$y^x$		(2) Raises $y$ to the power of $x$ . For $y < 0$ and CPXRES set, it may return complex numbers. See the DT tables in Sect. 2 of the OM for more.
Y.MD		(0) Sets the format yyyy-mm-dd for dates.
$y \leftrightarrow r$		Swaps $y$ and $r$ , in analogy to $x \leftrightarrow$ .
$zhàn \rightarrow m$		(1) {2}; {1} → {2} Converts distances. See pp. 137ff.
$z \leftrightarrow r$		Swaps $z$ and $r$ , in analogy to $x \leftrightarrow$ .
$\alpha INTL$		_submenu_. See pp. 113ff.
		Menu in AIM (see p. 125).
$\alpha LENG?$		(-1) {} → {1}
		Returns the number of characters found in the text string $r$ , similar to ALEN in HP-42S. <sup>24</sup>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
αMATH	f [CAT] CHARS αMATH	_submenu. See pp. 113ff.
	g [ ]	Menu in AIM. See p. 126.
αPOS?	g [INFO] g αPOS? r	(-1) {} → (1) Looks in the <i>text string r</i> for the <b>target</b> given in X. If a match is found, αPOS 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, αPOS returns -1. <sup>24</sup>
	g [a.FN] f αPOS? r	The <b>target</b> may be an individual character code or an <i>text string</i> . αPOS saves a copy of the <b>target</b> in L. It works similar to POSA in HP-42S.
αRL	g [a.FN] αRL r	(0) Rotates the <i>text string r</i> by <i>x</i> characters like AROT in HP-42S, but with $x \geq 0$ . αRL 0 executes as NOP, but loads L. <sup>24</sup>
αRR	g [a.FN] αRR r	(0) Works like αRL but rotates to the right.
αSL	g [a.FN] αSL r	(0) Shifts the <i>x</i> leftmost characters out of the <i>text string r</i> , like ASHF in HP-42S. This allows for deleting the first <i>x</i> characters in the string. αSL 0 executes as NOP, but loads L. <sup>24</sup>
αSR	g [a.FN] αSR r	(0) Works like αSL but for the <i>x</i> rightmost characters out of <i>r</i> , deleting the last <i>x</i> characters in the string. <sup>24</sup>
α.FN	g [a.FN]	Menu. See p. 126.
A...Ω	f [CAT] CHARS A...Ω	_submenu of Greek letters, see pp. 113ff.
α-	f [CAT] CHARS α-	_submenu. See pp. 113ff.
	g [ ]	Menu in AIM. See p. 126.

<sup>24</sup> This command will throw an error if there is no *text string* or an empty string in *r* at execution time.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\alpha \rightarrow x$		(-1) {} → {10 <sub>10</sub> } Pushes the character code of the leftmost character in the <i>text string r</i> on the <i>stack</i> and removes this character from the string, similar to ATOX in HP-42S. <sup>24</sup>
$\beta(x,y)$		(2) {2, 3}; {1} → {2} Returns <i>Euler's Beta function</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.
$\Gamma_{xy}$		(2) {2}; {1} → {2}
$\gamma_{xy}$		Returns the <i>upper/lower incomplete Gamma function</i> . See pp. 254ff for more.
$\Gamma(x)$		(1) {2, 3}; {1} → {2} Returns $\Gamma(x)$ . Note $x!$ calls $\Gamma(x + 1)$ . See also $\text{LN}\Gamma$ .
$\delta x$		Predefined global label for $f'(x)$ and $f''(x)$ – see Section 4 of the OM.
$\Delta\%$		(1) {2}; {1} → {2} Returns $100 \frac{x-y}{y}$ leaving $y$ unchanged. Use it also for calculating markups or margins as explained in the OM, Sect. 2.
$\varepsilon$		(-2) {} → {2} Calculates the <i>scattering factors</i> $\varepsilon_y$ and $\varepsilon_x$ for <i>log-normally</i> distributed sample data and pushes them on the <i>stack</i> . $\varepsilon$ works for the <i>geometric mean</i> $\bar{x}_g$ in analogy to the <i>standard deviation s</i> for the <i>arithmetic mean</i> $\bar{x}$ but <u>multiplicative</u> instead of additive. See pp. 221ff for more information.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\varepsilon_m$	f [STAT] g $\varepsilon_m$	(-2) {} → {2} Works like $\varepsilon$ above but returns the <i>scattering factors</i> of the two <i>geometric means</i> (in analogy to the standard error for <i>arithmetic means</i> ).
$\varepsilon_p$	f [STAT] g $\varepsilon_p$	(-2) {} → {2} Works like $\varepsilon$ but returns the <i>scattering factors</i> of the two populations.
$\zeta(x)$	g [X.FN] ▲ f $\zeta(x)$	(1) {2, 3} Returns <i>Riemann's Zeta</i> . See p. 258 for more.
$\pi$	g π	(-1) {} → {2} Recalls $\pi$ .
$\Pi_n$	f [ADV] $\Pi_n$ <u>labl</u>	Computes 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.
$\Sigma$	g $\Sigma$	Menu. See p. 127.
$s$	f [STAT] g	(-2) {} → {2}
$\Sigma^1/x$	g $\Sigma$ ▲ $\Sigma^1/x$ etc.	(-1) {} → {2}
$\Sigma^1/x^2$		Recall the corresponding statistical sums, necessary for statistical analyses 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. 158ff.).
$\Sigma^1/y$		
$\Sigma^1/y^2$		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Sigma \ln^2 x$		<p><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.</p> <p>For space reasons, two sums are abbreviated:</p> <p><math>\Sigma \ln xy</math> denotes <math>\sum \ln(x) \ln(y)</math> and</p> <p><math>\Sigma \ln y/x</math> denotes <math>\sum \frac{\ln(y)}{x}</math>.</p>
$\Sigma \ln^2 y$		
$\Sigma \ln x$		
$\Sigma \ln xy$		
$\Sigma \ln y$		
$\Sigma \ln y/x$		<p><b>Computes</b> a sum using the routine specified. See Section 4 of the OM for more.</p> <p><b>ATTENTION:</b> <math>\Sigma</math> fills all <i>stack registers</i> with <math>x</math> before calling the routine specified.</p>
$s_w$		<p>(-1) {} → {2}</p> <p>Works like <math>s_w</math> but returns the <i>standard deviation of the population</i> instead. See pp. 221ff.</p>
$\Sigma x, \Sigma x^2$		<p>(-1) {} → {2}</p> <p>Recall the corresponding statistical sums, necessary for statistical analyses and regressions (see <math>\Sigma^1/x</math> above for more).</p>
$\Sigma x^2 y$		
$\Sigma x^2/y$		
$\Sigma x^3$		
$\Sigma x^4$		
$\Sigma x \ln y$		
$\Sigma x y$		
$\Sigma x/y$		
$\Sigma y, \Sigma y^2$		
$\Sigma y \ln x$		

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\Sigma+$ <sup>25</sup>	<b>f</b> <b>STAT</b> <b><math>\Sigma+</math></b>	<b>{8} → {2}</b> If <b>X</b> contains an $n \times 2$ matrix then $\Sigma+$ adds $n$ 2D data points to the statistical sums. Then the display will show the last data point added (corresponding to the last row of said matrix) and the matrix will be saved in <b>L</b> . See the OM, Section 2.
		<b>{1, 2}</b> Adds one 2D data point to the statistical sums. Note both <b>X</b> and <b>Y</b> must contain <i>DT</i> 1 or 2.
$\Sigma-$ <sup>25</sup>	<b>f</b> <b>STAT</b> <b>f</b> <b><math>\Sigma-</math></b>	<b>{1, 2}</b> Works like $\Sigma+$ but subtracts one 2D data point. Updates neither $x_{\max}$ nor $x_{\min}$ .
$\chi^2_p(x)$	<b>g</b> <b>PROB</b> <b><math>\chi^2:</math></b>	<b>(1) {2}; {1} → {2}</b>
$\chi^2_{\Delta}(x)$	$\chi^2_p(x)$ etc.	<i>Chi-square distribution</i> (with its degrees of freedom given in <b>I</b> ). $\chi^2_{\Delta}(x)$ equals $Q(\chi^2)$ on HP-21S. See Section 2 of the OM for an application example and pp. 221ff for more.
$(\chi^2)^{-1}$		
<b><math>\chi^2:</math></b>	<b>g</b> <b>PROB</b> <b><math>\chi^2:</math></b>	<b>Submenu.</b> See p. 122.

<sup>25</sup>  $\Sigma+$  and  $\Sigma-$  return *temporary information* as shown in Section 2 of the OM and disable ASL. Both commands may also be used for 2D vector adding and subtracting (see the command SUM and the corresponding example in Section 2 of the OM)..

Item	Keystrokes	Remarks (see pp. 12ff for general information)									
$(-1)^x$	 	(1) {1, 2, 3, 8*, 9*, 10} If $x$ is non-integer, returns $\cos(\pi x)$ .									
$[M]^T$	 	(1) {8, 9} Returns the transpose of the matrix $X$ . The transpose is another matrix with rows changed by columns. If $A$ is an $n \times m$ matrix and $a_{ij}$ is an element of it then $A^T$ will be an $m \times n$ matrix $B$ with $b_{ij} = a_{ji}$ . The transpose is done in-situ and does not require any additional memory.									
$[M]^{-1}$	 	(0) {8, 9} Takes the square matrix in $X$ and inverts it in-situ.									
+		(2) Returns $y + x$ for compatible objects. <sup>26</sup>									
$+/-$	 (for closed input)	(1) 'Unary minus', returns $x \times (-1)$ . <sup>26</sup>									
$\pm\infty?$	 	(0) {2} → {1} Tests $x$ for infinity. Returns <table style="margin-left: 20px;"><tr><td>true</td><td>1</td><td>for <math>x = +\infty</math>,</td></tr><tr><td>true</td><td>-1</td><td>for <math>x = -\infty</math>, and</td></tr><tr><td>false</td><td>0</td><td>else.</td></tr></table>	true	1	for $x = +\infty$ ,	true	-1	for $x = -\infty$ , and	false	0	else.
true	1	for $x = +\infty$ ,									
true	-1	for $x = -\infty$ , and									
false	0	else.									
-		(2) Returns $y - x$ for compatible numeric objects. <sup>26</sup>									
$\times$		(2) Returns $y \times x$ for compatible numeric objects. <sup>26</sup>									
$\times\text{MOD}$	 	(3) {1, 2, 10} Returns $(z \times y) \bmod x$ for $x > 1, y > 0, z > 0$ . <sup>27</sup>									
/		(2) Like $\times$ , but returns $y \times x^{-1}$ . <sup>26</sup> Returns $y \div x$ if both $y$ and $x$ are of DT 1 or 10; cf. IDIV.									

<sup>26</sup> See the combination tables in the OM, Section 2, for details and compatibility.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\wedge\text{MOD}$	 	(3) {1, 2, 10} Returns $(z^y) \bmod x$ for $x > 1, y > 0, z > 0$ . <sup>27</sup>
$\rightarrow$		Reserved symbol for indirect addressing.
$\rightarrow\text{DATE}$	 	(3) {1, 2} $\rightarrow$ {6} Assumes the three components of a date (year, month, and day) supplied on the stack in proper order for the date format selected and converts them to a single <i>date</i> in $x$ . Thus inverts DATE $\rightarrow$ .
$\rightarrow\text{DEG}$	 	
$\rightarrow\text{D.MS}$	 	
$\rightarrow\text{GRAD}$	 	Convert angles as described on pp. 145f.
$\rightarrow\text{HR}$	  	(1) {5} $\rightarrow$ {2} Operates on <i>times</i> like $\rightarrow\text{REAL}$ below. Maintained for backward compatibility only.
$\rightarrow\text{H.MS}$	 (for closed input)	(1) {1, 2, 5} $\rightarrow$ {5} Converts $x$ to a sexagesimal <i>time</i> – cf. p. 108.
$\rightarrow\text{INT}$	 (for closed input)	(1) {1, 2, 10} $\rightarrow$ {10} Converts the integer part of $x$ to a <i>short integer</i> of the base specified. Conversion to decimal may be abbreviated by , to hexadecimal by . Note  converts to a <i>long integer</i> . Cf. p. 108.
$\rightarrow\text{MUL}\pi$	 	(1) {1, 2, 4} $\rightarrow$ {4} Converts angles as described on pp. 145f.

<sup>27</sup> See MOD.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
→POL	<b>g</b> <b>→P</b>	<p>{2}; {1} → {2}</p> <p>Assumes <b>X</b> and <b>Y</b> containing 2D Cartesian coordinates of a point or components of a vector (<math>x, y</math>). Converts them to the respective polar coordinates or components (<math>r, \theta</math>). Reverted by →REC, see there.</p>
		<p>For switching the display format of <i>complex numbers</i>, see POLAR.</p>
→RAD	<b>g</b> <b>L</b> →RAD	<p>(1) {1, 2, 4} → {4}</p> <p>Converts angles as described on pp. 145f</p>
→REAL	<b>f</b> <b>.d</b> (for closed input)	<p>(1) {1, 2, 4, 5, 6, 10} → {2}</p> <p>Converts <math>x</math> to a <i>real number</i>. Any object (e.g. a <i>time</i>) tagged sexagesimal will be converted in a decimal number. For <i>dates</i>, the date format chosen is taken into account. Numbers shown as fractions will be displayed as decimal numbers (cf. FRACT and PROPFR).</p> <p>To return the <i>real part</i> of a <i>complex number</i>, take RE. To cut a <i>complex number</i> into its parts, use <b>CC</b> or <b>CX</b>→RE.</p>
→REC	<b>f</b> <b>R</b>	<p>{2}; {1, 4} → {2}</p> <p>Assumes <b>X</b> and <b>Y</b> containing 2D polar coordinates of a point or components of a vector (<math>r, \theta</math>). Converts them to the respective Cartesian coordinates or components (<math>x, y</math>). Inverted by →POL. – For switching the format of <i>complex numbers</i>, see POLAR.</p>

Item	Keystrokes	Remarks (see pp. 12ff for general information)
$\text{X}$		<p><b>Shuffles</b> 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 ASL!),</li> <li><math>\text{xyxzt}</math> works like <math>x \leftarrow y</math>,</li> <li><math>\text{yzttx}</math> works like <math>R \downarrow</math> in a 4-level stack,</li> <li><math>\text{txxyz}</math> works like <math>R \uparrow</math> in a 4-level stack,</li> <li>but also <math>\text{yytt}</math> or <math>\text{zzzx}</math> is possible.</li> </ul> <p><b>ATTENTION:</b> This is a very powerful command although it does not look it. Note it will affect the <u>bottom four stack registers only</u>; there is no connection to A ... D, <u>regardless of stack size</u>. Playing with <math>\text{X}</math>, you may lose some <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 saved in <b>L</b>.</p>
$ x $	 or  or 	<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)
	<b>g X.FN</b> ▲ <b>f   </b>	(2) {2, 3}; {1} → {2} Returns $\left(\frac{1}{x} + \frac{1}{y}\right)^{-1}$ ; useful in electrical engineering especially. Returns 0. for $x \times y = 0$ .
%	<b>g FIN %</b>	(1) {2}; {1} → {2} Returns $\frac{xy}{100}$ , leaving $y$ unchanged.
%MRR	<b>g FIN %MRR</b>	(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	<b>g FIN %T</b>	(1) {2}; {1} → {2} Returns $100 \frac{x}{y}$ , interpreted as % of total. Leaves $y$ unchanged.
%Σ	<b>g FIN %Σ</b>	(1) {2}; {1} → {2} Returns $100 \frac{x}{\sum x}$ .
%+MG	<b>g FIN %+MG</b>	(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: $P_{sale} = y / \left(1 - \frac{x}{100}\right)$ 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>✓x</b> <b>g</b> <b>EXP</b> <b>✓x</b>	(1) {1, 2, 3, 8*, 9*, 10}; ({1} → {2}, {1, 2} → {3}) Returns the square root of $x$ . See the DT tables in Section 2 of the OM for more.
$\int$	<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 $\downarrow$ Lim and $\uparrow$ Lim, accuracy by ACC. $\int$ returns the (approximated) integral in X and an upper limit of its uncertainty in Y. <sup>28</sup> <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. <sup>28</sup>
$\int f$	<b>g</b> <b>EQN</b> <b>∫f</b>	Submenus. See pp. 119f.
$\int f dx$	<b>f</b> <b>ADV</b> <b>∫fdx</b>	
$\pi$	<b>g</b> <b>π</b> or <b>g</b> <b>CPX</b> <b>f</b> <b>π</b> or <b>f</b> <b>PARTS</b> <b>f</b> <b>π</b>	(1) {2} → {4} Returns 180° (or equivalent) for $x < 0$ and 0 else. (1) {3} → {4} Returns the phase or argument $arg(x) = \arctan\left(\frac{Im(x)}{Re(x)}\right)$ . Cf.   $x$  . (1) {9*} → {8} Returns a matrix with the phases of all input matrix elements. Cf.   $x$  .
$\pi \rightarrow$	<b>g</b> <b>L→</b>	<b>Menu</b> of angular conversions. See p. 127.

<sup>28</sup> See Section 4 of the OM for more.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
ADV	PRINT  ADV	(0) Prints the current contents of the print buffer and a linefeed. <b>ATTENTION:</b> The printer will actually print only when a linefeed is sent to it.
CHAR	PRINT   CHAR <i>n</i>	(0) Sends a single character (with the code specified) to the printer. Character codes <i>n</i> > 127 can only be specified indirectly.  MODE setting will be honored. See  ADV.
DLAY	PRINT   DLAY <i>n</i>	(0) Sets a delay of <i>n</i> ticks (see TICKS) to be used with each linefeed on the printer.
LCD	PRINT  LCD	(0) Sends the contents of the entire LCD to the printer, so you get a hardcopy of the screen.
MODE	PRINT   MODE <i>n</i>	(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 line. Works for plain ASCII only – no characters will be translated. Line setup is the same as for serial communication: 9600 baud, 8 bits, no parity.
PROG	PRINT  PROG	(0) Prints the listing of the <i>current program</i> (see Section 3 of the OM), one row per step.
r	PRINT  r <i>r</i>	(0) Prints the content of the <i>register</i> specified, right adjusted, <u>without</u> labeling the output. If you want a heading label, compose the string in X first or use  REGS. See  ADV.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
 REGS		(1) Interprets $x$ in the form $sss.nn$ . Prints the contents of $nn$ registers starting with number $sss$ . Each register takes one row starting with its label. <b>ATTENTION for <math>nn = 0</math> :</b> <ul style="list-style-type: none"><li>• For <math>sss \in [0; 99]</math>, printing will stop at <b>R99</b>.</li><li>• For <math>sss \in [100; 111]</math>, printing stops at <b>K</b>.</li></ul> For $sss \geq 112$ , printing stops at the highest allocated local register.
 STK		(0) Prints the entire stack contents. Each of the 4 or 8 registers prints in a separate row starting with its label.
 TAB		(0) Positions the print head to print column $n$ (0 to 165, where $n > 127$ can only be specified indirectly). Useful in formatting (in  MODE 1 or 2 in particular). Allows also for printer plots. If $n$ is less than current print head position, a linefeed will be entered to reach the new position. See  ADV.
 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 <b>R/S</b> to stop the listing.
 WIDTH		(-1) Returns the number of print columns that $x$ would take in the print mode set. See  MODE. Second use: in  MODE 1 or 2,  WIDTH returns the width of $x$ in px (including the last column being always blank) in the specified font.
 x		(0) Prints $x$ without a heading label. See  ADV.
 Σ		(0) Prints the summation registers. Each register prints in one row starting with its label.

Item	Keystrokes	Remarks (see pp. 12ff for general information)
¤#	g PRINT f ¤# n	(0) Sends a single <i>byte</i> , without translation, to the printer (e.g. a control code). <i>n</i> > 127 can only be specified indirectly. ¤MODE setting will not be honored. See ¤ADV.
#B	f BITS g #B	(1) {10} Counts the bits set in <i>x</i> (like on HP-16C).

## Names of System Variables and System Flags

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 *items* with their *names* printed on grey in the table below can be seen on the screen directly (e.g. in the *status bar*), for those printed on orange it is returned by STATUS. If the second column is green, the corresponding *item* may be modified by the user, if it is yellow, the *item* is read-only for the user and is written by the system exclusively. The contents of *items* printed on light blue can be stored by STOCFG and recalled by RCLCFG.

Some *system flags* can be accessed via lettered *user flags* as well (cf. Section 1 of the OM). Keystrokes are only listed if applicable.

Name	Keystrokes	Remarks (see pp. 12ff for general information)
A		Reserved variable for <i>register A</i>
ACC	f ADV ∫fdx ACC	Reserved <i>real</i> variable for the accuracy of integration (see Section 4 of the OM).

Name	Keystrokes	Remarks (see pp. 12ff for general information)
ADM		Reserved integer variable for the <i>ADM</i> : 0: DEG, 1: D.MS, 2: RAD, 3: MUL $\pi$ , 4: GRAD.
ALLEN <sup>G</sup>	[A]	
ALPHA		
ALP.IN		
ASLIFT		
AUTOFF		
AUTXEQ		
B		Reserved variables for <i>registers B</i> and <b>C</b> .
C		
CARRY	[C]	
CPXj		
CPXRES	[I] (imaginary)	
D		Reserved variable for <i>register D</i> .
DECIM.		
DENANY		
DENFIX		
DENMAX		Reserved integer variable for the maximum denominator, filled by the command DENMAX.
DMY		
FRACT		
FV	[g] [FIN] [TVM] [FV]	Reserved real variable for the future value of your investment or loan in TVM. <sup>29</sup>

<sup>29</sup> See Section 5 of the OM.

Name	Keystrokes	Remarks (see pp. 12ff for general information)
GRAMOD		Reserved integer variable determining how the AGRAPH image is displayed: <sup>30</sup> 0: It is merged (OR-ed) with the existing display. 1: It overwrites all pixels in that part of the display. 2: Duplicate “on” pixels get turned “off”. 3: It is XOR-ed with the existing display.
GROW		System flag – see next chapter.
I		Reserved variable for register I.
IGN1ER		System flags – see next chapter.
INTING		
ISM		Reserved integer variable for the <i>integer sign mode</i> : -1: sign and mantissa mode, 0: unsigned, 1: 1's complement, 2: 2's complement.
i%/a	g [FIN] TVM i%/a	Reserved real variable for the annual interest rate of your investment or loan in TVM. <sup>29</sup>
J		Reserved variables for registers J, K, and L.
K		
L		
LEAD.0	[L]	System flags – see next chapter.
LOWBAT		
Mat_A	f [MATX] SIM EQ Mat A	Reserved variables for solving systems of linear equations (see Section 2 of the OM).
Mat_B	f [MATX] SIM EQ Mat B	
Mat_X	f [MATX] SIM EQ Mat X	

<sup>30</sup> Working like flags 34 and 35 in HP-42S.

Name	Keystrokes	Remarks (see pp. 12ff for general information)
MDY		System flags – see next chapter.
MULT $\times$		
NPER	FIN TVM n <sub>PER</sub>	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		System flags – see next chapter.
OVERFL	(big)	
PER/a	FIN TVM 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	FIN TVM PMT	Reserved variable for the payment per period for your investment or loan in TVM. <sup>29</sup>
POLAR		
PRINT		System flags – see next chapter.
PROPFR		
PRTACT		
PV	FIN TVM PV	Reserved variable for the present value of your investment or loan in TVM. <sup>29</sup>
QUIET		System flag – see next chapter.
REALDF		Reserved integer variable for <i>real number</i> display format: 0: ALL, 1: FIX, 2: SCI, 3: ENG.
RUNIO		
RUNTIM		
SLOW		System flags – see next chapter.
SOLVING		

Name	Keystrokes	Remarks (see pp. 12ff for general information)
SPCRES	D (danger)	
SSIZE8		
T		
X		
Y		
Z		
TDM24		
TRACE	T	System flags – see next chapter.
USB		
USER	f USER	System flag toggled by USER – see next chapter
VMDISP		
YMD		
αCAP		
↑Lim	f ADV ffdx ↑Lim etc.	Reserved real variables for the upper and lower limit of integration (s. the OM, Sect. 4).
#DEC		Reserved integer variable for the number of decimals in real number formatting (actually the parameter specified in last ALL, FIX, SCI, or ENG).

## Purposes of System Flags

The *status bar*, especially its indicators (*SB!*), 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>31</sup>	Remarks
Time display	Time string	TDM24 (set)	Set for international 24h time display. Expands the date display in the <i>status bar</i> to four digits for the year.  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.
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 <i>flag</i> and clear the two others.
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> .
Polar notation	E / ⊙	POLAR	Set for polar display of <i>complex numbers</i> , clear for rectangular.
Fraction display	—	FRACT	Set for fraction display, clear for decimal display ( sets FRACT,  clears it). See next entries.
Fraction kind 1	—	PROPFR (set)	Set for <i>proper fractions</i> , clear for <i>improper fractions</i> ( toggles PROPFR: coming from decimal display, it sets it).  PROPFR 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> .

<sup>31</sup> The flags printed on green may be written by the user, those printed on yellow 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, orange, and light blue colors are used as in previous chapter.

Purpose	SBI	Flag <sup>31</sup>	Remarks
Fraction kind 2	see the OM	DENANY (set)	Set if any denominator up to DENMAX may appear (DENMAX is indicated in the <i>status bar</i> ). <sup>32</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 the OM	DENFIX <sup>33</sup>	Set if the value set by DENMAX is the one and only denominator allowed. Clear if the denominator may be an integer factor of DENMAX. <sup>34</sup>
Carry	$\frac{1}{c}$ or $\frac{0}{c}$	CARRY	Reflects the status of the carry bit.
Overflow	$0$ or $\frac{0}{c}$	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. Like flag 3 of HP-16C.
Alpha	A or $\alpha$	ALPHA	Set for AIM, else clear.
Upper case	A / $\alpha$	$\alpha$ CAP (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	ᵁ	USER	Set if your WP 43S is in user mode.
USB power	⎓	USB	Set if connected to a USB power source

<sup>32</sup> E.g. for DENMAX = 5 and DENANY set, denominators 1, 2, 3, 4, and 5 are allowed.

<sup>33</sup> DENFIX is evaluated only if DENANY is clear.

<sup>34</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 (note 60 was a holy number in ancient Babylon).

Purpose	SBI	Flag <sup>31</sup>	Remarks
Low battery	■	LOWBAT	Set if battery voltage is low (< 2.5 V, cf. BATT? and Section 2 of the OM).
Processor speed	—	SLOW	Kept clear for fresh batteries unless the user intervenes, set for battery low (cf. LOWBAT). Speed and power consumption will be reduced to ~50% with SLOW set.
Special results	—	SPCRES	Set for allowing special results of calculations (i.e. $\pm\infty$ and NaN).
Stack size	—	SSIZE8	Set for 8, clear for 4 stack registers. Note register contents will remain unchanged if SSIZE8 is modified (may also be by RCLCFG).
Beeper	—	QUIET	Set for disabled beeper.
Radix mark	—	DECIM. (set)	Set for a decimal point, clear for a comma.
Multiplication symbol	—	MULT $\times$ (set)	Set for multiplication symbol $\times$ , clear for ..
Overflow from ALL	—	ALLENG	Set if <i>real numbers</i> exceeding the range displayable in ALL or FIX shall be shown in ENGineer's format, clear for SCientific.
Matrix grow mode	—	GROW	Set (e.g. by M.GROW) if matrices may grow, else clear (e.g. by M.WRAP). See J+ in the <i>IOI</i> and Section 2 of the OM; cf. also GROW in the HP-42S OM, p. 213.
Automatic OFF	—	AUTOFF (set)	Set if automatic shutdown after 600 s is enabled. Else your WP 43S will remain ON until you will turn it off manually or battery voltage will drop below the lower limit (cf. BATT? and Sect. 2 of the OM). Works like flag 44 of HP-42S
Automatic execution	—	AUTXEQ	Like flag 11 of HP-42S.

Purpose	SBI	Flag <sup>31</sup>	Remarks
Printer activated	—	PRTACT	Like flag 21 (Print Enable) of <i>HP-42S</i> .
Data entry	—	NUM.IN, ALP.IN	Set for numeric or alphanumeric entry, respectively (like flags 22 and 23 of <i>HP-42S</i> ).
Automatic stack lift	—	ASLIFT (set)	Cleared by ENTER, CLX, $\Sigma+$ , and $\Sigma-$ , set by all other functions (see the <i>OM</i> , Sect. 1)
Error handling	—	IGN1ER	If set, your <i>WP 43S</i> ignores just 1 arbitrary error and clears IGN1ER then. The operation causing the error will not be executed. This works like flag 25 of <i>HP-42S</i>
Integrating	—	INTING	Set while the <i>Integrator</i> is running.
Solving	—	SOLVING	Set while the <i>Solver</i> 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.

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 – cf. the *OM*, Section 5). Also *RBR*, *STATUS*, as well as the applications *TIMER* and *TVM* cannot be programmed.

All *catalog* and *menu* calls themselves as well as the operations called by **EXIT**, **P/R**,  **$\alpha$** ,  **$\text{S}$** ,  **$\Delta$** ,  **$\blacktriangle$** ,  **$\blacktriangledown$** , and  **$\blacktriangleright$**  in *startup default* condition are neither programmable nor will they show any input echo in the top numeric row as the other commands do (cf. the *OM*, Section 2). See also *Section 2* here (on pp. 112ff) for more about this topic.

## 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. 108ff 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] ... [D],</b> <b>[I] ... [L], [T],</b> <b>[X] ... [Z]</b>	addressing	Enters the address of a <i>global GP register</i> or <i>user flag</i> .
<b>[A] ... [Z]</b> <b>[g] [A] ... [g] [O]</b> <b>[f] [0] ... [f] [9]</b>	entering a label, a <i>system flag</i> or variable <i>name</i>	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. 107 (cf. the OM, Section 2).
<b>[ENTER]</b>	arbitrary parameter input pending	If there is no input yet, assumes the default, if applicable. Else closes pending input, interprets it as a <i>register</i> or <i>user flag</i> address, a <i>system flag</i> or variable <i>name</i> , a label, or alike, 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] ... [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</i> or <i>local 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 <i>WP 43S</i> as it was before the current command was called.



Virtual keyboard in *alpha input mode (AIM)*. AIM is also active when a catalog is open, so you can use all accessible characters for alphabetic searching (see pp. 116f). Note there is an 'alpha helper' printed on the rear of your *WP 43S*.

## 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. 106f for command parameter input instead). The table lists the respective keys top left to bottom right on the keyboard:

Keystrokes in mode(s)	Meaning
<b>A</b> ... <b>Z</b>	<b>A, <math>\alpha</math></b> Appends the corresponding Latin or Greek letter to the <i>text string x</i> . Use <b>▼</b> and <b>▲</b> to switch cases. See the picture on previous page and cf. <i>Section 2</i> of the OM.
<b>g A</b> ... <b>g O</b>	<b>A, <math>\alpha</math></b> Appends <b>#</b> to the <i>text string x</i> .
<b>f #</b>	<b>A, <math>\alpha</math></b> Closes input of a <i>short integer</i>
<b>f # base</b>	<b>¬ (A, <math>\alpha</math>)</b> <i>sexagesimal angle</i>
<b>f d.ms</b>	<b>¬ (A, <math>\alpha</math>)</b> <i>date</i>
<b>f .d</b>	<b>¬ (A, <math>\alpha</math>)</b> <i>sexagesimal time</i> in X. <sup>35</sup>
<b>f h.ms</b>	<b>¬ (A, <math>\alpha</math>)</b> <i>sexagesimal time</i> in X. <sup>35</sup>
<b>f (x²) ( ✓ )</b>	<b>A, <math>\alpha</math></b> Appends a checkmark <b>✓</b> to the <i>text string x</i> .
<b>CC</b>	<b>¬ (A, <math>\alpha</math>)</b> Closes input of the first part (i.e. <i>real part</i> or <i>magnitude</i> ) of a <i>complex number</i> in X and waits for input of its second part (i.e. <i>imaginary part</i> or <i>phase</i> , see the <i>Key Response Table</i> and <i>Section 2</i> of the OM). Any additional <b>CC</b> in input will be ignored.
<b>f R↓ ( ↓ )</b>	<b>A, <math>\alpha</math></b> Makes the next character a subscript, if applicable.

<sup>35</sup> See *Section 2* of the OM. After **#**, any additional **#** in input will be ignored. At closure, input will be checked – *seconds* (or *minutes*) > 60 will be carried to *minutes* (or *hours*); illegal digits (e.g. 8 in octal input or C in decimal), bases, numbers, or characters found, or out-of-range conditions detected will cause an error thrown (see also the description of **ENTER** on next page and the error messages in *App. C*).

Keystrokes in mode(s)	Meaning
<b>ENTER↑</b>	<p>arbitrary input pending</p> <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 <u>alphanumeric</u> (i.e. if it contains at least one non-numeric character except <b>.</b>), takes it as a <i>text string</i>.</li> <li>• Else (i.e. if this input is purely numeric) 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> of said base;</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 x&gt;y</b>	<b>A, α</b> Appends <b>&gt;</b> to the <i>text string</i> <b>x</b> .
<b>+/</b>	$\neg(A, \alpha)$ Changes the sign of the number entered. Affects the exponent if pressed after <b>E</b> .
<b>f +/-</b>	<b>A, α</b> Appends <b>±</b> to the <i>text string</i> <b>x</b> .
<b>E</b>	$\neg(A, \alpha)$ Closes input of the mantissa and waits for input of the exponent (see Section 1 of the OM). Any additional <b>E</b> in input will be ignored.
<b>f [E] ( ^ )</b>	<b>A, α</b> Makes 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.
	$\alpha$ , $\alpha$ Appends  to the <i>text string x</i> .
	$\alpha$ , $\alpha$ If MULT $x$ is set then appends $x$ , else  to the <i>string x</i> .
,	$\alpha$ , $\alpha$ Appends the respective sign the <i>text string x</i> .
	$\neg (\alpha, \alpha)$ Numeric input for integer bases >10, appending the corresponding digit to $x$ . See Section 2 of the OM for more. Digits will be checked when input is closed (see the description of  above).
	$\neg (\alpha, \alpha)$ Standard numeric input, appending the corresponding digit to $x$ . Note you can enter ... <ul style="list-style-type: none"> <li>up to 34 digits plus a sign in the mantissa<sup>36</sup> and up to four digits plus a sign in the exponent for a <i>real number</i> or any part of a <i>complex number</i>,</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>
	$\alpha$ , $\alpha$ Appends  to the <i>text string x</i> .
	$\alpha$ , $\alpha$ Appends the respective digit to the <i>text string x</i> .
	$\alpha$ , $\alpha$ Appends  to the <i>text string x</i> .
	$\alpha$ Turns to upper case for the letters following.
	$\alpha$ Turns to lower case for the letters following.

<sup>36</sup> You can enter even more digits but it makes no sense.

Keystrokes in mode(s)	Meaning
.	<p>For sexagesimal angular input, separates <i>degrees</i> from <i>minutes</i>, <i>seconds</i>, and <i>hundredths of seconds</i>, so input format is dddd.ddmmsshh <b>d.ms</b> (cf. p. 108 and <i>Section 2</i> of the OM).</p> <p>For <i>time</i> input, separates <i>hours</i> from <i>minutes</i>, <i>seconds</i>, and fractions of <i>seconds</i>, so input format is hhmmss.ffff <b>h.ms</b> (cf. p. 108 and <i>Section 2</i> of the OM).</p> <p>Else inserts a radix mark as selected.</p>
Second .	<p>A 2<sup>nd</sup> . in input signals a fraction. See the OM, <i>Section 2</i> for examples. The 2<sup>nd</sup> . separates nominator and denominator in input. Any additional . in input will be ignored.</p> <p>Note you cannot enter E after you entered . twice but you may delete the 2<sup>nd</sup> dot while editing the input.</p>
.	Appends , to the <i>text string x</i> .
f .	Appends . to the <i>text string x</i> .
R/S	<p>!, program waiting for input</p> <p>Closes input and starts its checks and interpretation like <b>ENTER↑</b> above. Resumes program execution.</p>
	Appends a blank space to the <i>text string x</i> .
EXIT	<p>If there is an open <i>menu</i>, closes it.</p> <p>Else closes pending numeric or alphanumeric input and releases it for interpretation.</p>

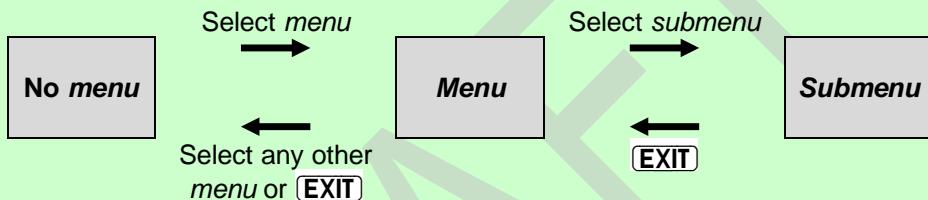
There are many more characters you can enter via the three alpha *menus* or **CATALOG CHARS** (see pp. 113 and 125ff). Call FBR for browsing the entire character sets provided.

Any other command not specified in the table above will close pending input and release it for interpretation like **ENTER↑**, **R/S**, and **EXIT** do.

## 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, and 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:



As shown in the picture above, exiting a *submenu* returns you to its ‘parent’ (calling) *menu*; exiting a *menu*, however, returns you to a screen with no *menu* (or **MyMenu** or **Myα**) displayed.

**Catalogs** are a special kind of *menus* with their contents sorted alphabetically. Your *WP 43S* provides 17 *catalogs*:

- CATALOG'CHARS'αINTL ,
- CATALOG'DIGITS ,
- CATALOG'FCNS (by far the largest *catalog* at startup),
- CATALOG'MENUS ,
- the two *submenus* of CATALOG'PROGS
- CATALOG'SYS.FL ,
- the nine *submenus* of CATALOG'VARS and
- CONST .

Within *catalogs*, some special operations ease your path accessing the *items* stored therein (as shown on pp. 116f).

## 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 **catalogued**. Individual *catalogued items* may be accessed quickly in a way demonstrated on pp. 116f.

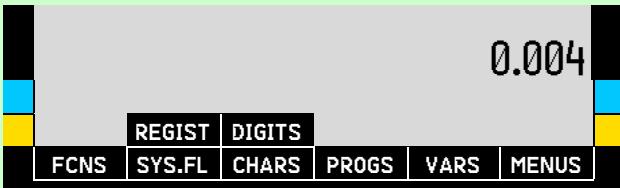
The contents of the various branches of **CATALOG** are presented below. Note they are printed in reverse order compared to the display of your *WP 43S*, taking care of your top-down reading habits:

							Remarks
<b>CATALOG:</b>	FCNS	SYS.FL	CHARS	PROGS	VARS	MENUS	top branches
		REGIST	DIGITS				
FCNS:	$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	$10^x$	1COMPL	$1/x$	$2^x$	catalog of all the some 740 functions provided
	2COMPL	$\sqrt[3]{\text{x}}$	ABS	ACOS	$\text{ac} \rightarrow \text{m}^2$	$\text{ac}_{\text{us}} \rightarrow \text{m}^2$	
	AGM	AGRAPH	ALL	AND	arccos	arcosh	
	...	...	#B				
SYS.FL:	ALLENG	ALPHA	ALP.IN	...			catalog of all the 41 system flags (cf. pp. 97ff)
	...						
CHARS:	$\alpha$ INTL	A... $\Omega$		$\alpha$ MATH	My $\alpha$	$\alpha$ -	character branches
$\alpha$ INTL:	A	$\grave{A}$	$\acute{A}$	$\hat{A}$	$\tilde{A}$	...	catalog of all the 99 international Latin letters, see p. 125
$\alpha$ MATH:	<	$\leq$	=	$\approx$	...		mathematical operators and symbols, see p. 126
A... $\Omega$ :	A	B	$\Gamma$	...			Greek letters, see p. 126
$\alpha$ •:	!	;	...				punctuation marks, see p. 127
PROGS:	RAM					FLASH	global labels currently defined

	<input type="checkbox"/>	Remarks					
RAM:	...						both branches are empty at startup; they will be filled with your creations
FLASH:	...						
VARS:	L.INTS	S.INTS	REALS	CPXS	STRING	MATRS	branches for various types of variables
	DATES	TIMES	ANGLES				
ANGLES:	...						catalogs of all variables currently defined, placed following their DTs – most of these submenus are empty at startup but will be filled and grow with your creations
CPXS:	...						
DATES:	...						
L.INTS:	ADM	DENMAX	GRAMOD	REALDF	#DEC	...	
MATRS:	Mat_A	Mat_B	Mat_X	REGS	...		
REALS:	ACC	FV	i%/a	n <sub>PER</sub>	PER/a	PMT	
	PV	↑Lim	↓Lim	...			
STRING:	...						
S.INTS	...						
TIMES:	...						
MENUS:	ADV	ANGLES	A:	BITS	Binom:	Cauch:	(sub-) 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
	CHARS	CLK	CLR	CONST	CPX	CPXS	
	DATES	DIGITS	DISP	EQN	EXP	Expon:	
	...						
	...	→					
A:	...						(sub-) menus provided unless mentioned above already, see pp. 118ff for predefined contents – here your creations will be inserted as new entries
Binom:	...						
BITS:	...						
...							
...							
REGIST:	A	B	C	D	I	J	register names defined
	K	L	T	X	Y	Z	
DIGITS:	0	1	2	3	4	5	digits defined
	6	7	8	9	A	B	
	C	D	E	F	i		

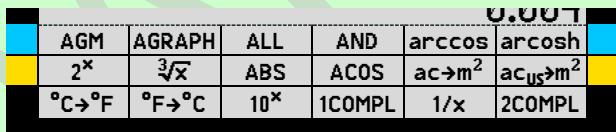
Three branches of **CATALOG** are expandable (**MENUS** and the submenus of **PROGS** and **VARS**) since you may create *items* of these kinds (cf. the OM, Section 6); the other ones are fixed size (**FCNS**, **REGIST**, **SYS.FL**, **DIGITS**, and **CHARS**) since all functions, *register names*, system flags, digits, and characters on your *WP 43S* are predefined.

Calling CATALOG will display its top level branches. The seven labels shown are pointers to the sub-



menus containing all the functions, register names, 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 CATALOG/FCNS showing up as pictured here:



Select an *item* by pressing the corresponding *softkey* (headed by  or  if applicable); e.g.

- call any function via CATALOG'FCNS,
  - call any *menu* via CATALOG'MENUS,
  - test any *system flag* via CATALOG'SYS.FL, or
  - recall any real variable defined via CATALOG'VARS'REALS.

Within **CATALOG** branches, browsing by **▲** will advance by six *items* per keystroke (and **▼** will go back by six) only.<sup>37</sup> **EXIT** will just leave the open branch without doing anything.

<sup>37</sup> Navigating in catalogs, *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.

You will find all the over 740 functions available on your *WP 43S* stored in CATALOG'FCNS (most of them may be accessed easier through other *menus* though, see the chapter after next chapter). Remember that each and every command and predefined *menu* featured on your *WP 43S*, the keystrokes calling it, and the necessary particular explanations are printed for your reference in the *IOI* on pp. 12ff. Find the other predefined *items* provided (*system flags* and variable *names*) on pp. 97ff.

See the *OM*, Section 6, to learn how to customize your *WP 43S* by creating your own *menus*, assigning them to your favorite keyboard locations, filling them, and easily accessing the functions you stored therein. You may also assign your favorite 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  $\blacktriangle$  and  $\blacktriangledown$  as explained in previous chapter. In CONST and major parts of CATALOG (FCNS, SYS.FL, MENUS, REGIST, DIGITS, CHARS  $\alpha$ INTL, and the *submenus* of PROGS and VARS), you may reach your target significantly faster taking advantage of the alphabetic access method demonstrated here. If we are looking for the function FS?S, for **example**:

1 User input

Return

**CATALOG FCNS**

Your *WP 43S* displays the first view  
in this catalog;<sup>38</sup> AIM is on.

AGM	AGRAPH	ALL	AND	arccos	arcosh
$2^x$	$\sqrt[3]{x}$	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	$1/x$	2COMPL

<sup>38</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 item starting with this character</b> <sup>39</sup> e.g.																		
	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;">FLOOR</td><td style="padding: 2px;">fm.<math>\rightarrow</math>m</td><td style="padding: 2px;">FP</td><td style="padding: 2px;">F<sub>p</sub>(x)</td><td style="padding: 2px;">FP?</td><td style="padding: 2px;">fr<math>\rightarrow</math>dB</td></tr> <tr> <td style="padding: 2px;">fēn<math>\rightarrow</math>m</td><td style="padding: 2px;">FF</td><td style="padding: 2px;">FIB</td><td style="padding: 2px;">FILL</td><td style="padding: 2px;">FIX</td><td style="padding: 2px;">FLASH?</td></tr> <tr> <td style="padding: 2px;">FB</td><td style="padding: 2px;">FBR</td><td style="padding: 2px;">FC?</td><td style="padding: 2px;">FC?C</td><td style="padding: 2px;">FC?F</td><td style="padding: 2px;">FC?S</td></tr> </table>	FLOOR	fm. $\rightarrow$ m	FP	F <sub>p</sub> (x)	FP?	fr $\rightarrow$ dB	fēn $\rightarrow$ m	FF	FIB	FILL	FIX	FLASH?	FB	FBR	FC?	FC?C	FC?F	FC?S
FLOOR	fm. $\rightarrow$ m	FP	F <sub>p</sub> (x)	FP?	fr $\rightarrow$ dB														
fēn $\rightarrow$ m	FF	FIB	FILL	FIX	FLASH?														
FB	FBR	FC?	FC?C	FC?F	FC?S														
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 item starting with the string you specified</b> e.g.																		
	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="padding: 2px;">f''(x)</td><td style="padding: 2px;">GAP</td><td style="padding: 2px;">GaussF</td><td style="padding: 2px;">GCD</td><td style="padding: 2px;">g<sub>d</sub></td><td style="padding: 2px;">g<sub>d</sub><math>^{-1}</math></td></tr> <tr> <td style="padding: 2px;">fz<sub>uk</sub><math>\rightarrow</math>m<sup>3</sup></td><td style="padding: 2px;">fz<sub>us</sub><math>\rightarrow</math>m<sup>3</sup></td><td style="padding: 2px;">F<sub>Δ</sub>(x)</td><td style="padding: 2px;">F<sub>Δ</sub>(x)</td><td style="padding: 2px;">F<sup>-1</sup>(p)</td><td style="padding: 2px;">f'(x)</td></tr> <tr> <td style="padding: 2px;">FS?</td><td style="padding: 2px;">FS?C</td><td style="padding: 2px;">FS?F</td><td style="padding: 2px;">FS?S</td><td style="padding: 2px;">ft.<math>\rightarrow</math>m</td><td style="padding: 2px;">ft<sub>us</sub><math>\rightarrow</math>m</td></tr> </table>	f''(x)	GAP	GaussF	GCD	g <sub>d</sub>	g <sub>d</sub> $^{-1}$	fz <sub>uk</sub> $\rightarrow$ m <sup>3</sup>	fz <sub>us</sub> $\rightarrow$ m <sup>3</sup>	F <sub>Δ</sub> (x)	F <sub>Δ</sub> (x)	F <sup>-1</sup> (p)	f'(x)	FS?	FS?C	FS?F	FS?S	ft. $\rightarrow$ m	ft <sub>us</sub> $\rightarrow$ m
f''(x)	GAP	GaussF	GCD	g <sub>d</sub>	g <sub>d</sub> $^{-1}$														
fz <sub>uk</sub> $\rightarrow$ m <sup>3</sup>	fz <sub>us</sub> $\rightarrow$ m <sup>3</sup>	F <sub>Δ</sub> (x)	F <sub>Δ</sub> (x)	F <sup>-1</sup> (p)	f'(x)														
FS?	FS?C	FS?F	FS?S	ft. $\rightarrow$ m	ft <sub>us</sub> $\rightarrow$ m														
4 User input	Press the corresponding softkey e.g. for <b>FS?S</b>																		

<sup>39</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 search for Greek letters via prefix **g**, e.g. **g** + **A** for  $\alpha$  (though watch the sorting order as printed at the beginning of the *IOI*). Also 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 locations in the *menu section* deviating from the ones you see in simple browsing using **▼** or **▲** exclusively.

You may put in more than one character – 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 string 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 the command, calls the program, recalls the constant or variable, or inserts the command, digit or character selected. *AIM* stays 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

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 740);
- any constant provided can be recalled by **f CONST** + 3 keystrokes maximum if you know its first character;
- any letter provided can be inserted by **f CATALOG CHARS**  $\alpha$  INTL (or in *AIM* by **f A**) + 3 keystrokes maximum;
- any system *flag* provided can be tested by **f CATALOG SYS.FL** + 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. Individual *items* may appear in more than one *menu* and also on the keyboard.

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	
	A	B	C	D	E	F	
	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 (second view)
	J $\rightarrow$ D	D $\rightarrow$ J		DAY	MONTH	YEAR	
	SETTIM	TDISP	SETDAT	D.MY	Y.MD	M.DY	
						J/G	
<b>CLR</b>	CLΣ	CLP	CF	CLMENU	CLCVAR	CLX	almost as in HP-42S
	CLREGS	CLPall	CLFall		CLLCD	CLSTK	
	CLall			DELITM		RESET	
<b>CONST</b>							catalog of constants, see pp. 127ff
<b>CPX</b>	dot	cross	UNITV	Re	conj	$\Re z$ Im	special complex functions
	CX $\rightarrow$ RE	RE $\rightarrow$ CX	sign	Im	x	$\neq$	
<b>DISP</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		RANGE	RANGE?		DSTACK	

Menu							Remarks
<a href="#">EQN</a>	NEW	EDIT	f''	f'	∫f	Solver	equations (see the OM, Sect. 4)
	DELETE						
<a href="#">Solver</a>							show the <i>names</i> of all variables of the current equation and more
<a href="#">f</a>							
<a href="#">f'</a>							
<a href="#">f''</a>							
<a href="#">EQ.EDI</a>	←	( )	^	:	=	→	Equation Editor
<a href="#">EXP</a>	x <sup>3</sup>	xy	log <sub>10</sub> y	lb x	2 <sup>x</sup>	√x	exponential, logarithmic, and hyperbolic functions
	3√x			ln 1+x	e <sup>x-1</sup>		
	sinh	arsinh	cosh	arcosh	tanh	artanh	
<a href="#">FIN</a>	%	%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	
<a href="#">FLAGS</a>	SF	FS?	FF	STATUS	FC?	CF	
	FS?S	FS?C	FS?F	FC?F	FC?S	FC?C	
						CLFall	
<a href="#">INFO</a>	SSIZE?	MEM?	RM?	ISM?	WSIZE?	KTYP?	system information plus one non-binary test (±∞?)
	LocR?	FLASH?	ULP?	NEIGHB	SDIGS?	BATT?	
	WHO?	VERS?	DIM?	±∞?	αPOS?	αLENG?	
	RANGE?	J/G?				BestF?	
<a href="#">INTS</a>	A	B	C	D	E	F	digits for <i>short integers</i> with bases > 10, integer operations
	IDIV	RMD	MOD	×MOD	FLOOR	LCM	
	DBL /	DBLR	DBL ×	^MOD	CEIL	GCD	
	1COMPL	2COMPL	UNSIGN	SIGNMT		WSIZE	
<a href="#">I/O</a>	LOAD	LOADP	LOADR	LOADSS	LOADV	LOADΣ	data exchange and signalling
	BEEP	TONE			RECV	SEND	

Menu							Remarks
<b>LOOP</b>	DSE	DSZ	DSL	ISE	ISZ	ISG	
	DEC					INC	
<b>MATX</b>	NEW	$[M]^{-1}$	$ M $	$[M]^T$	SIM EQ	EDIT	matrix operations (the items sorted 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	$\downarrow$	$\rightarrow$
	INSR		DELR		WRAP	GROW	Matrix Editor as in HP-42S
	M.SIMQ	Mat A	Mat B				Mat X
<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 pop up out of AIM <sup>40</sup>
<b>My<math>\alpha</math></b>							will pop up in AIM <sup>40</sup>
<b>PARTS</b>	IP	FP	MANT	EXPT	sign	DECOMP	some overlaps with HP-42S CONVERT
					x	$\neq$	
					Re	Im	

<sup>40</sup> ... as long as no other menu is called (see Section 6 of the OM).

Menu							Remarks
<a href="#">PRINT</a>							the PRINT commands of the HP-42S
<a href="#">PROB</a>	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#		lnΓ	Γ(x)	
	Binom:	Binom <sub>p</sub>		Binom <sub>△</sub>	Binom <sub>△</sub>		
	Cauch:	Cauch <sub>p</sub>		Cauch <sub>△</sub>	Cauch <sub>△</sub>		
	Expon:	Expon <sub>p</sub>		Expon <sub>△</sub>	Expon <sub>△</sub>		
	F:	F <sub>p</sub> (x)		F <sub>△</sub> (x)	F <sub>△</sub> (x)		
	Geom:	Geom <sub>p</sub>		Geom <sub>△</sub>	Geom <sub>△</sub>		
	Hyper:	Hyper <sub>p</sub>		Hyper <sub>△</sub>	Hyper <sub>△</sub>		
	LgNrm:	LgNrm <sub>p</sub>		LgNrm <sub>△</sub>	LgNrm <sub>△</sub>		
	Logis:	Logis <sub>p</sub>		Logis <sub>△</sub>	Logis <sub>△</sub>		
	NBin:	NBin <sub>p</sub>		NBin <sub>△</sub>	NBin <sub>△</sub>		
	Norml:	Norml <sub>p</sub>		Norml <sub>△</sub>	Norml <sub>△</sub>		
	Poiss:	Poiss <sub>p</sub>		Poiss <sub>△</sub>	Poiss <sub>△</sub>		
<a href="#">P.FN</a>	t:	t <sub>p</sub> (x)		t <sub>△</sub> (x)	t <sub>△</sub> (x)		additional programming functions (avoided a multi-view menu here).
	Weibl:	Weibl <sub>p</sub>		Weibl <sub>△</sub>	Weibl <sub>△</sub>		
	$\chi^2$ :	$\chi^2_p(x)$		$\chi^2_{\Delta}(x)$	$\chi^2_{\Delta}(x)$		
<a href="#">P.FN2</a>	INPUT	END	ERR	TICKS	PAUSE	P.FN2	
	PSTO	PRCL	VARMNU	MVAR	CNST	PUTK	
	R-CLR	R-COPY	R-SORT	R-SWAP	LocR	PopLR	
<a href="#">P.FN2</a>	MENU	KEYG	KEYX	CLMENU	EXITall	RTN+1	
	SDL	SDR	MSG	NOP			
	BACK	CASE	SKIP	AGRAPH	PIXEL	POINT	

Menu							Remarks
<b>STAT</b>	$\Sigma+$	$\bar{x}$	$s$	$\sigma$	$s_m$	SUM	for sample statistics.
	$\Sigma-$	$\bar{x}_w$	$s_w$	$\sigma_w$	$s_{mw}$		
	CLΣ	$\bar{x}_G$	$\varepsilon$	$\varepsilon_p$	$\varepsilon_m$	PLOT	
	L.R.	$r$	$s_{xy}$	Cov	$\hat{x}$	$\hat{y}$	for curve fitting and 2d sample statistics.
	$s(a)$	$\bar{x}_H$					
		$\bar{x}_{RMS}$	$x_{max}$	$x_{min}$		OrthoF	
	LinF	ExpF	LogF	PowerF		BestF	for choosing the fit model(s)
	GaussF	CauchF	ParabF	HypF	RootF		
<b>STK</b>	$x\vec{}$	$y\vec{}$	$z\vec{}$	$t\vec{}$	$\vec{}$	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).
	sinc	sincπ					
	sinh	arsinh	cosh	arcosh	tanh	artanh	
<b>U→</b>	E:	P:	year→s	F&p:	m:	x:	unit conversions (see pp. 137ff).
	°C→°F	°F→°C	s→year		V:	A:	
	power ratio → dB	dB → power ratio	Nm → lbf·ft → Nm		field ratio → dB	dB → field ratio	
	A:	acre → m²	m² → acre	ha→m²	m²→ha	acre <sub>US</sub> → m²	units of area
		mÜ→m²	m²→mÜ				
E:	cal→J	J→cal	Btu→J	J→Btu	Wh→J	J→Wh	units of energy

Menu							Remarks
F&p:	lbf→N	N→lbf	bar→Pa	Pa→bar	psi→Pa	Pa→psi	units of force and pressure
	in.Hg → Pa	Pa → in.Hg	torr → Pa	Pa → torr	atm→Pa	Pa→atm	
			mmHg → Pa	Pa → mmHg			
m:	lb.→kg	kg→lb.	cwt→kg	kg→cwt	oz→kg	kg→oz	units of mass
	stone → kg	kg → stone	short cwt→kg	kg → sh.cwt	tr.oz → kg	kg → tr.oz	
	ton→kg	kg→ton	short ton → kg	kg → short ton	carat → kg	kg → carat	
P:	hp_E→W	W→hp_E	hp_UK→W	W→hp_UK	hp_M→W	W→hp_M	units of power
V:	gl_UK→m³	m³→gl_UK	qt.→m³	m³→qt.	gl_US→m³	m³→gl_US	units of volume
	floz_UK → m³	m³ → floz_UK	barrel → m³	m³ → barrel	floz_US → m³	m³ → floz_US	
X:	au→m	m→au	l.y.→m	m→l.y.	pc→m	m→pc	units of length
	mi.→m	m→mi.	nmi.→m	m→nmi.	ft.→m	m→ft.	
	in.→m	m→in.			yd.→m	m→yd.	
	lǐ→m	m→lǐ	yǐn→m	m→yǐn	zhàng → m	m → zhàng	
	chǐ→m	m→chǐ	cùn→m	m→cùn	fēn→m	m→fēn	
	fathom → m	m → fathom	point → m	m → point	survey foot_US → m	m → survey foot_US	

X.FN	AGM	B <sub>n</sub>	B <sub>n</sub> *	erf	erfc	Orthog	advanced mathematical functions like Beta, Bessel, etc.
	FIB	g <sub>d</sub>	g <sub>d</sub> <sup>-1</sup>	I <sub>xyz</sub>	IΓ <sub>p</sub>	IΓ <sub>q</sub>	
	J <sub>y</sub> (x)	lnβ	lnΓ	max	min	NEXTP	
	W <sub>m</sub>	W <sub>p</sub>	W <sup>-1</sup>	β(x,y)	γ <sub>xy</sub>	Γ <sub>xy</sub>	
Orthog	ζ(x)	(-1) <sup>x</sup>					orthogonal polynomials
	H <sub>n</sub>	L <sub>m</sub>	L <sub>ma</sub>	P <sub>n</sub>	T <sub>n</sub>	U <sub>n</sub>	
Orthog	H <sub>np</sub>						

Menu	<input type="checkbox"/>	Remarks					
<a href="#">αINTL</a>	A a	À à	Á á	Â â	Ã ã	Ä ä	[α] catalog of all Latin letters provided. <sup>41</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.
	Å å	Æ æ	Ā ā	Ă ĕ	Ą ą	Ɓ b	
	C c	Ҫ ܰ	Ć ܲ	ܴ ܲ	D d	ܵ ܲ	
	ܶ ܲ	ܷ ܲ	E e	ܸ ܲ	ܹ ܲ	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	F f	G g	ܶ ܲ	H h	I i	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	J j	K k	L l	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	ܶ ܲ	M m	N n	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	O o	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	R r	ܶ ܲ	ܶ ܲ	S s	ܶ ܲ	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	T t	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	X x	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	
	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	ܶ ܲ	

<sup>41</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>42</sup>	÷ / :	∫	∞	∞	∞	
	¬	Λ	¥	≠		&	
	✗	£	⊥	³√	✓	✗	
	✗	ȴ	Ӯ	ӯ	Ӱ	ӻ	
	:=	≈	≡	E	C	R	
	⊗	⊙	⊕				
	±	^	T	-1	ℏ		
<a href="#">α.FN</a>	x→α	αRL	αRR	αSL	αSR	α→x	dedicated functions for <i>alphanumeric strings</i> , plus a font browser
					αLENG?	αPOS?	
	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>43</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	
	ζ	Τ τ	Υ υ	Φ φ	Χ χ	Ψ ψ	
	Ω ω	ά	έ	ή	ί	ύ	
	Ϊ ī	ó	ú	ÿ ü	ö	ó	

<sup>42</sup> With startup default settings, the multiplication dot is found here and the multiplication cross is called via in AIM. If MULTx is clear, however, this dot is called via in AIM and the multiplication cross via [αMATH](#). The symbols : and ÷ will swap, too.

<sup>43</sup> The Greek alphabet (sic!) goes alpha, beta, gamma, delta, e-psilon, zeta, eta, theta, iota, kappa, lambda, my, ny, xi, o-mikron, pi, rho, sigma, tau, y-psilon, phi, chi, psi, o-mega. About pronunciation, note that ancient Greek H, Θ, and Y are pronounced like Finnish ÄÄ, T, and Y; Finnish Y is spoken like French U or German Ü. Think of Nils Holgersson's goose Yksi (followed by Kaksi, Kolme, Neljä, Viisi, and Kuusi for obvious reasons – these suffice: there is no goose named Seitsemän appearing in that novel).

Menu							Remarks
<a href="#">α•</a>	!	;	:	'	"	✓	[α] for punctuation marks, currency symbols, arrows, and further special characters.
	ı	ż	ſ	ø	~	＼	
	\$	€	%	&	£	¥	
	←	↑	↑↓	↓	→	↖	
	«	»	»	⌚	•	*	
	⌚	⌚	⌚	⌚	⌚	*	
	,	"	...	-			
<a href="#">Σ</a>	n	$\Sigma x$	$\Sigma x^2$	$\Sigma xy$	$\Sigma y^2$	$\Sigma y$	all the sums necessary for the statistics in STAT.
		$\Sigma \ln x$	$\Sigma \ln^2 x$	$\Sigma \ln xy$	$\Sigma \ln^2 y$	$\Sigma \ln y$	
	$\Sigma x^2 y$	$\Sigma x \ln y$		$\Sigma \ln y / x$		$\Sigma y \ln x$	
	$\Sigma x^2 / y$	$\Sigma^1 / x$	$\Sigma^1 / x^2$	$\Sigma x / y$	$\Sigma^1 / y^2$	$\Sigma^1 / y$	
	$\Sigma x^3$	$\Sigma x^4$					
<a href="#">↔</a>	→DEG	→RAD	→GRAD		→D.MS	→MULπ	angular conversions, cf. pp. 145f.
	DEG→	RAD→	GRAD→		D.MS→	MULπ→	
	D→R	R→D		D→D.MS	D.MS→D		

## Constants

Your WP 43S contains a *catalog* of 77 physical, astronomical, and mathematical constants:

G	$G_0$	$G_c$	$g_e$	$GM_{\oplus}$	$g_{\oplus}$	
$c_2$	e	$e_E$	F	$F_{\alpha}$	$F_{\delta}$	
a	$a_0$	$a_M$	$a_{\oplus}$	c	$c_1$	

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>44</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
$a$ (0) <sup>45</sup>	365,242 5 d <i>(per definition)</i>	<i>Gregorian year</i>
$a_0$	$5,291\ 772\ 109\ 03 \cdot 10^{-11}$ m <i>(<math>1,5 \cdot 10^{-10}</math>)</i>	<i>Bohr radius</i> $a_0 = \alpha / 4\pi R_\infty$

<sup>44</sup> For most of the physical constants in CONST, their precise numeric values (incl. their units) and their relative standard deviations (*rel. SDs*) 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 SDs* are included in the table printed here though not contained in CONST. 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.

Apropos, the terms *resolution*, *precision*, and *accuracy* are confused frequently in measuring (and hence in advertising all the more). 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 we cannot know anything about any real-life object or process any better than we can measure it, these considerations are of fundamental importance. We recommend watching them – in your very own interest.

<sup>45</sup> The numbers in parentheses are to support determination of parameters for CNST – 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 $\approx 1,3$ <i>light seconds</i> .
$a_{\oplus}$	$1,495\,979 \cdot 10^{11} \text{ m}$ $(1 \cdot 10^{-6})$	Semi-major axis of the Earth's orbit around the sun. Within the uncertainty stated here, it equals 1 <i>astronomic unit</i> $\approx 499$ <i>light seconds</i> $\approx 8$ <i>light minutes</i> .
$c$	$2,997\,924\,58 \cdot 10^8 \text{ m/s}$ <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.
$c_1$ (5)	$3,741\,771\,85 \dots 10^{-16} \text{ W m}^2$ <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> $e = \frac{2}{K_J R_K} = \Phi_0 G_0$
$e_E$	$2,718\,281\,828\,459\,045\,2\dots$	<i>Euler's e.</i>
$F$	$96\,485,332\,12 \dots \text{ A s/mol}$ <i>(exact)</i>	<i>Faraday constant</i> $F = e N_A$
$F_\alpha$ (10)	$2,502\,907\,875\,095\,892\,8\dots$	
$F_\delta$	$4,669\,201\,609\,102\,990\,6\dots$	<i>Feigenbaum's <math>\alpha</math> and <math>\delta</math></i>
$G$	$6,674\,30 \cdot 10^{-11} \text{ m}^3/\text{kg s}^2$ $(2,2 \cdot 10^{-5})$	Newtonian constant of gravitation; also known as $\gamma$ from other authors. See $GM_{\oplus}$ below for a more precise value.
$G_0$	$7,748\,091\,729 \dots 10^{-5} / \Omega$ <i>(exact)</i>	Conductance quantum $G_0 = 2e^2/h = 2/R_K = eK_j$

Name	Numeric value and <i>rel. SD</i>	Remarks
$G_c$	0,915 965 594 177 219 0...	Catalan's constant
$g_e$ (15)	-2,002 319 304 362 56 <i>(1,7·10<sup>-13</sup>)</i>	Landé's electron g-factor
$GM_{\oplus}$	$3,986\,004\,418 \cdot 10^{14} \text{ m}^3/\text{s}^2$ <i>(2,0·10<sup>-9</sup>)</i>	Newtonian constant of gravitation times the Earth's mass with its atmosphere included (according to WGS84 <sup>46</sup> )
$g_{\oplus}$	$9,806\,65 \text{ m/s}^2$ ( <i>per def.</i> )	Standard earth acceleration (note the actual values vary from $9,780\,4 \text{ m/s}^2$ at equator to $9,832\,2 \text{ m/s}^2$ at the poles)
$h$	$6,626\,070\,15 \cdot 10^{-34} \text{ J s}$ <i>(exact)</i>	<b>Planck constant</b>
$\hbar$	$1,054\,571\,817 \dots 10^{-34} \text{ J s}$ <i>(exact)</i>	Reduced Planck constant $\hbar = h/2\pi$
$k$ (20)	$1,380\,649 \cdot 10^{-23} \text{ J/K}$ <i>(exact)</i>	<b>Boltzmann constant</b> $k = R/N_A$
$K_J$	$4,835\,978\,48 \dots 10^{14} \text{ Hz/V}$ <i>(exact)</i>	Josephson constant $K_j = 2e/h$
$l_{PL}$	$1,616\,255 \cdot 10^{-35} \text{ m}$ <i>(1,1·10<sup>-5</sup>)</i>	Planck length $l_{PL} = t_{PL}c$
$m_e$	$9,109\,383\,701\,5 \cdot 10^{-31} \text{ kg}$ <i>(3,0·10<sup>-10</sup>)</i>	Electron mass $\doteq 511,00 \text{ keV}$
$M_{\text{Moon}}$	$7,349 \cdot 10^{22} \text{ kg}$ <i>(5·10<sup>-4</sup>)</i>	Mass of the Moon

<sup>46</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
$m_n$ (25)	$1,674\,927\,498\,04 \cdot 10^{-27}$ kg $(5,7 \cdot 10^{-10})$	Neutron mass $\triangleq 939,57$ MeV
$m_n/m_p$	1,001 378 419 31 $(4,9 \cdot 10^{-10})$	Neutron to proton mass ratio
$m_p$	$1,672\,621\,923\,69 \cdot 10^{-27}$ kg $(3,1 \cdot 10^{-10})$	Proton mass $\triangleq 938,27$ MeV
$m_{PL}$	$2,176\,435 \cdot 10^{-8}$ kg $(1,1 \cdot 10^{-5})$	Planck mass $m_{PL} = \sqrt{\hbar c/G} \approx 22$ $\mu$ g
$m_p/m_e$	1 836,152 673 43 $(6,0 \cdot 10^{-11})$	Proton to electron mass ratio
$m_u$ (30)	$1,660\,539\,066\,60 \cdot 10^{-27}$ kg $(3,0 \cdot 10^{-10})$	Atomic mass constant $\approx 10^{-3}$ kg/ $N_A$
$m_u c^2$	$1,492\,418\,085\,60 \cdot 10^{-10}$ J $(3,0 \cdot 10^{-10})$	Energy equivalent of the atomic mass constant $\approx 931,49$ MeV
$m_\mu$	$1,883\,531\,627 \cdot 10^{-28}$ kg $(2,2 \cdot 10^{-8})$	Muon mass $\triangleq 105,66$ MeV
$M_\odot$	$1,989\,1 \cdot 10^{30}$ kg $(5 \cdot 10^{-5})$	Mass of the Sun
$M_\oplus$	$5,973\,6 \cdot 10^{24}$ kg $(5 \cdot 10^{-5})$	Mass of the Earth. See $GM_\oplus$ above for a more precise value.
$N_A$ (35)	$6,022\,140\,76 \cdot 10^{23}$ / mol <i>(exact)</i>	<b>Avogadro's number</b>
<b>NaN</b>	<i>Not a Number</i>	See p. 167 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 (exact)	Molar gas constant
r <sub>e</sub>	2,817 940 326 2·10 <sup>-15</sup> m (4,5·10 <sup>-10</sup> )	Classical electron radius $r_e = \alpha^2 a_0$
R <sub>K</sub> (40)	25 812,807 45... Ω (exact)	Von Klitzing constant $R_K = h/e^2$
R <sub>Moon</sub>	1,737 530·10 <sup>6</sup> m (5·10 <sup>-7</sup> )	Mean radius of the Moon
R <sub>∞</sub>	10 973 731,568 160 / m (1,9·10 <sup>-12</sup> )	Rydberg constant $R_\infty = \frac{\alpha^2 m_e c}{2 h}$
R <sub>⊕</sub>	6,96·10 <sup>8</sup> m (5·10 <sup>-3</sup> )	Mean radius of the sun
R <sub>⊕</sub>	6,371 010·10 <sup>6</sup> m (5·10 <sup>-7</sup> )	Mean radius of the Earth
S <sub>a</sub> (45)	6,378 137 0·10 <sup>6</sup> m ( <i>p. def.</i> )	Semi-major axis
S <sub>b</sub>	6,356 752 314 2·10 <sup>6</sup> m (1,6·10 <sup>-11</sup> )	Semi-minor axis
S <sub>e<sup>2</sup></sub>	6,694 379 990 14·10 <sup>-3</sup> (1,5·10 <sup>-12</sup> )	First eccentricity squared
S <sub>e<sup>1,2</sup></sub>	6,739 496 742 28·10 <sup>-3</sup> (1,5·10 <sup>-12</sup> )	Second eccentricity squared
S <sub>f<sup>-1</sup></sub>	298,257 223 563 ( <i>per def.</i> )	Flattening parameter
T <sub>0</sub> (50)	273,15 K ( <i>per definition</i> )	= 0°C, standard temperature

Name	Numeric value and <i>rel. SD</i>	Remarks
$T_p$	$1,416\,785 \cdot 10^{32} \text{ K}$ <i>(1,1·10<sup>-5</sup>)</i>	<i>Planck temperature</i> $T_P = \frac{c^2}{k} \sqrt{\frac{\hbar c}{G}} = \frac{M_P c^2}{k} = \frac{E_P}{k}$
$t_{PL}$	$5,391\,245 \cdot 10^{-44} \text{ s}$ <i>(1,1·10<sup>-5</sup>)</i>	<i>Planck time</i> $t_{PL} = l_{PL}/c$
$V_m$	$0,022\,413\,969\,5\dots \text{ m}^3/\text{mol}$ <i>(exact)</i>	Molar volume of an ideal gas at standard conditions $V_m = \frac{RT_0}{P_0} \approx 22,4 \text{ l/mol}$
$Z_0$	$376,730\,313\,668 \Omega$ <i>(1,5·10<sup>-10</sup>)</i>	Characteristic impedance of vacuum
$\alpha$ (55)	$7,297\,352\,569\,3 \cdot 10^{-3}$ <i>(1,5·10<sup>-10</sup>)</i>	Fine-structure constant $\alpha = \frac{e^2}{2\varepsilon_0 h c} \approx \frac{1}{137}$
$\gamma$	$6,674\,30 \cdot 10^{-11} \text{ m}^3/\text{kg s}^2$ <i>(2,2·10<sup>-5</sup>)</i>	Newtonian constant of gravitation; also known as G from other authors. See $\mathbf{GM}_\oplus$ below for a more precise value.
$\gamma_{EM}$	$0,577\,215\,664\,901\,532\,9\dots$	<i>Euler-Mascheroni constant</i>
$\gamma_p$	$2,675\,221\,874\,4 \cdot 10^8 \text{ Hz/T}$ <i>(4,2·10<sup>-10</sup>)</i>	Proton gyromagnetic ratio $\gamma_p = 4\pi \mu_p/h$
$\Delta\nu_{Cs}$	<b>9 192 631 770 Hz</b> <i>(exact)</i>	<b>Hyperfine transition frequency of <math>^{133}\text{Cs}</math></b>
$\varepsilon_0$ (60)	$8,854\,187\,812\,8 \cdot 10^{-12} \frac{\text{As}}{\text{Vm}}$ <i>(1,5·10<sup>-10</sup>)</i>	Vacuum electric permittivity $\varepsilon_0 = 1/\mu_0 c^2$ (note the so-called Coulomb's constant is just $1/4\pi\varepsilon_0$ )

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
$\lambda_{cp}$	$1,321\,409\,855\,39 \cdot 10^{-15} \text{ m}$ $(3,1 \cdot 10^{-10})$	
$\mu_0$	$1,256\,637\,062\,12 \cdot 10^{-6} \frac{\text{Vs}}{\text{Am}}$ $(1,5 \cdot 10^{-10})$	Vacuum magnetic permeability
$\mu_B$ (65)	$9,274\,010\,078\,3 \cdot 10^{-24} \text{ J/T}$ $(3,0 \cdot 10^{-10})$	Bohr magneton $\mu_B = e\hbar/2m_e$
$\mu_e$	$-9,284\,764\,704\,3 \cdot 10^{-24} \text{ J/T}$ $(3,0 \cdot 10^{-10})$	Electron magnetic moment
$\mu_e/\mu_B$	$-1,001\,159\,652\,181\,28$ $(1,7 \cdot 10^{-13})$	Ratio of electron magnetic moment to Bohr's magneton
$\mu_n$	$-9,662\,365\,1 \cdot 10^{-27} \text{ J/T}$ $(2,4 \cdot 10^{-7})$	Neutron magnetic moment
$\mu_p$	$1,410\,606\,797\,36 \cdot 10^{-26} \text{ J/T}$ $(4,2 \cdot 10^{-10})$	Proton magnetic moment
$\mu_u$ (70)	$5,050\,783\,746\,1 \cdot 10^{-27} \text{ J/T}$ $(3,1 \cdot 10^{-10})$	Nuclear magneton $\mu_u = e\hbar/2m_p$
$\mu_\mu$	$-4,490\,448\,30 \cdot 10^{-26} \text{ J/T}$ $(2,2 \cdot 10^{-8})$	Muon magnetic moment

Name	Numeric value and <i>rel. SD</i>	Remarks
$\sigma_B$	$5,670\,374\,41\dots \cdot 10^{-8} \frac{W}{m^2 K^4}$ <i>(exact)</i>	Stefan-Boltzmann constant $\sigma_B = \frac{2\pi^5 k^4}{15 h^3 c^2}$
$\Phi$	$1,618\,033\,988\,749\,894\,8\dots$	Golden ratio $\Phi = \frac{1}{2}(1 + \sqrt{5})$
$\Phi_0$	$2,067\,833\,848\dots \cdot 10^{-15} V\,s$ <i>(exact)</i>	Magnetic flux quantum $\Phi_0 = \frac{\hbar}{2e}$
$\omega$ (75)	$7,292\,115 \cdot 10^{-5} \text{ rad/s}$ <i>(<math>2 \cdot 10^{-8}</math>)</i>	Angular velocity of the Earth according to WGS84 (see footnote 46 on p. 130).
$-\infty$	$-\infty$	Note both these ‘constants’ are counted as numeric values in your WP 43S.
$\infty$	$\infty$	They can be recalled and used with SPCRES set, else an error will be thrown.

Note that these constants will appear in routines with a heading # (e.g. # **c**) as shown in the OM, Section 3.

A few more constants with unknown accuracy, not stored in CONST, follow here for your convenience:

Numeric value	Remarks
$11,2 \cdot 10^3 \text{ m/s}$	Escape speed from Earth
$1,217 \text{ kg/m}^3$	Air density at standard conditions
$331 \text{ m/s}$	Speed of sound in air at standard conditions
$28,97 \cdot 10^{-3} \text{ kg/mol}$	Molar mass of air
$1370 \text{ W/m}^2$	Solar constant (average incident power at the mean distance of Earth to the Sun outside the atmosphere)
$1,62 \text{ m/s}^2$	Gravity acceleration on the Moon

Some more values found in nature are known with up to 1, 2, or 3 digits precision only – they may be helpful for quick estimates nevertheless:

Radius of an atomic nucleus	$\sim 10^{-15}$ m
Radius of an atom <sup>47</sup>	$\sim 10^{-10}$ m
Radius of our home galaxy	$\sim 10^5$ l.y. $\approx 10^{21}$ m
Radius of the observable universe <sup>48</sup>	$\sim 45 \times 10^9$ l.y. $\approx 4.3 \times 10^{26}$ m
Age of the universe	$13.8 \times 10^9$ a = $4.35 \times 10^{17}$ s
Hubble ‘constant’	$\sim 70$ (km/s)/Mpc $\approx 1/(4.4 \times 10^{17}$ s)
Baryonic mass <sup>49</sup> in observable universe	$\sim 10^{53}$ kg
Number of stars in our home galaxy <sup>50</sup>	$\sim 2 \times 10^{11}$
Number of neuron connections in human brain	$\sim 10^{14}$
Number of stars in observable universe	$\sim 10^{23}$

<sup>47</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. You can even touch many of these real-world objects. Think about it!

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

<sup>48</sup> For more information, please see [https://en.wikipedia.org/wiki/Observable\\_universe](https://en.wikipedia.org/wiki/Observable_universe) (or [https://de.w.../Beobachtbares\\_Universum](https://de.w.../Beobachtbares_Universum) or [https://fr.w.../Univers\\_observable](https://fr.w.../Univers_observable) or [https://es.wikipedia.org/wiki/Universo\\_observable](https://es.wikipedia.org/wiki/Universo_observable) etc. – the latter site includes a picture [https://es.wikipedia.org/wiki/Universo\\_observable#/media/Archivo:Universoobservable.PNG](https://es.wikipedia.org/wiki/Universo_observable#/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).

Note the radius of the observable universe divided by the radius of our home galaxy returns a value in the same ballpark as the radius of an atom divided by the radius of a nucleus.

<sup>49</sup> I.e. the mass of all common matter (i.e. atoms etc.). Physicists think this cannot be everything (for good reasons) and talk about ‘dark matter’ but this was not detected yet.

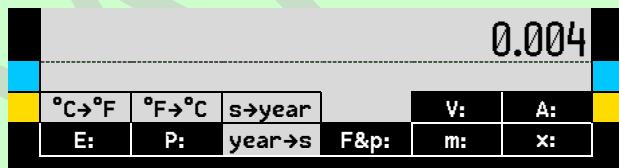
<sup>50</sup> Assume our home galaxy fills a huge flat cylinder 1000 l.y. high, what will be the average distance between its stars? So what will happen when two such galaxies collide? (Calculate yourself, then feel free looking up footnote 55 for an estimate.)

Amount of atoms in the Sun	<sup>51</sup>	$\sim 10^{57}$
Amount of atoms in observable universe		$\sim 10^{80}$

Note these quantities are all far within the range of *reals* allowed on your *WP 43S* (see *App. B*). Physical constants are seldom more precisely known than twelve digits. Please take both facts into account when assessing very small numeric differences as well as when talking about very large numbers.

## Unit Conversions

Your *WP 43S* features 14 angular conversions provided in **A** (cf. p. 127) and 94 unit conversions in **U**. The latter is subdivided into various branches as explained in the OM, Section 5. Its top view looks like this:



with

- **E:** standing for the *submenu* of energy unit conversions,
- **P:** for power,
- **F&p:** for force and pressure,
- **m:** for mass,
- **x:** for length,
- **A:** for area, and
- **V:** for volume.

See pp. 123f for more details of the structure.

<sup>51</sup> Take this number for the amount of atoms in our solar system as well – the stuff beyond the sun is neglectable here.

The seven basic *SI* units are: *kelvin*, *meter*, *kilogram*, *second*, *ampere*, *mol*, and *candela* (the latter measuring *luminous intensity*<sup>52</sup>). Beyond these and products or powers of them, knowledge of the names of some *SI derived units* is helpful. Each conversion contained in U either begins or ends in one of these *SI* units:

Quantity	Unit	Symbol and formula
Temperature	<i>degree Celsius</i>	$\vartheta[\text{°C}] = T[\text{K}] - 273.15$
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>	$1 \text{ C} = 1 \text{ A s}$
Capacitance	<i>farad</i>	$1 \text{ F} = 1 \text{ C/V} = 1 \text{ As/V}$
Conductance	<i>siemens</i>	$1 \text{ S} = 1 \text{ A/V}$
Resistance	<i>ohm</i>	$1 \Omega = 1 \text{ V/A}$
Magnetic flux	<i>weber</i>	$1 \text{ Wb} = 1 \text{ Vs}$
Magnetic flux density	<i>tesla</i>	$1 \text{ T} = 1 \text{ Wb/m}^2 = 1 \text{ Vs/m}^2$
Inductance	<i>henry</i>	$1 \text{ H} = 1 \text{ Wb/A} = 1 \text{ Vs/A}$
Frequency	<i>hertz</i>	$1 \text{ Hz} = 1/\text{s}$
Absorbed dose	<i>gray</i>	$1 \text{ Gy} = 1 \text{ J/kg}$
Plane angle	<i>radian</i>	$1 \text{ rad} = 1 \text{ m/m}$

<sup>52</sup> Translator's note for German readers: Das heißt *Lichtstärke*. Umseitig entspricht *luminous flux* dem *Lichtfluss* oder *Lichtstrom* und *luminance* der *Leuchtdichte*.

Quantity	Unit	Symbol and formula
Solid angle	<i>steradian</i>	$1 \text{ sr} = 1 \frac{\text{m}^2}{\text{m}^2}$
Luminous flux	<i>lumen</i>	$1 \text{ lm} = 1 \text{ cd sr}$
Luminance, illuminance	<i>lux</i>	$1 \text{ lx} = 1 \frac{\text{cd}}{\text{m}^2}$

For talking about inputs and results, knowing also the symbols and names of SI prefixes is beneficial. They cover 36 orders of magnitude:

Prefix	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	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 the conversions featured in  $\text{U}\rightarrow$  and  $\text{x}\rightarrow$  are explained in alphabetical order below. Numeric values are either exact (printed on white background) or rounded to six significant digits for your orientation (your WP 43S uses more precise values wherever applicable). Commas are printed as radix marks for better visibility.

Softkey	Calculation	Remarks	Branch
${}^\circ\text{C} \rightarrow {}^\circ\text{F}$	$\times 1,8 + 32$	$\theta [{}^\circ\text{C}] = (T [\text{K}] + T_0)$ and $\tau [{}^\circ\text{F}] = (t [{}^\circ\text{R}] + T_0 \times 1,8)$	$\text{U}\rightarrow$
${}^\circ\text{F} \rightarrow {}^\circ\text{C}$	$- 32) / 1,8$		

Softkey	Calculation	Remarks	Branch
acre → m <sup>2</sup>	× 4 046,86	This acre is based on the ‘internat. foot’, see below	
acre <sub>US</sub> → m <sup>2</sup>	× 4 046,87	This acre is based on the U.S. survey foot, see below	U → f A:
atm → Pa	× 1,013 25 × 10 <sup>5</sup>	Atmosphere	U → F&p:
au → m	× 1,495 98 × 10 <sup>11</sup>	Astronomic unit	U → x:
barrel → m <sup>3</sup>	× 0,158 987	(U.S.) barrel of oil, abbr. bbl	U → f V:
bar → Pa	× 100 000	1 mbar = 1 hPa	U → F&p:
Btu → J	× 1 055,06	British thermal unit	
cal → J	× 4,186 8	Calory	U → E:
carat → kg	× 0,000 2		U → m:
chǐ → m	/ 3	‘Chinese foot’ 1 市尺 := 10 cùn	U → x:
cùn → m	/ 30	‘Chin. inch’ 1 市寸 := 10 fēn	
cwt → kg	× 50,802 4	1 (long) hundredweight := 112 lbs	U → m:
dB → field ratio	10 <sup>R<sub>dB</sub>/20</sup>	Decibel	
dB → power ratio	10 <sup>R<sub>dB</sub>/10</sup>		U → ▼
fathom → m	× 1,828 8	1 fathom := 2 yards := 6 feet	
fēn → m	/ 300	1 市分 := 0,1 cùn	U → x:
field ratio → dB	20 lg(a <sub>1</sub> /a <sub>2</sub> )	Also known as amplitude ratio	U → ▼
floz <sub>UK</sub> → m <sup>3</sup>	× 2,841 31 × 10 <sup>-5</sup>	Fluid ounce	
floz <sub>US</sub> → m <sup>3</sup>	× 2,957 35 × 10 <sup>-5</sup>		U → f V:
ft. → m	× 0,304 8	This is the so-called ‘international foot’ of 1959 1 foot := 12 inches	U → x:

Softkey	Calculation	Remarks	Branch
gl <sub>UK</sub> →m <sup>3</sup>	× 4,546 09×10 <sup>-3</sup>	Gallon; 1 (Imperial) gallon := 4 quarts	[U→] [f] [V:]
gl <sub>US</sub> →m <sup>3</sup>	× 3,785 42×10 <sup>-3</sup>		
ha→m <sup>2</sup>	× 10 000	Hectare (see m <sup>2</sup> below)	[U→] [f] [A:]
hp <sub>E</sub> →W	× 746	Electric horsepower	
hp <sub>M</sub> →W	× 735,499	So-called 'metric' horsepower (equivalent to PS in German)	[U→] [P:]
hp <sub>UK</sub> →W	× 745,700	British Imperial horsepower	
in.→m	× 0,025 4	1 inch := 1000 mil	[U→] [x:]
in.Hg → Pa	× 3 386,39	Inch of mercury	[U→] [F&p:]
J→Btu	/ 1 055,06	Joule	
J→cal	/ 4,186 8		[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] := 1000 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	Pound force	[U→] [F&p:]
lbf·ft → Nm	× 1,355 82	Pound force times foot	[U→] [▼]
lb.→kg	× 0,453 592	Pound; 1 lb := 16 ounces	[U→] [m:]

Softkey	Calculation	Remarks	Branch
$\text{lǐ} \rightarrow \text{m}$	$\times 500$	'Chin. mile' 1 市里 := 15 yīn	$\text{U}\rightarrow$ $x:$
$\text{l.y.} \rightarrow \text{m}$	$\times 9,460\ 73 \times 10^{15}$	<i>Light year</i>	
$\text{m}^2 \rightarrow \text{acre}$	$/ 4\ 046,86$	<i>Square meter;</i>	
$\text{m}^2 \rightarrow \text{acre}_{\text{US}}$	$/ 4\ 046,87$	$1 \text{ a [are]} := 100 \text{ m}^2,$	$\text{U}\rightarrow$ $f$ $A:$
$\text{m}^2 \rightarrow \text{ha}$	$/ 10\ 000$	$1 \text{ ha [hectare]} := 10\ 000 \text{ m}^2,$	
$\text{m}^2 \rightarrow \text{mǔ}$	$\times 0,001\ 5$	$1 \text{ km}^2 = 100 \text{ ha} = 10^6 \text{ m}^2$	
$\text{m}^3 \rightarrow \text{barrel}$	$/ 0,158\ 987$		
$\text{m}^3 \rightarrow \text{floz}_{\text{UK}}$	$/ 2,841\ 31 \times 10^{-5}$		
$\text{m}^3 \rightarrow \text{floz}_{\text{US}}$	$/ 2,957\ 35 \times 10^{-5}$	<i>Cubic meter;</i>	$\text{U}\rightarrow$ $f$ $V:$
$\text{m}^3 \rightarrow \text{gl}_{\text{UK}}$	$/ 4,546\ 09 \times 10^{-3}$	$1 \text{ liter} := 1 \text{ dm}^3 = 10^{-3} \text{ m}^3,$	
$\text{m}^3 \rightarrow \text{gl}_{\text{US}}$	$/ 3,785\ 42 \times 10^{-3}$	$1 \text{ ml [milliliter]} = 1 \text{ cm}^3$	
$\text{m}^3 \rightarrow \text{qt.}$	$/ 1,136\ 52 \times 10^{-3}$		
$\text{mi.} \rightarrow \text{m}$	$\times 1\ 609,344$	$1 \text{ mile} := 1\ 760 \text{ yards}$	$\text{U}\rightarrow$ $x:$
$\text{mmHg} \rightarrow \text{Pa}$	$\times 133,322$	See Pa below.	$\text{U}\rightarrow$ $F&p:$
$\text{mǔ} \rightarrow \text{m}^2$	$/ 0,001\ 5$	平方面 (píng fāng mǔ), Chinese unit for areas, in particular for pieces of land	$\text{U}\rightarrow$ $f$ $A:$
$\text{m} \rightarrow \text{au}$	$/ 1,495\ 98 \times 10^{11}$		
$\text{m} \rightarrow \text{chǐ}$	$\times 3$		
$\text{m} \rightarrow \text{cùn}$	$\times 30$		
$\text{m} \rightarrow \text{fathom}$	$/ 1,828\ 8$		
$\text{m} \rightarrow \text{fēn}$	$\times 300$		
$\text{m} \rightarrow \text{ft.}$	$/ 0,304\ 8$		
$\text{m} \rightarrow \text{in.}$	$/ 0,025\ 4$		
$\text{m} \rightarrow \text{lǐ}$	$/ 500$		
$\text{m} \rightarrow \text{l.y.}$	$/ 9,460\ 73 \times 10^{15}$		

Softkey	Calculation	Remarks	Branch
m→mi.	/ 1 609,344	Meter	(U→) x:
m→nmi.	/ 1 852		
m→pc	/ $3,085\,68 \times 10^{16}$		
m → point	/ $352,778 \times 10^{-6}$		
m → survey foot <sub>us</sub>	/ 0,304 801		
m→yd.	/ 0,914 4		
m→yīn	× 0,03		
m → zhàng	× 0,3		
nmi.→m	× 1 852	Nautical mile	
Nm → lbf·ft	/ 1,355 82	Newton meter	(U→) ▼
N→lbf	/ 4,448 22	Newton	(U→) F&p:
oz→kg	× 0,028 349 5	Ounce	(U→) m:
Pa→atm	/ $1,013\,25 \times 10^5$	Pascal; 1 hPa = 1 mbar	
Pa→bar	/ 100 000		
Pa → in.Hg	/ 3 386,39		
Pa → mmHg	/ 133,322		
Pa→psi	/ 6 894,76		
Pa → torr	/ 133,322	For all real-world purposes (i.e. within experimental errors), torr are equivalent to millimeters of Hg. Possible differences are merely calculatory. Please check also the document linked below this table.	
pc→m	× $3,085\,68 \times 10^{16}$	Parsec	
point → m	× $352,778 \times 10^{-6}$	1 (typographical) point := 1/72 inch	(U→) x:
power ratio → dB	$10 \lg(p_1/p_2)$		(U→) ▼
psi→Pa	× 6 894,76	Pound per square inch	(U→) F&p:
qt.→m <sup>3</sup>	× $1,136\,52 \times 10^{-3}$	1 (Imperial) quart := 40 (Imp.) fluid ounces	(U→) f v:

Softkey	Calculation	Remarks	Branch
short cwt → kg	× 45,359 2	1 short hundredweight := 100 lbs	
short ton → kg	× 907,185	1 short ton := 2000 lbs	m:
stone → kg	× 6,350 29		
survey foot <sub>US</sub> → m	× 0,304 801	1 U.S. survey foot := $\frac{1200}{3937}$ m	x:
s → year	/ 31 556 952		
ton → kg	× 1 016,05	1 Imperial ton := 200 cwt	m:
torr → Pa	× 133,322	See Pa above.	F&p:
tr.oz → kg	× 0,031 103 5	Troy ounce	m:
Wh → J	× 3 600	Watt-hour	E:
W → hp <sub>E</sub>	/ 746	Watt	
W → hp <sub>M</sub>	/ 735,499		P:
W → hp <sub>UK</sub>	/ 745,700		
yd. → m	× 0,914 4	1 yard := 3 feet	
yīn → m	/ 0,03	1 市引 := 10 zhàng	x:
year → s	× 31 556 952	= $365,242\frac{5}{12} \times 24 \times 60^2$	
zhàng → m	/ 0,3	1 市丈 := 10 chi	x:

The *British Imperial* units in this table cover what is most popular in the UK and its ex-colonies and territories. The Chinese units are a selection taken from the market standard *Shizhì* (市制) valid for mainland China.

Some more, really simple conversions (hence not included in U→) are listed here:

- 1 ångström  $\equiv 1 \text{ Å} = 10^{-10} \text{ m}$  for atomic diameters and wavelengths,

- 1 *barn*  $\equiv 1 \text{ b} = 10^{-28} \text{ m}^2$  for cross sections in nuclear and particle physics (note the name),
- 1 *tex*  $= 10^{-6} \text{ kg/m}$  for yarn density in textile industry,
- 1 *muggeseggele*  $\approx 2 \dots 0.5 \mu\text{m}$  for Swabian precision mechanics.<sup>53</sup>

 ...	Remarks (see also the OM, Section 2)
<b>DEG→</b>	Takes an integer or <i>real</i> <sup>54</sup> $x$ as an angular input in <i>decimal</i> or <i>sexagesimal degrees</i> , resp., and converts it to the current <i>ADM</i> .
<b>D.MS→D</b>	Takes an integer or <i>real</i> <sup>54</sup> $x$ as an angular input in <i>sexagesimal degrees</i> (formatted dddd.d.msshh) and converts it to an <i>angle in decimal degrees</i> (corresponding to the old command H.MS→H).
<b>D→R</b>	Takes an integer or <i>real</i> <sup>54</sup> $x$ as an angular input in ... <i>radians</i> . <sup>55</sup>
<b>D→D.MS</b>	Takes an integer or <i>real</i> <sup>54</sup> $x$ as an angular input in <i>decimal degrees</i> and converts it to ... <i>sexagesimal degrees</i> (corresponding to the old command H→H.MS).
<b>GRAD→</b>	... <i>grades/gon</i> ...
<b>MULπ→</b>	Takes an integer or <i>real</i> <sup>54</sup> $x$ as an angular input in ... <i>multiple of π</i> ... to the current <i>ADM</i> .
<b>RAD→</b>	... <i>radians</i> <sup>55</sup> ...

<sup>53</sup> See <https://en.wikipedia.org/wiki/Muggeseggele> for more about this. Find further special and exotic units of the (mainly English speaking part of the) Western world in a 90-page guide of NIST (<https://physics.nist.gov/cuu/pdf/sp811.pdf>); this text covers many outdated and weird units, too, but also tells comprehensively how to deal with them. The angular conversions following are found therein as well.

<sup>54</sup> If  $x$  is neither integer nor *real* (i.e. neither DT 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.



...

**Remarks** (see also the OM, Section 2)

<b>R→D</b>	Takes an integer or <i>real</i> <sup>54</sup> $x$ as an angular input in <i>radians</i> and converts it to <i>decimal degrees</i> . <sup>55</sup>
<b>→DEG</b>	Takes an integer ( <i>DT 1</i> ) or <i>real</i> ( <i>DT 2</i> ) $x$ as an angular input in the current <i>ADM</i> and converts it to <i>decimal degrees, sexagesimal degrees, grades/gon, multiples of π</i> , or <i>radians</i> , respectively. <sup>55</sup>
<b>→GRAD</b>	If $x$ is a tagged <i>real</i> ( <i>DT 4</i> ), on the other hand, this information is used in conversion (e.g. if $x = 1.5\pi$ then →GRAD will return <b>300°</b> regardless of current <i>ADM</i> ).
<b>→MULπ</b>	If $x$ is neither of <i>DT 1</i> , <i>2</i> , nor <i>4</i> , error 24 will be thrown ('illegal input data type for this operation').
<b>→RAD</b>	

Angular output is tagged always.<sup>56</sup>

<sup>55</sup> Note that *real* angles given in *radians* cannot represent full circles (or multiples of them, as well as simple fractions of  $\pi$  like  $\pi/2$ ,  $\pi/3$ ,  $\pi/4$ , etc.) exactly but with an accuracy of 34 digits 'only'. If you want to avoid rounding errors caused by that but must keep  $\pi$  in play, *multiples of π* may be a better choice for the *angular display mode* here.

Note that large numeric inputs in trigonometric functions are reduced to values between  $-\pi$  and  $+\pi$  before calculating (as mentioned in Section 2 of the OM). Such reductions may easily introduce inaccuracies when *radians* are used – all other angular units are uncritical in this aspect.

<sup>56</sup> Solution of footnote 50: In this very simple model, a volume of 150 (*l.y.*)<sup>3</sup> is available for each star in our galaxy on average, i.e. a sphere with a diameter of 6 *l.y.* So in zeroth order approximation, nothing spectacular is expected.

For estimating the consequences of a galactic collision a bit more realistically, take the orientation of both galaxies relative to each other into account when they collide. And star density is highest in the galactic centers and decreases significantly from there outwards. Furthermore, there used to be giant amounts of free gas (although very thin) and dust between the stars.

## **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 know how to call *items* appearing on the keyboard or in *menus* (including *catalogs*). In *Section 6* of the *OM*, you have learned about storing *items* in user *menus* and/or assigning them to specific locations on your *WP 43S*. There is one more way you can use for calling and executing operations: take **[XEQ]** followed by the *name* of the operation typed in *AIM*.

In the two chapters following thereafter, we will list all the functions requiring parameters and those changing *data types*.

### **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* then; 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, Section 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- RCLx RCL/ RCL <sup>†</sup> RCL <sup>‡</sup> STO STOCFG STOS STO+ STO- STOx STO/ STO <sup>†</sup> STO <sup>‡</sup> t <sup>‡</sup> VIEW x <sup>‡</sup> x=? x≠? x≈? x<? x≤? x≥? x>? y <sup>‡</sup> z <sup>‡</sup> aLEN <sup>?</sup> aPOS? aRL aRR aSL a→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 Π <sub>n</sub> Σ <sub>n</sub>		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 → X**

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

Operations requiring two trailing parameters	First parameter	Second parameter
ASSIGN	<i>Item</i>	Sequence of keystrokes
KEYG KEYX	Key number (1 ... 18)	Program label

Operation requiring four trailing parameters	1 <sup>st</sup> to 4 <sup>th</sup> 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 *DT* of the contents of the lowest *stack register(s)* regardless of specific input values, as mentioned at various locations in the *OM*. These operations are collected here:

Input <i>DT</i>	Operation(s)	Output <i>DT</i>	Output <i>registers</i>
1	1/x $\sqrt[3]{x}$ AGM ALL cos ENG erf erfc e <sup>x</sup> FIX f' f'' gd gd <sup>-1</sup> J <sub>y</sub> (x) LN LN $\beta$ LN $\Gamma$ LOG <sub>10</sub> LOG <sub>2</sub> LOG <sub>xy</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	$2^{57}$	X
	→POL →REC		X, Y
	SLVQ		X, Y, Z
	f'(x) f''(x) SOLVE		X, Y, Z, T
	all angular conversions		X
	→H.MS		X
	J→D →DATE		X
	x→α		X
	M.GET M.NEW		X
	→INT		X

---

<sup>57</sup> The functions printed on yellow background will return *long integers* (*DT* 1) wherever possible.

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

Input <i>DT</i>	Operation(s)	Output <i>DT</i>	Output <i>registers</i>
8	M.DIM?	1	X, Y
	DET DOT ENORM  M	2	X
	$\Sigma+$	2	X, Y, statistic registers
	$V_4$	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
	$e^x \text{ LN } \log_{x,y} \rightarrow \text{REAL}$	2	X
	$x \rightarrow \alpha$	7	X

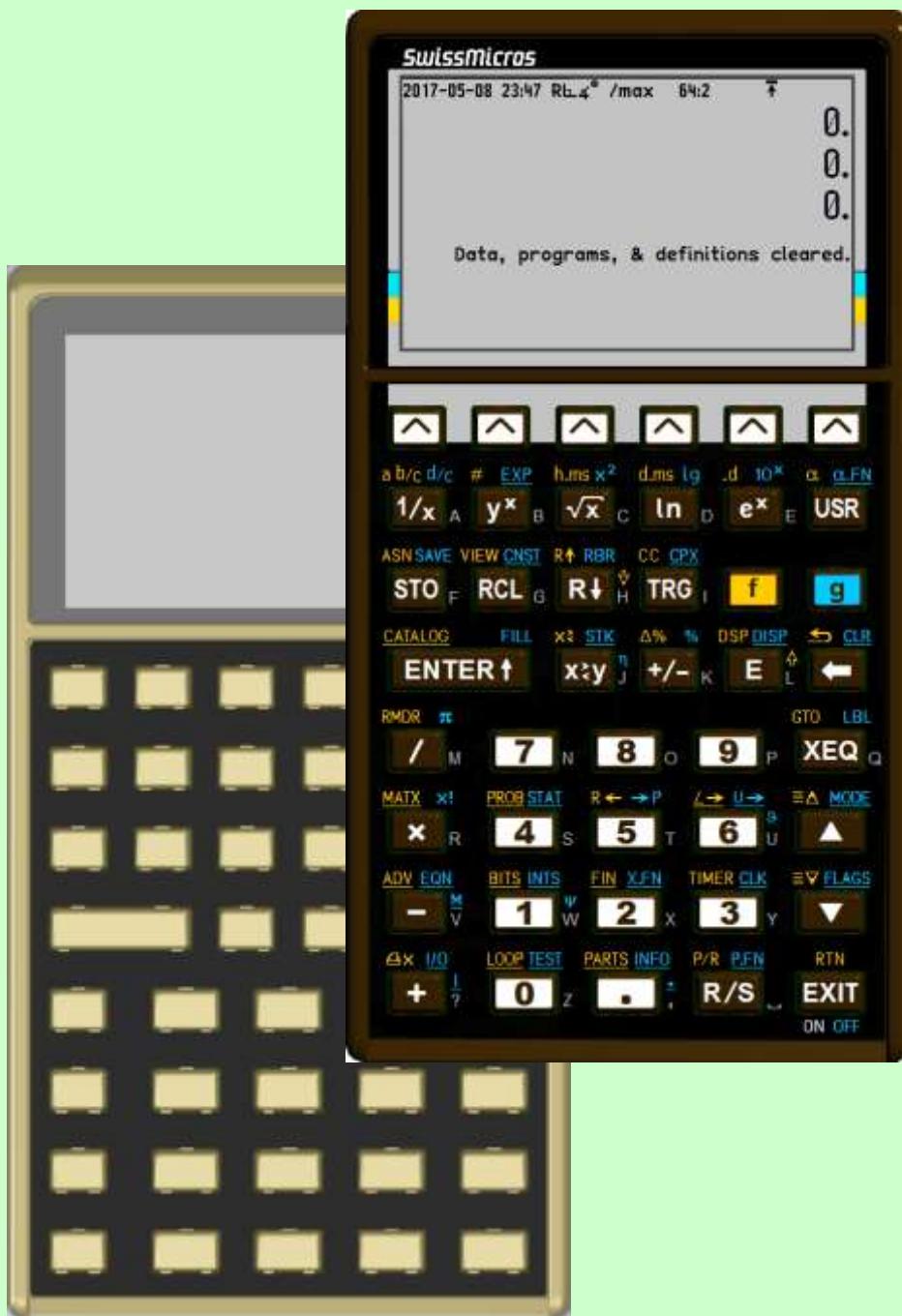
## APPENDIX A: HARDWARE

- Dimensions: wedge-shaped 77 mm × 144 mm × 13 mm or 8 mm (see a picture on next page).
- Mass: 180 g incl. battery.
- LCD: monochrome high contrast (14:1) transreflective memory display with an active area of 58.8 mm × 35.3 mm, 400 × 240 quadratic pixels, and dot pitch 147 µm.
- Processor: low power ARM Cortex-M4F (*STMicroelectronics STM32L476*) incl. real-time clock running at 25 MHz on battery power or 80 MHz when power is supplied through *USB* (see below; look up <https://www.st.com/en/evaluation-tools/32l476gdiscovery.html> for the development board used by *SwissMicros*).
- Memory: 1 MB *FM*, 128 kB *RAM* (see *App. B* on pp. 158ff), 32 MB additional external *FM* on a *QSPI* chip; user *RAM* is 96 kB, user *FM* is 32 MB. xxx
- Power supply: 3 V by one *CR2032* lithium coin cell (battery life up to 3 years, non-rechargeable); optionally powered through *USB* port (good battery shall be installed); typical average currents drawn: power on & busy: 4.2 mA; idle: 0.1 mA; power off: 3 µA.
- Buzzer: piezo-electric with 4 kHz resonance frequency, tunable from 1 Hz up to 20 kHz in steps of 1 Hz.
- Connectivity: infrared port compatible with *HP-82240A/B* printers,  
*micro-USB-B* port connecting to a host computer as external mass storage device.
- Keyboard overlays: Three short slots on either side of the keyboard are provided in the calculator frame for easily fixing your overlay sheets with your personal layouts printed on. See *App. F* for more (on p. 216). Look up *Section 6* of the *OM* for inspiration.



Seven pictures of the hardware are displayed here and on the pages following. The default keyboard layout as delivered by SwissMicros 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 key-  
board side of the *PCB*  
carrying the switching  
domes, carefully re-  
lease the *LCD* connec-  
tion **A**, then unfasten  
the two Philips bolts **B**  
pictured best below.  
**Note all these opera-**  
**tions are at your own**  
**risk.**



This picture shows the *PCB* of an early *DM42* of spring 2017. *RESET* is the top left button here.



Please use the following link to find a discussion of the various hardware components used on the *DM42 PCB* (of February 2018) as pictured on previous page: <https://www.hpmuseum.org/forum/thread-10143.html>.

## APPENDIX B: MEMORY MANAGEMENT

### Memory Map

0x08 00 00 00 – 0x08 0F FF FF	1024 KiB <i>FM</i> for the <i>WP 43S</i> program and its <u>constant</u> data (incl. fonts, <i>menus</i> , messages, etc.) – this memory is in the <i>CPU</i> .
0x10 00 00 00 – 0x10 00 7FFF	32 KiB system <i>RAM</i> for the headers <sup>58</sup> of the 112 global <i>registers</i> and for other global <i>WP 43S</i> variables like expandable <i>submenus</i> (cf. pp. 113ff).
0x20 00 00 00 – 0x20 01 FF FF	96 KiB user <i>RAM</i> for programs, <i>registers</i> , <i>flags</i> , <i>menus</i> , and variables. STATUS and MEM? show the free space there.
0x90 00 00 00 – 0x90 1F CF FF	2036 KiB <i>QSPI</i> (= Quad Serial Peripheral Interface) <i>FM</i> for the operating system
0x90 1F D0 00 – 0x90 1F DF FF	4 KiB <i>QSPI user FM</i>
0x90 1F E0 00 – 0x90 1F FF FF	8 KiB <i>QSPI FM</i>
0x90 20 00 00 – 0x90 7F FF FF	6144 KiB <i>FM</i> for the <i>FAT</i> (= File Allocation Table) system, where backups and snapshots are stored. This part of the memory of your <i>WP 43S</i> is visible on your computer and may accessed by it as long as ‘activate <i>USB disk</i> ’ is selected.

Of these 9 1/8 MB, we printed the sections writable by the *WP 43S* system only (some 3 MB) on yellow, the user-writable sections on green. Within the 96 KiB of user *RAM*, global and local *registers*, *flags*, variables, and statistical sums use its beginning part and user programs occupy its end.

<sup>58</sup> Containing variable pointers (see overleaf).

## Data Types

There are ten *DTs* 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 144 (i.e. 112 global plus 32 local) *user flags* and 112 *system flags* in 256 *bits* in total,<sup>59</sup>
- two *DTs* for two kinds of *menus*,
- one *DT* of variable length for storing *configurations* (see RESET, STOCFG, and RCLCFG),
- another *DT* for *expressions* in EQN (see Section 4 of the OM), and
- two more for program steps and routines (see Section 3 of the OM).

Generally, data – outside of routines – can be contained in (global or local) *registers* or named variables.

A 4-byte *register header* is specified for each of the 112 global *registers*, containing a pointer to the data contained in this register<sup>60</sup>, the *internal DT* (see overleaf), and some data information.<sup>61</sup>

For each (sub-) routine level, 12 *bytes* are reserved in RAM ensuring proper return. For every (sub-) routine requiring *n* local *registers*, 4 + 4 *n bytes* are allocated in addition, with the first 4 *bytes* for the 32 local flags.

---

<sup>59</sup> We need far less than 112 *system flags* so far.

<sup>60</sup> I.e. to the first memory block number of the *register* content. This allows access to  $65\ 535 \text{ blocks} \times 4 \text{ bytes / block} = 262\ 140 \text{ bytes} = 256 \text{ kB} - 4 \text{ bytes}$ . A special value is reserved for the NULL pointer.

<sup>61</sup> Like display base for a *short integer* (2 - 16), sign for a *long integer* (0: zero, 1: negative, 2: positive), angular unit for an *angle* or *real number* (0: *degree*, 1: *gradian* or *gon*, 2: *radian*, 3: *multiple of  $\pi$* , 4: *sexagesimal degree*, 5: no angle = plain *real number*).

An 8-byte *named variable header* is specified for each named variable, containing a pointer to the data contained in this variable, the *internal DT*, some data information,<sup>61</sup> a pointer to the name of the variable, and its length.

The data themselves are then stored the following way:

DT number and meaning		Size [bytes]
1	0	Z Long integer <sup>62</sup>
2	1	R Real number <sup>63</sup> (real34)
3	2	C Complex number, always stored in rectangular notation (complex34)
4	1	Angle <sup>64</sup>
5	3	Time <sup>65</sup>
6	4	Date <sup>66</sup>
7	5	Alphanumeric string (a.k.a. text string)

<sup>62</sup> This DT is for number theory kind of problems. 4 bytes (= 1 block) heading are for the size (in blocks) of the integer following. 1 block following allows for signed integers up to  $2^{31} \approx 2 \times 10^9$ . Size is increased in 1-block steps when required. Max. long integer size is 416 bytes equivalent to 1001 decimal digits. Look up the display limits further below.

<sup>63</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>64</sup> A tagged *angle* is stored as a *real number* but with a special header (cf. previous page).

<sup>65</sup> Internally, a *time* or time interval is stored as a *real number* of *seconds*, just with a specific header. Decimal times are displayed in *hours*. One day corresponds to 86 400 s. This format allows for expressing intervals of some 100 billion years with *femtoseconds* precision.

<sup>66</sup> A *date* is stored as *real number* of *seconds* passed since -4713-01-01 12:00:00 (noon). This is date and time zero for *Julian Day Number* counting. Cf. also previous footnote.

<sup>67</sup> The length of a *text string* in *blocks* is  $L = (j + 2k + 1) / 4$ , with  $j$  being the number of characters contained requiring only 1 byte and  $k$  being the number of characters needing 2 bytes (bit 15 will be set always for them). There is a 1-block header indicating  $L$  and one trailing byte containing 00. The minimum size of such a string is 2 blocks = 8 bytes, minimum size increment is 1 block.

DT number and meaning			Size [bytes]
8	6	Real matrix (of $n$ rows and $m$ columns) <sup>68</sup>	$4 + n \times m \times 16$
9	7	Complex matrix (of $n$ rows and $m$ columns) <sup>68</sup>	$4 + n \times m \times 32$
10	8	Short integer <sup>69</sup>	8
11	9	Configuration (as stored by STOCFG)	$4 + M^{70}$
12	5	Label (or name – up to 7 characters) <sup>67</sup>	$1 + j + 2 k = 2 - 15$
13		Constant <sup>71</sup>	$4 + 0 = 4$
14		System and user flags (112 + 144 flags)	32
15		Extended precision real (39 digits, for internal use only, not exposed to the user) <sup>72</sup>	$4 + 32 = 36$
16		System integer (for internal use only)	4
17		User-created menu (limited to 1 view)	$4 + 18 \times 7 \times 2 = 256$
18		Predefined menu (featuring $n$ views)	$4 + n \times 18 \times 14$
19		Program step, see pp. 176f	See pp. 176f
20		Program, containing $n$ program steps	$4 + M$
21		Expression (for members of EQN), may be stored as text string (DT 7) as well	$4 + M$
22		Directory (proposed by P. 2012-12)	$4 + M$

In programs, *text strings* are shorter: there is just 1 *byte* heading and no trailing 00. See also the last chapter of this App.

<sup>68</sup> 2 bytes for  $n$ , 2 bytes for  $m$ , then follow the individual matrix elements row by row, taking either 2 or 4 bytes each.

<sup>69</sup> This DT is for computer science problems.

<sup>70</sup> The size will vary with the number of user assignments being part of the configuration (see Section 6 of the OM).

<sup>71</sup> A pointer to the constant is sufficient here, regardless of its precision.

<sup>72</sup> There are even longer (i.e. more precise) *reals* used in internal computations. See further below.

The *DTs* 7 - 9, 11, and 19ff are of ‘infinite’ size limited by available memory (**M**) only. The size of each individual object is fixed though.

As mentioned above, any object of any *DT* 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 – monitoring the free space available by **MEM?**, you may experience differences following e.g. changing contents of your *stack*.

## Statistical Summation Registers

Your *WP 43S* features a block of 23 special *registers* for accumulating and storing statistical sums (like the 14 summation *registers* of the *WP 34S* and *WP 31S* before) plus 4 for  $x_{\min}$ ,  $x_{\max}$ ,  $y_{\min}$ , and  $y_{\max}$ . These statistical *registers* neither overlap nor interfere with any *GP registers* unlike they did on *HP*’s pocket calculators. Their contents can be recalled individually using their names (cf. pp. 55 and 87f).

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

Each statistical register requires 60 *bytes*. Hence, this block occupies  $27 \times 60 = 1620$  *bytes*. We need them twice to allow for UNDO.

## SAVE and LOAD...

SAVE stores the calculator *configuration*, all *flags* and *registers* (including the *summation registers*, if allocated), and all programs

present in **RAM** in a file in the **FAT system in FM**. Thus, this storage will survive **RESETs**, even hard ones via the RESET button, and is battery fail safe.<sup>73</sup> So you can use it as on-board backup of your programs and data, for instance.

A second SAVE will overwrite the first one.

The various flavours of LOAD allow resuming calculator operation after such RESET events, according to your requests:

- LOADSS recovers the *configuration* only, similar to RCLCFG,<sup>73</sup>
- LOADΣ recalls just the *summation registers*,
- LOADR all the numbered *registers*,
- LOADP the programs, and
- LOAD recalls the entire data set stored by SAVE at once.

Turn to the *IOI* for more information about these individual commands.

## 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. Its software is based on the *decNumber library* supporting arbitrary precision *BCD* numbers.

As mentioned at some places in the *IOI*, internal computations are usually carried out with 39 digits.<sup>74</sup> Results should be accurate within

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<sup>73</sup> Note STO CFG stores the calculator *configuration* in a *register* or variable, i.e. in **RAM** instead.

<sup>74</sup> Actually, 39 digits are the minimum; some modulo calculations for trigonometric functions are performed with more than a thousand digits to avoid cancellation.

Feel free to test any calculator you may use with this expression:  $729^{33.5}/_{3^{201}} - 1$ . Your *WP 43S* will return precisely 0.

$\pm 1 \times 10^{-33}$  per operation (e.g.  $n$   $\text{1/x}$   $2n$   $\times$ ) returns a plain 2 for all primes  $< 500$  – except  $7$   $\text{1/x}$   $1$   $4$   $\times$   $2$   $-$  returning  $1 \times 10^{-33}$ , and for 67 and 83 the respective results are  $-1 \times 10^{-33}$ ). Note that rounding errors due to calculating with a finite number of digits will accumulate (as other errors do).<sup>75</sup>

Results  $|x| < 10^{-6176}$  are set to zero. For results  $|x| \geq 10^{6145}$ , 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 on your WP 43S in sixteen bytes using an internal format coarsely following decimal128 packed coding,<sup>76</sup> though with some exceptions:

<sup>75</sup> There is a quasi-standard established to find out about processors, firmware, and accuracy of calculators – compute  $\arcsin\{\arccos[\arctan(\tan\{\cos[\sin(9^\circ)]\})]\}$  (although this formula is mathematical nonsense). An ideal brainless number cruncher featuring infinite internal precision would return exactly  $9^\circ$  or equivalent (see e.g. [https://www.wolframalpha.com/input/?i=arcsin\(arccos\(arctan\(tan\(cos\(sin\(pi/20\)\)\)\)\)\)](https://www.wolframalpha.com/input/?i=arcsin(arccos(arctan(tan(cos(sin(pi/20)))))))).

Real calculators (computing with a finite number of digits) deviate for obvious reasons. Your WP 43s returns

$$8,999\,999\,999\,999\,999\,999\,999\,999\,999\,937\,535 = 9 - 6,246\,5 \cdot 10^{-29} \\ \text{for } \arcsin\{\text{real}(\arccos\{\text{real}[\arctan(\tan\{\cos[\sin(9^\circ)]\})]\})\}.$$

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

Another test discussed in the internet works far simpler: Enter 1,000 000 1 and then press  $\boxed{x^2}$  just 27 times. Your WP 43s will then return

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

Although this is the most precise result known for a pocket calculator so far (the WP 34S with DBLON and Free42 concur) only its first 25 digits are correct! Calculating with unlimited precision returns

$$674\,530,470\,741\,084\,559\,382\,689\,178\,029\,746\,8 \text{ instead for the first 34 of } 10^9 \\ \text{digits of the entire result (you get 896 decimals after 7 presses of } \boxed{x^2} \text{ already).}$$

Please take this information into account when assessing small deviations or many decimals returned by your WP 34S, in particular after long calculations. It will return up to 34 digits always but not all of them are guaranteed being true.

<sup>76</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).

- Real zero is stored as integer zero, i.e. all bits cleared.
- The *significand* (not mantissa<sup>77</sup>) of a *real number* is encoded as pure integer in eleven groups of three digits. Each such group is packed into ten 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 its least significant 110 bits. Trailing zeros are omitted, so the *significand* will be right adjusted.
- The most significant (128<sup>th</sup>) bit carries the sign of the *significand*.
- The remaining 17 bits are used for the exponent and the leftmost digit of the *significand*. Of those 17, the lowest twelve are reserved for the exponent (<4096). For the top five bits (below the sign bit) it becomes complicated – following the standard *IEEE 754*. If these five bits read...
  - 00ttt,  
01ttt, or  
10ttt then ttt takes the leftmost digit of the *significand* (0 – 7), and the top two bits will be the most significant bits of the exponent;
  - 11uut then t will be added to 1000<sub>2</sub> and the result (8<sub>10</sub> or 9<sub>10</sub>) will represent the leftmost digit of the *significand*.  
If uu reads 00, 01, or 10<sub>2</sub> then these will represent the two most significant bits of the exponent. If it reads 11<sub>2</sub>, there are bit patterns specified for encoding special numbers (see below).

Thus, the maximum absolute value of the stored exponent is  $10\ 1111\ 1111\ 1111_2 = 12\ 287_{10}$ . For reasons becoming obvious below,  $6176_{10}$  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  $-6176 + 34 = -6142$ , DT2 can support 34-digit numbers within  $10^{-6143} \leq |x| < 10^{+6145}$ .

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<sup>77</sup> The *significand* does not contain a radix mark.

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. *SE* stands for *stored exponent* in the following:

Floating point number	Hexadecimal value stored	Bottom bits in groups of 10	Top 18 bits in binary notation	SE
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		0010 0010 0000 1000 00	6176
111.111 (111 111×10 <sup>-3</sup> )	22 07 40 00 00 00 00 00 00 00 00 00 00 01 bc 6f	06f 06f	0010 0010 0000 0111 01	6173
-123.000 123 (-123 000 123 ×10 <sup>-6</sup> )	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
9.99×10 <sup>99</sup> (999×10 <sup>97</sup> )	22 20 40 00 00 00 00 00 00 00 00 00 00 00 03 e7		0010 0010 0010 0000 01	6273
1×10 <sup>-99</sup>	21 ef 40 00 00 00 00 00 00 00 00 00 00 00 00 01		0010 0001 1110 1111 01	6077
-1×10 <sup>-6143</sup>	80 08 40 00 00 00 00 00 00 00 00 00 00 00 00 01		1000 0000 0000 1000 01	33

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 in the *significand*, stored as 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	SE
<b>9.999 999 999 999 999 999 999 999 999 999 999 <math>\times 10^{6144}</math> (= 9 999 ... 999 999 <math>\times 10^{6110}</math>)</b>	<b>77 ff be 7f 9f e7 f9 fe 7f 9f e7 f9 fe 7f 9f e7</b>	9 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7 3e7	0111 0111 1111 1111 10	<b>12 286</b>

This *real number* (featuring 34 times the digit 9) is the maximum which can be keyed in directly. It will be displayed as  $\infty$  in *startup default* format;  $9.999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\times 10^{6144}$  will be only unveiled by SHOW (see p. 69). The greatest legal *significand* on your WP 43S 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

Neither an exponent nor a *significand* is applicable here. Note that **these three ‘special reals’ ( $\infty$ ,  $-\infty$ , and NaN) may be legal outputs of your WP 43S if SPCRES is set** – no error will be thrown then. NaN (i.e. ‘Not a Number’) 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).  **$\infty$  and  $-\infty$  may be also legal numeric inputs on your WP 43S.**

Remember not every 34-digit number displayed will be true to 34 digits – cf. footnote 74 on pp. 163f. And errors accumulate as explained in footnote 44 on p. 128. As mentioned above, some internal calculations are executed in “*internal high precision*”, employing even more digits than 34: it may mean 39, 72, 75, or even > 1000 digits in special cases.

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

## Limitations

### Maximum numeric input for *data type* ...

- 1:  $\pm 10^{1001}$  (if your patience will suffice for the input) or  $\pm 2^{3326}$  (if you are less patient)
- 2:  $\pm 9.999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999\ 999 \times 10^{\text{RANGE}-1}$  (absolute maximum for **RANGE** is 6145)
- 3:  $\pm 9.999\dots \times 10^{\text{RANGE}-1}$  for either part
- 4:  $\pm 9.999\dots \times 10^{\text{RANGE}-1}$  in arbitrary *ADM*, so the actual absolute maximum is  $9.999\dots \times 10^{\text{RANGE}-1} \pi$
- 5:  $\pm(10^{19} - 1)$  s  $\approx \pm 317 \times 10^9$  years (with  $10^{-15}$  s precision).
- 6: dates xxx
- 8:  $\pm 9.999\dots \times 10^{\text{RANGE}-1}$  for each matrix element
- 9:  $\pm 9.999\dots \times 10^{\text{RANGE}-1}$  for either part of each matrix element
- 10: For arbitrary word size **n** and unsigned mode,  $x_{max} = 2^n - 1$  (i.e.  $\sim 1.8 \times 10^{19}$  for **n**=64); for signed modes,  $x_{max} = 2^{n-1} - 1$ .

### Internal limits:

- PRIME? works like the other binary tests described in the OM. Above 3 317 044 064 679 887 385 961 981 (i.e.  $3.3 \times 10^{24}$ ), however, NEXTP cannot find primes anymore but ‘probable primes’ only (cf. p.

58). If you want to apply NEXTP or PRIME? above this limit, consult appropriate reference literature.<sup>78</sup>

- Trigonometric functions actually operate between  $+\pi$  and  $-\pi$  for *radians* exclusively. The necessary modulo  $2\pi$  reduction ensures that these functions return correct 34-digit results for the entire legal range of angles. ADMs other than *radians* are easier to deal with.

## Maximum numeric output for *data type* ...

- 1:  $\pm 10^{1001}$  with full 1001-digit precision (though you can see and read up to 296 digits only of such numbers – cf SHOW, p. 69).
- 2, 3, 8, and 9: The maxima are as specified for input above. Any (intermediate) result exceeding  $-10^{\text{RANGE}} < x < 10^{\text{RANGE}}$  will be displayed as  $-\infty$  or  $\infty$ , and any (intermediate) result within  $-10^{-\text{RANGE}} < x < 10^{-\text{RANGE}}$  will be displayed as '0'.  
But any (intermediate) result within  $-10^{-6176} < x < 10^{-6176}$  will be assessed and displayed as 0. (cf. previous chapter). Any (intermediate) result exceeding  $-10^{6145} < x < 10^{6145}$  will be assessed as  $-\infty$  or  $\infty$ , respectively, and will then be treated according to the system settings at display time: if SPCRES is set, it will be shown as  $-\infty$  or  $\infty$ , else an overflow error will be thrown.
- 4: For angular conversions, the maxima are as specified for input above. The functions ARCSIN, ARCCOS, and ARCTAN return values between  $-\pi$  and  $\pi$  (or their equivalents) only.
- 5: The maximum is as specified for input above.
- 6: **xxx**

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<sup>78</sup> See [https://en.wikipedia.org/wiki/Miller%20-%20Rabin\\_primality\\_test](https://en.wikipedia.org/wiki/Miller%20-%20Rabin_primality_test) for a start (also available in other languages). Whatever is a prime will be confirmed by PRIME? – a composite may be falsely assessed as being prime with a probability of  $9 \times 10^{-16}$ . With some care and a lot of time, NEXTP can find ‘probable primes’ for *long integers* up to some  $6.3 \times 10^{1001}$ , and PRIME? will check them and their neighbouring numbers (*USB*-power recommended) but you cannot see most of their 1002 digits directly. On the other hand, you can get a 296-digit prime within some 40 *seconds* – and read it entirely on the screen of your WP 43S using SHOW.

- 10: The maxima are as specified for input above.

## Further output limitations for *data type* ...

- 11: *Configurations* cannot be displayed. Thus, if any register or variable containing such data is on screen, **Configuration data** is shown instead of its content.

## What Happens when Changing Word Size?

WSIZE affects *short integer* contents of the allocated *stack registers* and **L** exclusively: Reducing word size will truncate all *short integer* values therein down to the new size. Increasing word size will fill empty bits in the significant side of each *short integer* concerned, up to the new size specified.

**ATTENTION:** Increasing word size will just add empty bits. Thus, a negative *short integer* will immediately become positive then. There is no automatic sign extension! If you want it, take care of it yourself.

All other memory content of your WP 43S will stay as it is. This differs from the implementation as known from the HP-16C, where all registers were remapped on word size changes.

When *short integers* are recalled from memory which are longer than current word size, these integers will be truncated during recall. When *short integers* are recalled from memory which are shorter than current word size, these integers will be filled during recall.

## Special Results

Throughout this chapter, SPCRES is presumed to be set. Thus, infinities and non-numeric results are legal – no error messages will be thrown if such results happen to occur (cf. p. 167).<sup>79</sup>

The following monadic functions will return either  $\infty$ ,  $-\infty$ , or **NaN** under the conditions stated below:

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

And the following monadic functions operate also on infinities:

Input $x$	Operation(s)	Output for $\mathbb{R}$ lit
$-\infty$	$x^3$ , $\sqrt[3]{x}$	$-\infty$
	$\text{arctan}$	$-90^\circ$ or equivalents
	$\tanh$	-1.
	$\frac{1}{x}$ , $e^x$ , $10^x$ , $2^x$ , $\text{sinc}$	0.
	$x^2$ , $\text{arsinh}$	$\infty$

<sup>79</sup> Results were crosschecked against *WP 34S* wherever possible. Additionally, *Wolfram Alpha* was used for checking results with finite arguments. Where deviations are observed we are confident your *WP 43S* returns the correct results.

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

For dyadic functions, we combined the respective tables:

Input $y$	$x$	Op.(s)	Output for ℝ lit
$\infty$	$x \neq -\infty$	+	$\infty$ <sup>80</sup>
	$x \neq \infty$		$-\infty$ <sup>80</sup>
$-\infty$	$\infty$	+	NaN <sup>80</sup>
	$x \neq \infty$		$\infty$ <sup>81</sup>
$-\infty$	$x \neq -\infty$	-	$-\infty$ <sup>81</sup>
	$-\infty$		NaN
$\infty$	$\infty$	x	$\infty$ <sup>80</sup>
	$x > 0$		$-\infty$ <sup>80</sup>
$-\infty$	$x < 0$	x	$\infty$ <sup>80</sup>
	$x < 0$		$-\infty$ <sup>80</sup>
$-\infty$	$x > 0$	x	NaN <sup>80</sup>
	0 or 0.		NaN <sup>80</sup>

<sup>80</sup> Swapping  $x$  and  $y$  will return the same result here.

<sup>81</sup> Swapping  $x$  and  $y$  will return this result times -1.

Input	$y$	$x$	Op.(s)	Output for $\mathbb{R}$ lit
0 < $y \leq \infty$	0.		$/$	$\infty$
				$-\infty$
- $\infty \leq y < 0$	0.		$/$	NaN
- $\infty$ or $\infty$	- $\infty$ or $\infty$		$/$	NaN
0 or 0.	0.		$/$ , $y^x$	NaN
- $\infty$ or $\infty$	0. or 0		$y^x$	NaN
- $\infty \leq y < 0$	- $\infty$ or $\infty$		$\sqrt[x]{y}$	NaN
- $\infty < y < 0$	non-integer $x$		$y^x$ , $\sqrt[x]{y}$	NaN
- $\infty$		odd $x > 0$		$-\infty$
- $\infty$	even $x > 0$		$y^x$	$\infty$
			$\sqrt[x]{y}$	NaN
y ≠ 0	- $\infty$		$y^x$	0.
	$\infty$		$y^x$	$\infty$
0.	- $\infty \leq x < 0$		$y^x$	$\infty$
	0 < $x \leq \infty$		$y^x$	0.
	- $\infty < x < 0$		$\sqrt[x]{y}$	$\infty$
	0 ≤ $x < \infty$		$\sqrt[x]{y}$	0.
0 ≤ $y \leq \infty$	- $\infty$ or $\infty$		$\sqrt[x]{y}$	1.
$\infty$	- $\infty \leq x < 0$		$y^x$	0.
	0 < $x \leq \infty$		$y^x$	$\infty$
	- $\infty < x < 0$		$\sqrt[x]{y}$	0.
	0 ≤ $x < \infty$		$\sqrt[x]{y}$	$\infty$
0.	0 < $x < \infty$		$\log_x y$	$-\infty$

The functions printed on light yellow background in the three tables above will also return NaN (or NaN+i×NaN) with complex results allowed (i.e. CPXRES set). Others will change their output when C is lit.

Some particular returns of elementary transient functions operating at the edge of the complex plane at  $\pm\infty$  or close to it (or returning a value at the edge) are listed here:

Input <sup>82</sup> Re( $x$ )	Im( $x$ )	r( $x$ )	$\varphi(x)$	Op.	Output for C lit
$-\infty$	—	—	—		
$-\infty$	0	$\infty$	$180^\circ$	$\text{fx}$	$\infty \neq 90^\circ = 0 + i \times \infty$
$-\infty$	0	$\infty$	$180^\circ$		$\infty \neq 360^\circ = \infty + i \times 0.$
0.	$\infty$	$\infty$	$90^\circ$		$\infty \neq 180^\circ = -\infty + i \times 0.$
$-\infty$	—	—	—		$-\infty$
$-\infty$		$\infty$			$-\infty + i \times 0.$ <sup>83</sup>
$-10^{999}$	0	$10^{999}$	$180^\circ$	$\sqrt[3]{x}$	$1 \times 10^{333} \neq 60^\circ = 0.5 \times 10^{333} + i \times 0.866 025 404 \times 10^{333} = 5 \times 10^{332} (1 + i \times \sqrt{3})$
$-\infty$	—	—	—		$-\infty$
$-\infty$	0	$\infty$	$180^\circ$	$x^3$	$-\infty + i \times 0.$
$-\infty$	—	—	—		
$-\infty$	0	$\infty$	$180^\circ$	$\ln$	$\infty + i \times 3.141 592 65\dots = \infty + i\pi$
$-\infty$	$\infty$	$\infty$	$135^\circ$		$\infty + i \times 2.356 194 49\dots = \infty + i^{3\pi/4}$
0.	$\infty$	$\infty$	$90^\circ$	$\ln$	$\infty + i \times 1.570 796 32\dots = \infty + i^{\pi/2}$
$\infty$	$\infty$	$\infty$	$45^\circ$		$\infty + i \times 0.785 398 16\dots = \infty + i^{\pi/4}$

<sup>82</sup> Complex infinities should be treated in polar notation (see an article by HP in <http://hparchive.com/Journals/HPJ-1984-07.pdf>, p. 27, left column for reasons).

<sup>83</sup> This result may be calculatory correct but is mathematically incorrect – compare next row. For mathematical reasons, similar cases may occur with other roots or powers operating near the edge of complex plane. Note *complex numbers* are stored in Cartesian coordinates in your WP 43S.

Input <sup>82</sup>		Re( $x$ )	Im( $x$ )	r( $x$ )	$\varphi(x)$	Op.	Output for $\mathbb{C}$ lit
—	—	—	—	—	—	$\text{In}$	$\infty$
$\infty$	0	$\infty$	0°	$\infty$	0°		$\infty + i \times 0.$
$\infty$	- $\infty$	$\infty$	-45°	$\infty$	-45°		$\infty - i \times 0.785\ 398\ 16\dots = \infty - i \pi/4$
0.	- $\infty$	$\infty$	-90°	$\infty$	-90°		$\infty - i \times 1.570\ 796\ 32\dots = \infty - i \pi/2$
- $\infty$	- $\infty$	$\infty$	-135°	$\infty$	-135°		$\infty - i \times 2.356\ 194\ 49\dots = \infty - i^{3\pi/4}$
0.	0.	0.	0.	0.	0.		$-\infty + i \times 0.$
0.	—	—	—	—	—		$-\infty$
- $\infty$	0	$\infty$	180°	$\infty$	180°	$e^x$	$0. + i \times 0.$
-10 <sup>999</sup>	10 <sup>999</sup>	10 <sup>999</sup>	135°	$\infty$	135°		$0. + i \times 0.$
- $\infty$	$\infty$	$\infty$	—	$\infty$	—		NaN+i×NaN
0.	$\infty$	$\infty$	90°	$\infty$	90°		NaN+i×NaN
$\infty$	$\infty$	$\infty$	45°	$\infty$	45°		NaN+i×NaN
$\infty$	0	$\infty$	0°	$\infty$	0°	$e^x$	$0. + i \times 0.$
$\infty$	- $\infty$	$\infty$	-45°	$\infty$	-45°		NaN+i×NaN
0.	- $\infty$	$\infty$	-90°	$\infty$	-90°		NaN+i×NaN
- $\infty$	- $\infty$	$\infty$	-135°	$\infty$	-135°		$0. + i \times 0.$
-10 <sup>999</sup>	-10 <sup>999</sup>	10 <sup>999</sup>	—	$\infty$	—		

Computation of  $\text{lg}$  and  $\text{lb } x$  is derived from  $\text{In}$ . The same applies in analogy for  $e^x$ ,  $10^x$ , and  $2^x$ .

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

## Program Step Size

Program steps are 1 to 3 *bytes* long typically but may be significantly longer. Popular commands (like  $1/x$ ,  $2^x$ , ARCCOS, CF, DEC, ENTER $\uparrow$ , FILL, GTO, IP, ISG, LN, MOD, NEXTP, RTN, R $\downarrow$ , STO, TAN,  $x^2$ , XEQ,  $x \gtrless y$ ,  $y^x$ , +,  $\sqrt{x}$ , and almost all binary tests) take 1 *byte*, less frequently used ones take 2 *bytes* each – see the list overleaf. Commands with numeric parameters (like RCL+ 02), lettered registers (like  $x < ? Y$ ), or local labels (like LBL 55) take one additional byte for the parameter; using indirect addressing costs another byte more.

Within programs, numeric constants (*reals*) take 4 to 18 *bytes* – see the examples below. Constants recalled from CONST take 2 *bytes* only. Short integers take 11 *bytes*, complex constants 7 to 34 *bytes*. Long integers (like 42) take 4 to **xxx** *bytes*.

Global LBL steps specifying an *n*-letter label take *n* + 3 *bytes*. Same applies to commands operating on named variables. Also pure *text strings* in programs consisting of *n* characters take *n* + 3 *bytes*. These statements hold for characters below U+0080<sub>16</sub> only; any character above requires 2 *bytes* (cf. DT7 as described on p. 160).

### Examples:

**GTO 17** is encoded in 2 *bytes* as follows:

- 1 *byte* for the GTO statement itself;
- 1 *byte* for the local label 17.

**RCL+ →X** is encoded in 3 *bytes* as follows:

- 1 *byte* for the RCL+ statement itself;
- 1 *byte* signaling indirect access;
- 1 *byte* for the destination X (= **R100**).

**LBL ‘Prime’** is encoded in 8 *bytes* as follows:

- 1 *byte* for the LBL statement itself;
- 1 *byte* signaling a global label;
- 1 *byte* indicating the length of the label following (here: 5 usual letters);
- 5 *bytes* for these letters.

**STO** 'Count\_1' is encoded in 10 *bytes* as follows:

- 1 *byte* for the STO statement itself;
- 1 *byte* signaling a named variable;
- 1 *byte* indicating the length of the variable following (7 usual letters);
- 7 *bytes* for these letters.

**1e3** is encoded in 6 *bytes* as follows:

- 1 *byte* signaling a numeric constant following;
- 1 *byte* telling its data type (short *real*);
- 1 *byte* indicating its length (3);
- 3 *bytes* for the characters constituting the number.

**-1.5** is encoded in 7 *bytes* as follows:

- 1 *byte* signaling a numeric constant following;
- 1 *byte* telling its data type (short *real*);
- 1 *byte* indicating its length (4);
- 4 *bytes* for the characters.

**4.160 643 081 028 110 401 606 014 040 140 401 $\times 10^{-6083}$**  (and any similarly large and/or precise *real number*) is encoded in 18 *bytes* as follows:

- 1 *byte* signaling a numeric constant following;
- 1 *byte* telling its data type (long *real*);
- 16 *bytes* = 128 *bits* for the number (cf. p. 163ff for the representation).

**8 07 06 05 04 03 02 01<sub>16</sub>** is encoded in 11 *bytes* as follows:

- 1 *byte* signaling a numeric constant following;
- 1 *byte* telling its data type (*short integer*);
- 1 *byte* telling its display base (here 16);
- 8 *bytes* for the digits (any *short integer* ≤ 64 *bits* can be stored therein).

**-12 345** is encoded in 9 *bytes* as follows:

- 1 *byte* signaling a numeric constant following;
- 1 *byte* telling its data type (shorter *long integer*);
- 1 *byte* indicating its length (6);
- 6 *bytes* for the sign and digits.

**12 345** is encoded in 8 *bytes* as follows:

- 1 *byte* signaling a numeric constant following;

1 byte telling its data type (*longer long integer*);

1 byte indicating its length (5);

5 bytes for the digits.

Here is the list of all commands taking 1 *byte* only:

- the four basic arithmetic operators +, -, ×, and ÷,
- **sin, sinh, cos, cosh, tan, tanh**, and their inverses,
- the basic flag commands CF, FC?, FF, FS?, and SF,
- all of LOOP: DEC, DSE, DSL, DSZ, INC, ISE, ISG, and ISZ,
- the four basic Boolean operations AND, OR, XOR, and NOT,
- most *stack* commands: DROP, ENTER↑, FILL, R↑, R↓, x~~y~~, and x~~y~~y,
- RCL, RCL+, RCL-, RCL×, RCL/ as well as ST0, ST0+, ST0-, ST0×, and ST0/,
- seven angular conversions: D→R, R→D, →DEG, →D.MS, →GRAD, →MULπ, and →RAD,
- nine basic programming commands: GTO, INPUT, LBL, PAUSE, ROUND, RTN, STOP, VIEW, and XEQ,
- the basic transcendent functions: 10<sup>x</sup>, 2<sup>x</sup>, 3√x, e<sup>x</sup>, LN, LOG<sub>10</sub>, LOG<sub>2</sub>, LOG<sub>xy</sub>, x<sup>2</sup>, x<sup>3</sup>, √y, y<sup>x</sup>, and √x,
- 1/x, CEIL, CLX, COMB, FLOOR, FP, GCD, IDIV, IP, LCM, max, min, MOD, NEIGHB, NEXTP, PERM, RMD, x!, π, +/-, and |x|,
- almost all of TEST: CONVG?, CPX?, ENTRY?, EVEN?, FC?, FP?, FS?, INT?, KEY?, MATR?, M.SQR?, NaN?, ODD?, PRIME?, REAL?, SPEC?, STRI?, TOP?, ±∞?, and all nine comparisons with x.

All other commands take 2 *bytes*.

## **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, one of the following messages will be thrown (listed alphabetically – *EC* means *error code* here):

	<i>EC</i>	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>84</sup>
Bad time or date input	2	{2, 5, 6} Invalid date format or incorrect <i>date</i> or time in input, e.g. month > 12, day > 31. Will be thrown as soon as 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. LGNRM is called with $j < 0$ ).
Flash memory is full	23	Delete a program from <i>FM</i> to regain space.

<sup>84</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 input is closed.
<b>Input data types do not match</b>	31	Attempt to operate on different <i>DTs</i> (e.g. for a <i>Boolean</i> operation: real AND short integer).
<b>Input is too long</b>	10	{7} Keyboard input is too long for the buffer.
<b>Invalid input data type for this operation</b>	24	Convert what is necessary, if possible (see also “ <i>operation is undefined in this mode</i> ”). But this error may also appear in attempts to calculate with a <i>configuration</i> .
<b>Invalid or corrupted data</b>	18	Thrown when there is a checksum error either in <i>FM</i> or as part of a serial download. Also thrown 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>

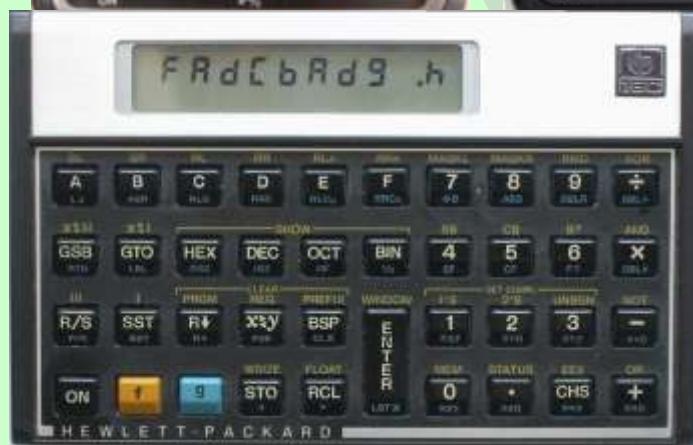
	EC	Explanations, countermeasures and examples
No backup data found	35	Futile attempt to LOAD something from FM.
No root found	20	{2} The Solver did not converge.
No such function	7	Thrown when calling a nonexistent function via <b>XEQ</b> <b>α</b> ... <b>ENTER↑</b> (check for typos!) or running a routine containing a nonprogrammable command.
No such label found	6	Attempt to address an undefined label.
No summation data present	28	Attempt to address an un-allocated summation register.
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 more decimals than 34, <i>word size</i> &gt; 64, 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 &gt; 9 999, 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>
Output would exceed 196 characters	33	{7} Maximum length of <i>alphanumeric strings</i> .

	EC	Explanations, countermeasures and examples
<b>Overflow at <math>+\infty</math></b>	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. 162).</li> </ul>
<b>Overflow at <math>-\infty</math></b>	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. 162).</li> </ul>
<b>Please enter a NEW name</b>	26	Attempt to define a new variable or user <i>menu</i> with a <i>name</i> already in use.
<b>RAM is full</b>	11	May be caused by attempts to write too large routines, allocate too many variables, and the like (see pp. 158ff for the space required by different <i>DTs</i> ). May happen also in program execution due to dynamic allocations (see <i>Section 3</i> of the <i>OM</i> ).
<b>Singular matrix</b>	22	<p>{8, 9}</p> <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>
<b>Stack clash</b>	12	STOS or RCLS attempts using <i>registers</i> that would overlap the <i>stack</i> (see <i>Section 1</i> of the <i>OM</i> ). Will happen with e.g. ssIZE8 set and STOS 93 .
<b>This does not work with an empty string</b>	34	{7} Self-explanatory.

	EC	Explanations, countermeasures and examples
This system flag is write protected	32	Self-explanatory.
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?
Undefined source variable	36	Try to recall a variable which is not defined yet.
Word size is too small	14	{10} User 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 CONST on pp. 127ff and the tables on pp. 167ff). 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 **C** or **EXIT** will erase it and allow continuation most easily. Any other key pressed will erase the message as well, but will also – if applicable – execute with the stack contents present.



## APPENDIX D: 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	Disposable	You can merge text and numeric data easily as described in <i>Section 2</i> of the OM.
ALENG	<b>αLENG</b>	In <u>α.FN</u>
ALLΣ	Disposable	Your <i>WP 43S</i> runs in ALLΣ mode always. The summation <i>registers</i> do not overlap with <i>GP registers</i> .
<b>ALPHA</b>	<b>α</b>	See the description of <i>AIM</i> in <i>Sect. 2</i> of the OM.

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

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
CLV	See remark	Variables are cleared as specified in <i>Section 6</i> of the OM.
<b>COMPLEX</b>	<b>CC</b>	You can also enter <i>complex numbers</i> 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 CUSTOM menu. See <i>Section 6</i> of the OM.
DECM	Disposable	Any input featuring a <b>0</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>x</b>	In <u>STAT</u>
FCSTY	<b>y</b>	
FNRM	<b>ENORM</b>	In <u>MATX</u> . Euclid is older than Frobenius.
GAMMA	<b>Γ(x)</b>	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	Disposable	Press <b># H</b> for converting any closed integer number or integer part in <b>x</b> to hexadecimal.
H.MS+	Disposable	Your WP 43S executes the respective command automatically for sexagesimal times in <b>x</b> and <b>y</b> 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 menu is featured (see CUSTOM).
<b>LASTx</b>	<b>RCL</b> <b>L</b>	
LBL		Press <b>LBL</b> .
LCLBL	Disposable	Obsolete since no CUSTOM menu is featured (see CUSTOM). Nevertheless, your WP 43S provides local labels (see Section 3 of the OM).
LINΣ	Disposable	Your WP 43S runs in ALLΣ mode always.
LIST	n/a	Use <b>PROG</b> instead.
LOG	$\text{LOG}_{10}$	Press <b>lg</b> .
MAN	CF <b>T</b>	Manual print mode is <i>startup default</i> here.
MAT?	<b>MATR?</b>	In <u>TEST</u>
MEAN	$\bar{x}$	In <u>STAT</u>
MOD		Press <b>MOD</b> .
<b>MODES</b>	<b>MODE</b>	
N!	$x!$	
NEWMAT	M.NEW	In <u>MATX</u>
NORM	n/a	Not featured.
OCTM	Disposable	Press <b>#</b> <b>8</b> for converting any closed integer number or integer part in $x$ to octal.
OLD	<b>RCLEL</b>	In <u>MATX</u>
ON	n/a	Programmable ON is not featured.
<b>PGM.FCN</b>	<b>P.FN</b>	<b>GTO</b> , <b>LBL</b> , <b>RTN</b> , <b>VIEW</b> are on the keyboard.
PI	$\pi$	Press <b>π</b> .
POSA	$\alpha\text{POS}$	In <u><math>\alpha\text{FN}</math></u>

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
PRA		In <u>PRINT</u>
<b>[PRGM]</b>	<b>[P/R]</b>	
PRLCD		In <u>PRINT</u>
PROFF		
PROMPT	Disposable	Use  ,  instead.
PRON		
PRP		
PRSTK		
PRUSR		In <u>PRINT</u>
PRV		
PRX		Press .
PRΣ		In <u>PRINT</u>
PUTM	M.PUT	In <u>MATX</u>
PWRF	PowerF	In <u>STAT</u>
RAN	RAN#	In <u>PROB</u>
RND	ROUND	In <u>PARTS</u>
RNRM	RNORM	In <u>MATX</u>
ROTXY	RL, RLC, RR, and RRC	In <u>BITS</u>
RTN		Press .
SDEV	s	In <u>STAT</u>
SIZE	Disposable	There are 100 global <i>GP registers</i> always.
SLOPE	L.R.	In <u>STAT</u>
SOLVE	SLV	In <u>ADV</u>
SQRT		
<b>[SST]</b>	()	Shortcut works if no <i>multi-view menu</i> is open.
STR?	STRI?	In <u>TEST</u>

<b>HP-42S</b>	<b>WP 43S</b>	<b>Remarks</b>
<b>TOP.FCN</b>	Disposable	Obsolete – no top functions are overwritten.
TRACE	SF	
TRANS	[M] <sup>T</sup>	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 <b>VIEW</b> .
WMEAN	$\bar{x}_w$	In <u>STAT</u>
WRAP	M.WRAP	In <u>MATX</u>
XTOA	$x \rightarrow \alpha$	The conversion is done in <b>X</b> .
$X < 0?, X < Y?$	$x < ?$	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 <b><math>y^x</math></b> .
$\Sigma REG$	Disposable	There are 100 global <i>GP registers</i> always.
$\Sigma REG?$		Statistical registers are separate.
$\rightarrow DEC$	$\rightarrow INT$ 10	Press <b>#</b> <b>D</b>
$\rightarrow HR$		Press <b>.d</b>
$\rightarrow H.MS$		Press <b>h.ms</b> ... for closed input.
$\rightarrow OCT$	$\rightarrow INT$ 8	Press <b>#</b> <b>8</b>
$\rightarrow POL$		Press <b><math>\rightarrow P</math></b> .
$\rightarrow REC$		Press <b>R<math>\leftrightarrow</math></b> .
%CH	$\Delta\%$	Press <b><math>\Delta\%</math></b> .
		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 its keyboard layout, starting top left. As for the *HP-42S*, only functions carrying different names on both calculators are listed.

<i>HP-16C</i>	<i>WP 43S</i>	<i>Remarks</i>
[RL], [RLn]	RL	In <u>BITS</u>
[RR], [RRn]	RR	
[RLC], [RLCn]	RLC	
[RRC], [RRCn]	RRC	
÷	/	(see also ISO 80000-2: "The symbol ÷ should not be used.")
DBL÷	DBL/	In <u>INTS</u>
x <sup>i</sup> (i)	Disposable	Any register may be used for indirection.
x <sup>i</sup>		
SHOW HEX	n/a	
SHOW DEC		
SHOW OCT		
SHOW BIN		
B?	BS?	In <u>BITS</u>
GSB	XEQ	
HEX	# H	
DEC	# D	
OCT	# 8	
BIN	# 2	
SF 3, CF 3	SF L, CF L	Leading zeros.
SF 4, CF 4	SF C, CF C	Carry.
SF 5, CF 5	SF B, CF B	Overflow.
F?	FS?	In <u>FLAGS</u>
(i)	Disposable	Any register may be used for indirection.
I		

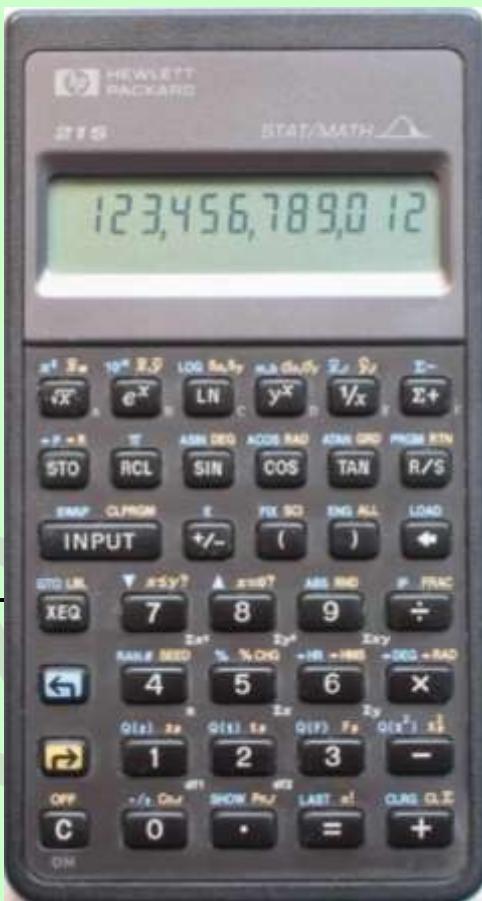
HP-16C	WP 43S	Remarks
<b>CLEAR PRGM</b>	<b>CLP</b>	In <u>CLR</u> . Note here is also CLPALL.
<b>CLEAR REG</b>	<b>CLREGS</b>	In <u>CLR</u>
<b>CLEAR PREFIX</b>	Dispensable	See Section 2 of the OM.
<b>WINDOW</b>	Dispensable	64 bits can be displayed in one row.
<b>SET COMPL 1S</b>	<b>1COMPL</b>	
<b>SET COMPL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

## Corresponding Operations on HP-21S

The table for the functions of *HP-21S* follows the same rules as the one for *HP-16C*. It is, however, 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
$\bar{x}_w$	$\bar{x}_w$	In <u>STAT</u>
$\bar{x} \cdot \bar{y}$	$\bar{x}$	
$S_x, S_y$	$s$	
$m.b$	L.R.	
$\sigma_x, \sigma_y$	$\sigma$	
$\hat{x} \cdot r$	$r, \hat{x}$	
$\hat{y} \cdot r$	$r, \hat{y}$	
<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>	Dispensable	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>	Dispensable	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>	In <u>PARTS</u>
<b>RND</b>	<b>ROUND</b>	
<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>Δ%</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 <i>normal distribution</i> for <u>arbitrary</u> $\mu$ and $\sigma$ instead of the <u>standardized</u> 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 <i>OM</i> , Section 2). Labeling these functions on the <i>HP-21S</i> using the letter $p$ may add some confusion.
<b>zp</b>	<b>Norm<sup>-1</sup></b>	
<b>Q(t)</b>	<b>t<sub>Δ</sub>(x)</b>	
<b>tp</b>	<b>t<sup>-1</sup>(p)</b>	
<b>Q(F)</b>	<b>F<sub>Δ</sub>(x)</b>	
<b>Fp</b>	<b>F<sup>-1</sup>(p)</b>	
<b>Q(x<sup>2</sup>)</b>	<b>x<sup>2</sup><sub>Δ</sub>(x)</b>	
<b>X<sup>2</sup>p</b>	<b>(x<sup>2</sup>)<sup>-1</sup></b>	
<b>Cn.r</b>	<b>COMB</b>	In <u>PROB</u>
<b>Pn.r</b>	<b>PERM</b>	
<b>LAST</b>	<b>RCL</b> <b>L</b>	
<b>=</b>	Dispensable	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	Binom <sub>▲</sub>	
Binom <sub>u</sub>	Binom <sub>▲</sub>	
Binom	Binom <sub>▲</sub>	
Cauch <sub>u</sub>	Cauch <sub>▲</sub>	
CL <sub>a</sub>	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 DTs per default – it does neither need nor feature a <i>double precision mode</i> .
DBLON		
Expon	Expon <sub>▲</sub>	
Expon <sub>u</sub>	Expon <sub>▲</sub>	
F(x)	F <sub>▲</sub> (x)	
F <sub>u</sub> (x)	F <sub>▲</sub> (x)	

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
dRCL	Disposable	Your WP 43S features various <i>data types</i> .
gCLR, gDIM, gDIM?, gFLP, gPIX?, gPLOT, gSET	n/a	The <i>LCD</i> 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 HP-42S (AGRAPH, CLLCD, PIXEL) plus POINT.
Geom	<b>Geom</b> <sub>△</sub>	
Geom <sub>u</sub>	<b>Geom</b> <sub>△</sub>	
GTO $\alpha$	Disposable	Use <b>GTO</b> with an appropriate parameter instead.
H.MS+, H.MS-	Disposable	Your WP 43S features a dedicated <i>DT</i> for <i>times</i> , so <b>+</b> and <b>-</b> suffice for adding or subtracting sexagesimal times, respectively.
INTM?	Disposable	Your WP 43S features dedicated <i>DTs</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>	<b>I<sub>xyz</sub></b>	This is a triadic function after all.
Lgnrm	<b>LgNrm</b> <sub>△</sub>	
Lgnrm <sub>u</sub>	<b>LgNrm</b> <sub>△</sub>	
L <sub>n</sub>	<b>L<sub>m</sub></b>	Renamed to avoid search conflict with LN.
L <sub>na</sub>	<b>L<sub>ma</sub></b>	Renamed in consequence to L <sub>m</sub> .
Logis	<b>Logis</b> <sub>△</sub>	
Logis <sub>u</sub>	<b>Logis</b> <sub>△</sub>	
MROW+ $\times$ , MROW $\times$	Disposable	Obsolete matrix commands.
MROW $\Leftarrow$	<b>M.R<math>\Leftarrow</math>R</b>	
M+ $\times$	Disposable	Obsolete matrix command.
M $^{-1}$	<b>[M]<math>^{-1}</math></b>	

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
M-ALL, M-COL, M-DIAG, M-ROW	Disposable	Obsolete matrix commands.
Mx	Disposable	Your WP 43S features two dedicated <i>DTs</i> for matrices. Thus you can simply multiply two matrices using <b>X</b> and copy matrices like any other objects.
M.COPY	Disposable	
M.IJ, M.REG	Disposable	Obsolete matrix commands.
nBITS	#B	
nCOL, nROW	Disposable	Obsolete matrix commands.
Norml	Norml <sub>Δ</sub>	
Norml <sub>u</sub>	Norml <sub>Δ</sub>	
Poiss	Poiss <sub>Δ</sub>	
Poiss <sub>u</sub>	Poiss <sub>Δ</sub>	
REALM?	Disposable	Your WP 43S features a dedicated <i>DT</i> for <i>reals</i> – it does not need a <i>real</i> mode.
REGS, REGS?	Disposable	The number of global <i>GP registers</i> is fixed to 100 on your WP 43S.
SENDA, SENDP, SENR, SENDΣ	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	

WP 34S	WP 43S	Remarks
t(x)	$t_{\Delta}(x)$	
$t_u(x)$	$t_{\Delta}(x)$	
VIEWa, VWa+	Disposable	Use <b>VIEW</b> instead; <i>alphanumeric strings</i> are just another <i>DT</i> . Combine text and numeric data easily using $\text{+}$ as shown in the OM, Section 2.
Weibl	<b>Weibl</b> $_{\Delta}$	
Weiblu	<b>Weibl</b> $_{\Delta}$	
XEQa	Disposable	Use <b>XEQ</b> with an appropriate parameter instead.
XTAL?	Disposable	A quartz crystal is installed by default.
YDOFF, YDON	Disposable	Your <i>WP 43S</i> displays <i>y</i> whenever possible and wanted. See DSTACK.
$\alpha$ DATE, $\alpha$ DAY	Disposable	You can combine text and numeric data easily using $\text{+}$ as shown in <i>Section 2</i> of the OM.
$\alpha$ GTO	Disposable	Use <b>GTO</b> w/ an appropriate parameter instead.
$\alpha$ IIP, $\alpha$ MONTH	Disposable	You can combine text and numeric data easily using $\text{+}$ as shown in <i>Section 2</i> of the OM.
$\alpha$ RCL, $\alpha$ RC#	Disposable	Your <i>WP 43S</i> features various <i>data types</i> and 'knows' which type is in the <i>register</i> specified. Appending texts is done by $\text{+}$ .
$\alpha$ STO	Disposable	Simply press <b>STO</b> instead (any <i>register</i> can take a <i>text string</i> ).
$\alpha$ TIME	Disposable	See $\alpha$ DATE.
$\alpha$ XEQ	Disposable	Use <b>XEQ</b> with an appropriate parameter instead.
$\beta$	$\beta(x,y)$	
$\Gamma$	$\Gamma(x)$	
$\Delta$ DAYS	Disposable	Simply subtract two <i>dates</i> .
$\zeta$	$\zeta(x)$	
$\Phi(x) \dots$	Disposable	Use NORML... with $\mu=0$ and $\sigma=1$ instead.
$\chi^2(x)$	$\chi^2_{\Delta}(x)$	

<b>WP 34S</b>	<b>WP 43S</b>	<b>Remarks</b>
$\chi^2_u(x)$	$\chi^2_{\Delta}(x)$	
$\rightarrow H$	$\rightarrow HR$	
$\blacksquare PLOT$	n/a	See gCLR.
$\blacksquare C_{XY}$	Disposable	Use $\blacksquare r$ instead.
$\blacksquare \alpha,$ $\blacksquare \alpha +,$ $\blacksquare + \alpha$	Disposable	Combine text and numeric data easily using $\blacksquare +$ as shown in <i>Section 2</i> of the OM. Then use $\blacksquare r$ .
$\blacksquare ?$	Disposable	A quartz crystal and the proper firmware for printing are installed by default.

## New Commands on your WP 43S

The following table lists the commands and pseudo-commands created for your *WP 43S* (and for preceding *WP* calculators, if applicable), offering new or extended functionality compared to earlier *HP RPN* and algebraic pocket calculators. In total, these are more than 350 operations, not counting the unit conversions and constants provided; 80 of them are even new or extended compared to earlier *WP* calculators. The commands are printed below as spelled on your *WP 43S*.

<b>Command</b>	<b>WP 43S</b>	<b>WP 31S</b>	<b>WP 34S</b>
<b>2<sup>x</sup> AGM</b>	●	—	new
<b>ALL</b>	●	●	extended
<b>AND ASR NOT OR XOR</b>	●	—	extended
<b>BACK CASE SKIP</b>	●	—	new
<b>BATT?</b>	●	●	new
<b>BC? FB</b>	●	—	new
<b>BestF</b>	extended	●	●
<b>BestF?</b>	new	—	—

Command	WP 43S	WP 31S	WP 34S
<code>Binom<sub>p</sub></code> <code>Binom<sub>A</sub></code> (of Binomial distribution)	●	●	new
<code>B<sub>n</sub></code> <code>B<sub>n</sub>*</code> <code>CEIL</code> <code>FLOOR</code>	●	—	new
<code>Cauch<sub>p</sub></code> <code>Cauch<sub>A</sub></code> <code>Cauch<sub>A</sub></code> <code>Cauch<sup>-1</sup></code>	●	●	new
<code>CauchF</code> <code>GaussF</code> <code>HypF</code> <code>ParabF</code> <code>RootF</code>	new	—	—
<code>CLCVAR</code>	new	—	—
<code>CLFall</code> <code>CLPall</code> <code>CONJ</code> <code>CONVG?</code> <code>COV</code>	●	—	new
<code>CX→RE</code> <code>RE→CX</code>	new	—	—
<code>DATE TIME</code>	●	—	(●)
<code>DATE→ DAY MONTH YEAR →DATE</code>	●	—	new
<code>DEC</code> <code>DSL</code> <code>INC</code> <code>ISE</code>	●	—	new
<code>DECOMP</code>	●	●	new
<code>DEG→ D.MS→ GRAD→ RAD→</code>	●	—	new
<code>DELITM</code>	new	—	—
<code>DROP</code>	●	—	new
<code>DROPy DSTACK</code>	new	—	—
<code>D→J J→D</code>	●	—	new
<code>EIGVAL EIGVEC</code>	new	—	—
<code>ENTRY?</code>	●	—	new
<code>EQ.DEL</code> <code>EQ.EDI</code> <code>EQ.NEW</code>	new	—	—
<code>erf</code> <code>erfc</code> <code>ERR</code> <code>MSG</code>	●	—	new
<code>EVEN?</code> <code>ODD?</code>	●	—	new
<code>Expon<sub>p</sub></code> <code>Expon<sub>A</sub></code> <code>Expon<sub>A</sub></code> <code>Expon<sup>-1</sup></code>	●	●	new
<code>EXPT MANT</code>	●	—	new
<code>FBR</code>	new	—	—
<code>FC?F</code> <code>FC?S</code> <code>FF</code> <code>FS?F</code> <code>FS?S</code>	●	—	new
<code>FIB</code>	●	—	new
<code>FILL</code>	●	●	new

Command	WP 43S	WP 31S	WP 34S
FLASH? FP?	●	—	new
$F_p(x)$ $F_{\Delta}(x)$ (of $F$ distribution)	●	●	new
$f'$ $f''$	new	—	—
$f'(x)$ $f''(x)$	extended	—	new
GAP	extended	●	new
GCD LCM	●	●	new
$g_d$ $g_d^{-1}$	●	—	new
Geom <sub>p</sub> Geom <sub>Δ</sub> Geom <sub>Δ</sub> Geom <sup>-1</sup>	●	—	new
$H_n$ $H_{nP}$ $L_m$ $L_{m\alpha}$ $P_n$ $T_n$ $U_n$	●	—	new
Hyper <sub>p</sub> Hyper <sub>Δ</sub> Hyper <sub>Δ</sub> Hyper <sup>-1</sup>	new	—	—
IDIV	●	—	new
IDIVR IM RE	new	—	—
INT? ISM? $I_{xyz}$ $I\Gamma_p$ $I\Gamma_q$	●	—	new
$J_y(x)$ J/G?	new	—	—
J/G	extended	●	new
KEY? KTyp? LBL? LEAP?	●	—	new
LgNrm <sub>p</sub> LgNrm <sub>Δ</sub> LgNrm <sub>Δ</sub> LgNrm <sup>-1</sup>	●	—	new
$\text{LN}\beta$ $\text{LN}\Gamma$ LOADP LOADR LOADSS LOADΣ LocR LocR? LOG <sub>2</sub> LOG <sub>xy</sub>	●	—	new
LOAD SAVE	●	●	new
Logis <sub>p</sub> Logis <sub>Δ</sub> Logis <sub>Δ</sub> Logis <sup>-1</sup>	●	●	new
max min MIRROR	●	—	new
MOD	●	●	new
MULπ MULπ→	new	—	—
M.LU M.SQR? NAND NaN? NEIGHB NOR	●	—	new
NBin <sub>p</sub> NBin <sub>Δ</sub> NBin <sub>Δ</sub> NBin <sup>-1</sup>	new	—	—
NEXTP PRIME?	extended	●	new
Norml <sub>p</sub> Norml <sub>Δ</sub> Norml <sub>Δ</sub> Norml <sup>-1</sup>	●	●	new

Command	WP 43S	WP 31S	WP 34S
$n\Sigma$ (callable by name)	●	●	new
OrthoF PLOT POINT	new	—	—
PAUSE	●	—	extended
Poiss <sub>p</sub> Poiss <sub>Δ</sub> Poiss <sub>Δ</sub> Poiss <sup>-1</sup>	●	●	new
PopLR PRCL PSTO PUTK	●	—	new
RANGE RANGE? RANI#	new	—	—
RBR	●	●	new
RCLCFG STOCFG	extended	—	new
RCLS STOS	●	—	new
RCL↑ RCL↓ STO↑ STO↓	●	—	new
RDP RECV SEND	●	—	new
Re $\leftrightarrow$ Im	new	—	—
RJ	●	—	new
RL RLC RR RRC	●	—	extended
RMD	●	●	extended
RM RM? ROUNDI RSD RTN+1 R-CLR R-COPY R-SORT R-SWAP	●	—	new
SDIGS? SETSIG	new	—	—
SDL SDR SETCHN SETEUR SETIND SETJPN SETUK SETUSA	●	—	new
SETDAT SETTIM	●	—	(●)
SIGNMT sinc	●	—	new
sinc $\pi$	new	—	—
SL SR	●	—	extended
SLVQ SPEC?	●	—	new
S <sub>m</sub> S <sub>mw</sub> S <sub>w</sub>	●	●	new
SNAP	new	—	—
SSIZE?	●	●	new

Command	WP 43S	WP 31S	WP 34S
STATUS	extended	—	extended
s <sub>xy</sub>	●	—	new
s(a) TDISP	new	—	—
TICKS	●	—	new
TIMER	●	—	(●)
TOP? ULP?	●	—	new
t <sub>p</sub> (x) t <sub>▲</sub> (x) (of <i>t distribution</i> )	●	●	new
t <sub>‡</sub> y <sub>‡</sub> z <sub>‡</sub> ‡	●	—	new
undo (UNDO)	●	new	—
V <sub>4</sub>	new	—	—
VERS? WDAY WHO?	●	●	new
Weibl <sub>p</sub> Weibl <sub>▲</sub> Weibl <sub>△</sub> Weibl <sup>-1</sup>	●	●	new
W <sub>m</sub> W <sub>p</sub> W <sup>-1</sup> WSIZE? X <sub>G</sub> XNOR	●	—	new
X <sub>H</sub> X <sub>max</sub> X <sub>min</sub> X <sub>RMS</sub> X→DATE	new	—	—
x<? x≤? x=? x≠? x≥? x>?	extended	—	extended
x=+0? x=-0? x≈?	●	—	new
y <sup>x</sup>	extended	●	●
Y.MD	●	●	new
αLENG?	extended	—	●
αPOS?	extended	—	—
αRL αRR αSL αSR	●	—	extended
β(x,y) Γ <sub>xy</sub> γ <sub>xy</sub> ε ε <sub>m</sub> ε <sub>p</sub> ζ(x) Π <sub>n</sub> Σ <sub>n</sub> σ <sub>w</sub>	●	—	new
Σ <sup>1</sup> /x Σ <sup>1</sup> /x <sup>2</sup> Σ <sup>1</sup> /y Σ <sup>1</sup> /y <sup>2</sup> Σlny/x Σx <sup>2</sup> /y Σx <sup>3</sup> Σx <sup>4</sup> Σx/y	new	—	—
Σln <sup>2</sup> x Σln <sup>2</sup> y Σlnx Σlny Σx Σx <sup>2</sup> Σx <sup>2</sup> y Σlny Σxy Σy Σlnx Σy <sup>2</sup> (callable by names)	●	●	new
χ <sup>2</sup> <sub>p</sub> (x) χ <sup>2</sup> <sub>▲</sub> (x) (of chi-square distribution)	●	●	new

Command	WP 43S	WP 31S	WP 34S
(-1) <sup>x</sup> ×MOD ^MOD	●	—	new
±∞?	new	—	—
→DEG →RAD	●	●	new
→D.MS →MULπ	new	—	—
→GRAD	●	—	new
→INT →REAL	new	—	—
■ADV ■CHAR ■r ■REGS ■TAB ■# ■MODE	●	—	(new)
■WIDTH	extended	—	(new)
	●	●	new

The statements in parentheses in the rightmost column refer to the WP 34S with optional quartz and capacitors installed (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. All the manuals listed below are entirely contained in a document set distributed by the *Museum of HPC* (see <http://www.hpmuseum.org/cd/cddesc.htm>). They can be also found in the internet, some even provided by HP still.

Topic	Recommended literature
General calculation examples & applications	All vintage HP calculator manuals can be recommended.
Statistical distributions and their application	<i>HP-21S Owner's Manual</i> , especially pp. 63 – 105. <sup>85</sup>
Manipulating bits and short integers	<i>HP-16C Owner's Handbook</i> <sup>86</sup>
Root finding and numeric integration	<i>HP-34C Owner's Handbook &amp; Programming Guide</i> <sup>87</sup> <i>HP-15C Owner's Handbook</i> <sup>88</sup> <i>HP-15C Advanced Functions Handbook</i> <sup>89</sup> <i>HP-42S Programming Examples &amp; Techniques</i> <sup>90</sup>
Accuracy of numeric calculations	<i>HP-15C Advanced Functions Handbook</i> , pp. 172 – 211. <sup>89</sup>
Programming	<i>HP-42S Owner's Manual</i> <sup>91</sup> <i>HP-42S Programming Examples &amp; Techniques</i> <sup>90</sup>
Financial calculations	<i>HP-17BII+ User's Guide</i> <sup>92</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

<sup>85</sup> Download from <https://literature.hpcalc.org/community/hp21s-om-en.pdf>

<sup>86</sup> Download from <http://www.hp41.net/forum/fileshp41net/hp16c.pdf>

<sup>87</sup> Read <https://www.yumpu.com/en/document/read/19323790/hp34c-slide-rule-museum> or download from <https://literature.hpcalc.org/community/hp34c-oh-en.pdf>

<sup>88</sup> Download a reprint from <http://h10032.www1.hp.com/ctg/Manual/c03030589.pdf>

<sup>89</sup> Download a reprint from <http://h10032.www1.hp.com/ctg/Manual/c03308725.pdf>

<sup>90</sup> Download from <https://literature.hpcalc.org/community/hp42s-prog-en.pdf>

<sup>91</sup> Download from <http://www.hp41.net/forum/fileshp41net/manual-hp42s-us.pdf>

<sup>92</sup> Download a reprint from <http://h10032.www1.hp.com/ctg/Manual/c00363348.pdf>

you compute (and check footnote 100 on p. 230 below, as well as the last paragraph on p. 16 of the OM).

- ☞ The floating point standard *IEEE 754* was developed in 1985, after most of the calculators mentioned above were launched already (see [https://en.wikipedia.org/wiki/Floating-point\\_arithmetic](https://en.wikipedia.org/wiki/Floating-point_arithmetic) as a starter, also about floating point numbers in general).

DRAFT

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

### 1) Under Windows, you can ...

- 1.a) use **MSYS2 MinGW 64-bit**, a runtime environment for *gcc*. You get it at <https://www.msys2.org>. Install it following the on-site instructions (but in **c:/msys64**) until step 7. Then enter in the black *MinGW* window:

```
pacman -S mingw-w64-x86_64-gcc git base-devel mingw-w64-x86_64-gtk3  
This step may take many minutes.
```

```
git clone https://gitlab.com/Over_score/wp43s.git
```

```
git config pull.rebase false
```

```
PATH=/mingw64/bin:$PATH
```

```
PKG_CONFIG_PATH=/mingw64/lib/pkgconfig:$PKG_CONFIG_PATH
```

```
cd wp43s          for changing to the proper directory.  
                  Continue at 5).
```

- 1.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*. Continue at 6).

### 2) Under *Linux*:

You have to install the standard development tools, *git*, *gtk+ 3 dev*, and *libgmp dev* packages.

Then, the first time, simply run:

```
git clone https://gitlab.com/Over_score/wp43s.git
```

```
cd wp43s          for changing to the proper directory.  
                  Continue at 5).
```

### 3) Under OSX (Mac):

Here is *Harald Overbeek's* step by step solution:

- 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** Continue with 6).

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_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.

#### 4) Updating the simulator:

4.a) The following is for *Linux*, only if necessary:

`cd wp43s` Continue at 4b).

4.b) The following is for *Windows* (within the *MinGW* window) & *Linux*:

`git pull` for pulling all the changed files from *gitlab* repository.<sup>93</sup> Continue at 4c)

4.c) Optionally enter

`rm backup.bin` if you want to start the simulator reset to default.  
Continue at 5).

#### 5) Enter

`make` for compiling and building a new executable.<sup>94</sup>

`./wp43s.exe` for starting the simulator.

6) The **simulator window will open**, looking like one of the two pictures overleaf though larger.

---

<sup>93</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 into your language). Then enter `git reset --hard` and try again thereafter.

<sup>94</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 or error messages in compilation (do not care for warnings or notes); then `make rebuild` will clean the field before it starts a fresh compilation. True software errors will remain, however.

Operate the simulator with the mouse. The ten digits as well as **[.**, **ENTER↑**, **+**, **-**, **×**, and **/** may also be entered via the numeric keypad of your computer directly, **▲** and **▼** via the cursor keys, and **←** via [**← Backspace**]. Further computer keyboard shortcuts to simulator keys are presented on next page.

(A vertical screen size of  $\geq 980$  px is required for the portrait window; else the landscape window will open needing  $1000 \times 568$  px. The lower picture shows an old calculator keyboard here.)





Right clicking will call **g**-shifted labels directly in any calculator mode.

Pressing ...

- ... **h** copies the entire simulator screen image to the clipboard.
- ... **x** copies the full content of **X** thereto.<sup>95</sup>
- ... **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 **B** making no sense on a computer application, ‘SL’ is displayed far right in the *status bar* whenever *ASL* is enabled (cf. *Section 1* of the *OM*).

<sup>95</sup> Capitals are printed **green** here for better differentiation.

<sup>96</sup> This is the way to output very *long integer* results  $> 10^{296}$  in their full glory.

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

There are two ways to get your hands on a *WP 43S*:

1. You can buy a *WP 43S* off the shelf or
2. you can flash an existing *DM42* (or *DM41X*).

Way 2 allows you to repurpose a *DM42* (or *DM41X*) you own already, so you may save costs – but you will have to live with stickers on 17 keys at least then. This way is explained in next chapter.

The chapter thereafter (beginning on p. 215) shows how to update your existing *WP 43S*, be it bought or flashed, when a new firmware becomes available.

### **How to Create Your *WP 43S* by Flashing a *DM42***

1. Start your computer. Take a *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 *Micro USB* socket using a suitable data cable. Ensure it connects properly on the calculator side – cutting back the plastic isolation a bit may be necessary.

- 6** Activate *USB* disk. The flash disk of your *DM42* should show up as an external mass storage volume on your computer now.

2. Start the internet browser on your computer and go to [https://gitlab.com/Over\\_score/wp43s/tree/master/DM42\\_binary](https://gitlab.com/Over_score/wp43s/tree/master/DM42_binary).



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

(Option: Copying also keymap.bin to the *DM42* flash disk will reassign keys to match the *WP 43S* layout also after leaving *WP 43S*. Unless you have done this, EXIT/ON stays bottom left.)

3. Press **SETUP** (5)  
**2** **4** **3** WP43S.pgm  
**ENTER↑** **ENTER↑**.  
 Wait some 15 s for flashing completed.  
 Then press **EXIT**  
**EXIT** (1) **EXIT**. Now, your *WP 43S* is up and waiting for your commands.

As long as you rely on a converted *DM42*, the graphic files supplied in [https://gitlab.com/Over\(score\)/wp43s/-/tree/master/artwork](https://gitlab.com/Over(score)/wp43s/-/tree/master/artwork) may ease your life. Print them, cut, and apply (see above for an earlier *WP 43S* layout). The picture at the bottom indicates for which keys a sticker shall be printed.



To leave the *WP 43S* program, enter **MODE 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); else EXIT/ON returns to the bottom left key now.

To retrieve the original **DM42 keyboard layout** (cf. p. 154), copy the file `original_DM42_keymap.bin` to the *DM42* flash disk, rename it `keymap.bin` and RESET the *DM42*. Look here for more information: [https://technical.swissmicros.com/dm42-devel/dmcp-devel\\_manual/](https://technical.swissmicros.com/dm42-devel/dmcp-devel_manual/)

## How to Update Your *WP 43S*

If you have *Free42* still running on your *DM42* then proceed as demonstrated in previous chapter.

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

1. Start your computer.
2. Take your calculator and turn it on. **SAVE** your programs and data. Then leave *WP 43S* by pressing **MODE** **SYSTEM** to return to the *DMCP* system. If you copied `keymap.bin` of *WP 43S* before last flashing, key assignments will stay as they were in your *WP 43S* when navigating in the *DMCP* system – else the *DM42* assignments will become valid (cf. p. 154).
3. Connect your computer to your calculator *Micro USB* socket using a suitable data cable (ensure it connects properly to the calculator – cutting the plastic isolation back a bit may be necessary). The flash disk of your calculator should show up as an external mass storage volume after you pressed ...

### ⑥ Activate *USB Disk*

4. 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 root directory of the *DM42* flash disk.

Option: Copy `keymap.bin` to the *DM42* flash disk if you have not done so far. This will reassign the keys to match the *WP 43S* layout also when leaving *WP 43S*. Else ON remains bottom left.

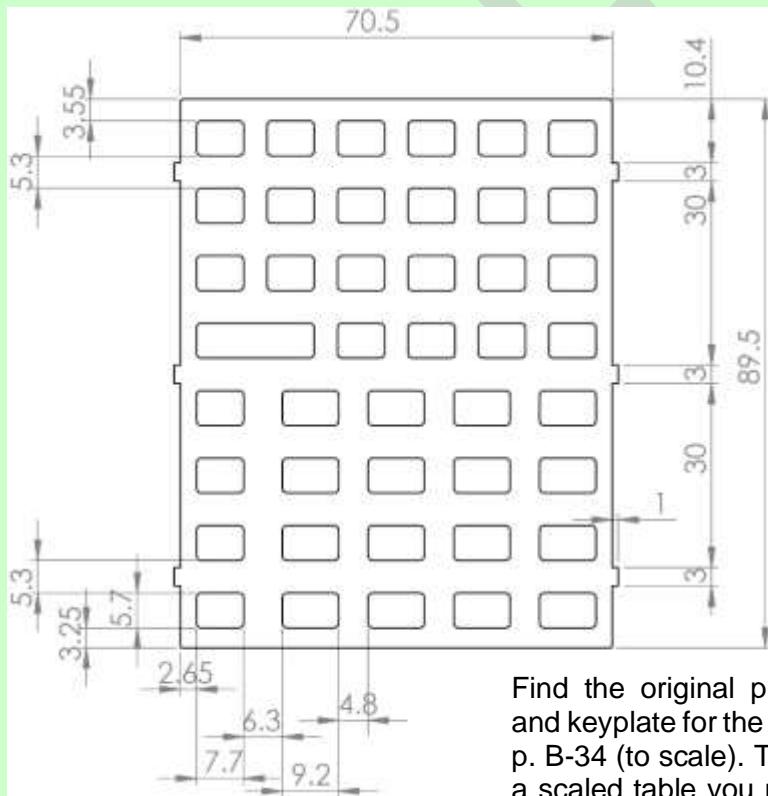
5. Press **EXIT** **ENTER↑** **3** (Load Program), use the cursor keys to select `WP43S.pgm`, and press **ENTER↑** **ENTER↑**.

6. Wait for flashing completed (~15 s). Then press **EXIT** **EXIT** **1** **+**. Recall your saved programs and data via **I/O LOAD**. You can resume your work with your updated *WP 43S* now.

Sometimes, you may need an update of the *DMCP* on your *WP 43S*; see [https://technical.swissmicros.com/dm42/doc/dm42\\_user\\_manual/#DMCP\\_update\\_guide](https://technical.swissmicros.com/dm42/doc/dm42_user_manual/#DMCP_update_guide) for how to do this.

## Overlays

See here the drawing for a blank overlay. All dimensions are given in *millimeters*. Note the overall width is 72.5 mm.



Find the original print of keys and keyplate for the *WP 43S* on p. B-34 (to scale). There is also a scaled table you may use for creating your own overlay.

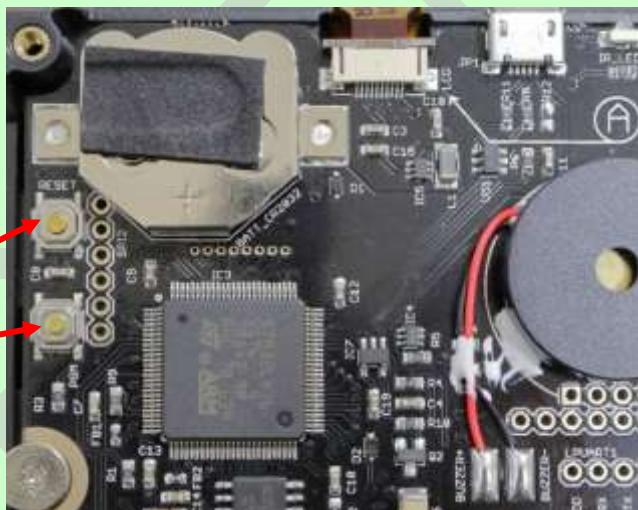
## **APPENDIX G: TROUBLESHOOTING GUIDE**

### **Calculator Frozen**

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 find a printed circuit board (*PCB*) with its top probably looking like this → (cf. p. 157 for an earlier *PCB*).

In any case, you will see two small buttons, one labeled **RESET**, the other one called **PGM** or **BOOT0**.



2. Now:
  - a. Press and hold the PGM (or BOOT0) button.
  - b. Press and release the RESET button.
  - c. Release the PGM (or BOOT0) button.

This shall reset your *DM42* and put it in bootloader mode.<sup>97</sup>

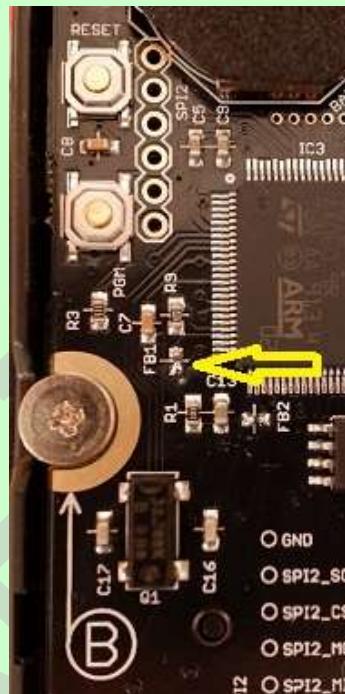
3. Then you can reflash your calculator using `dm_tool.exe` as explained in [https://www.swissmicros.com/dm42/doc/dm42\\_user\\_manual/](https://www.swissmicros.com/dm42/doc/dm42_user_manual/).

<sup>97</sup> If this method should not work, however, this may point to a real hardware problem. We recommend contacting SwissMicros then.

## Fresh Battery Constantly Low

This was observed with factory-fresh calculators in 2020: The low-battery indicator  is lit and BATT? stubbornly returns 1.21 V, although the battery is actually good and measures over 3 V. If resetting the calculator, removing the battery, updating the firmware, etc. does not change the output of BATT?, open the calculator and inspect the PCB. There may be an improper soldering at FB1 (compare previous picture).

If you have the right tools and experience, feel free to fix this yourself – else contact SwissMicros.



## Keymap Trouble

If you find you have loaded a `keymap.bin` not matching the layout you wanted or you do not find the keys properly assigned then proceed this way (assuming both calculator and computer running and connected):

1. Find where MODE went on the calculator keyboard and call it.
2. With MODE open, enter  **SYSTEM** to return to the *DMCP* system.
3. Press **6** (Activate *USB Disk*).
4. 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).
5. Copy `original_DM42_keymap.bin` to the flash disk, rename it `keymap.bin` and **RESET** the *DM42*.
6. Press **EXIT**, then the bottom left key – else you will run into the same trouble again.

Then your *WP 43S* is up and waiting for your orders.

## 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* and *complex* domain functions.

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 – else 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)
$B_n$ , $B_n^*$	$B_n$ 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: $B_n^* = 2 \cdot \frac{(2n)!}{(2\pi)^{2n}} \cdot \zeta(2n)$ See p. 258 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!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 56, 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. 221): In a <i>Galton box</i><sup>98</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</i> domain.</p>
FIB	<p>For integers, FIB returns the <i>Fibonacci</i> number <math>f_n</math> with <math>n = x</math>. The Fibonacci 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. For <i>long integers</i>, <math>f_{4791}</math> is the maximum on your WP 43S.</p> <p>For non-integers, 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 number</i> <math>x</math>, with <math>\Phi = \frac{1+\sqrt{5}}{2}</math> denoting the <i>golden ratio</i>.</p>

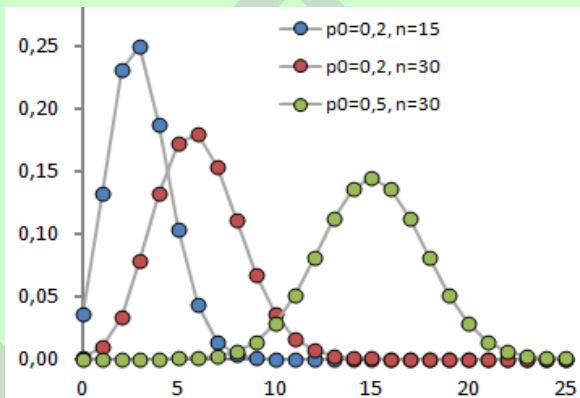
<sup>98</sup> Translator's note: This is called «Planche de Galton» in French, “Galtonbrett” in German, and “macchina di Galton” in Italian. Note the subtle differences in naming. Galton invented his box in 1889.

## Statistical Distribution Functions (PMF, PDF, CDF, etc.)

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 eight continuous ones thereafter. Typical plots are shown for the *PMF's* or *PDF's*.

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



BINOM<sub>P</sub> returns

$$p_B(g; n; p_0) = \binom{n}{g} p_0^g (1 - p_0)^{n-g} = C_{n,g} p_0^g (1 - p_0)^{n-g} \quad (\text{see COMB on p. 220 for the explanation of the notation}).$$

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

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

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

.03 [STO] J 15 [STO] K 0 [PROB] g Binom: Binom<sub>M</sub>

returning 0.633 – so the odds are almost two out of three that you

will not detect any defect in your sample! <sup>99</sup>

Read here for more information:

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

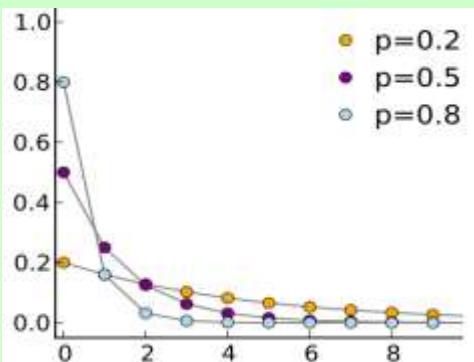
### Geom: Geometric distribution:

GEOM<sub>P</sub> returns

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

GEOM<sub>A</sub> returns

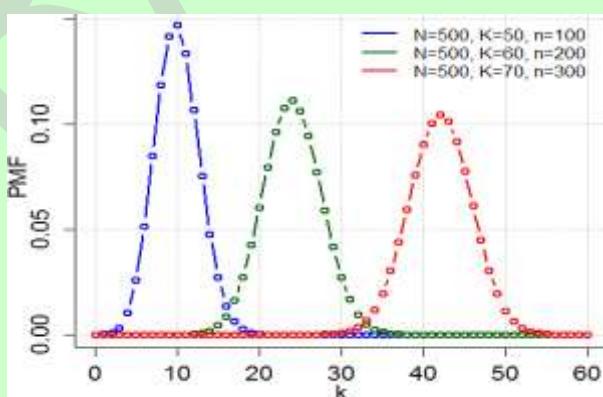
$F_{Ge}(m) = 1 - (1 - p_0)^{m+1}$ , being the probability for a first success after  $m=x$  Bernoulli experiments. The probability  $p_0$  for a success in each such experiment must be specified in I.



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>99</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.

HYPERP 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. 220 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 so-called ‘large’ batches ( $n_0 > 10$ ) and for 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  $\mathbf{J}$ .

NBINP returns  $p_{NB}(f; n; p_0) = \binom{n-1}{f-1} \times p_0^f \times (1-p_0)^{n-f} = C_{n-1; f-1} \times p_0^f \times (1-p_0)^{n-f}$  (s. COMB on p. 220 and cf. BINOM).

Start reading here for more:

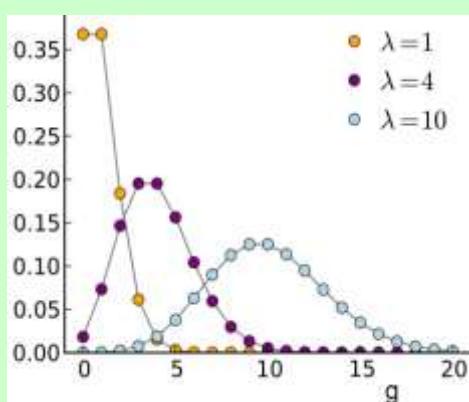
[http://en.wikipedia.org/wiki/Negative\\_binomial\\_distribution](http://en.wikipedia.org/wiki/Negative_binomial_distribution).

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

POISSP 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  $\mathbf{X}$ .



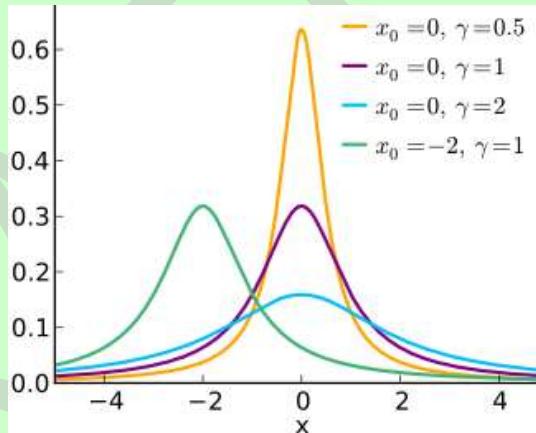
The *Poisson distribution* provides the mathematically simplest model for industrial sampling tests – use  $\lambda = np_0$  with the gross error probability  $p_0$  and the sample size  $n$  (cf. BINOM). For the example introduced with BINOM above, POISS returns 0.638.

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**.



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

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

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

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).

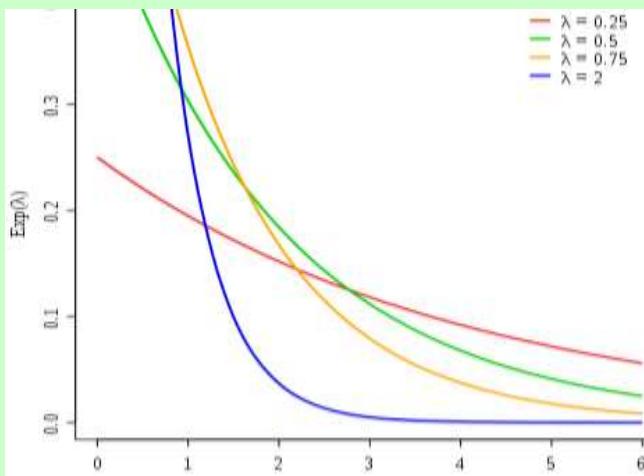
**Expon:** Exponential distribution with the rate  $\lambda$  in **I**.

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

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

Read here for more information:

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



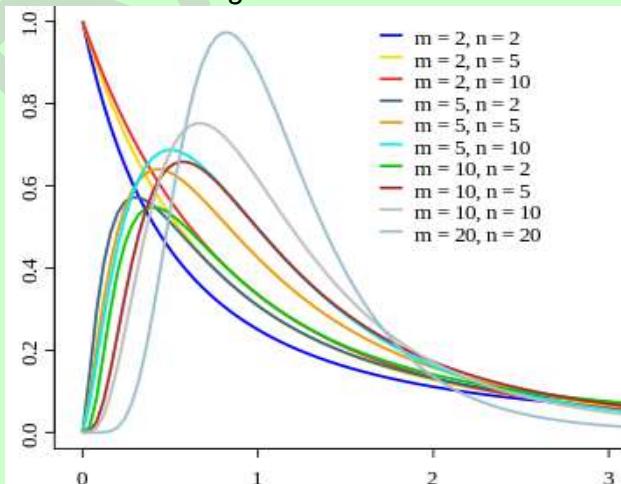
**F(x):** Fisher's F distribution with the degrees of freedom in **I** and **J**.

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

The graph presents the PDFs plotted for different degrees of freedom **m** and **n** corresponding to *i* and *j*.

Read here for more information:

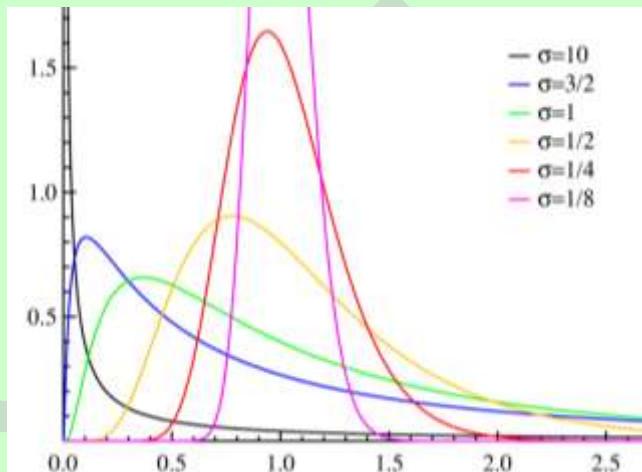
<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3665.htm>



**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).

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

**LGNRM<sub>A</sub>:** returns  $F_{Ln}(x) = \Phi\left(\frac{\ln(x)-\mu}{\sigma}\right)$  with  $\Phi(z)$  denoting the *standardized normal CDF* as presented on p. 227.



Read here for more information:

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

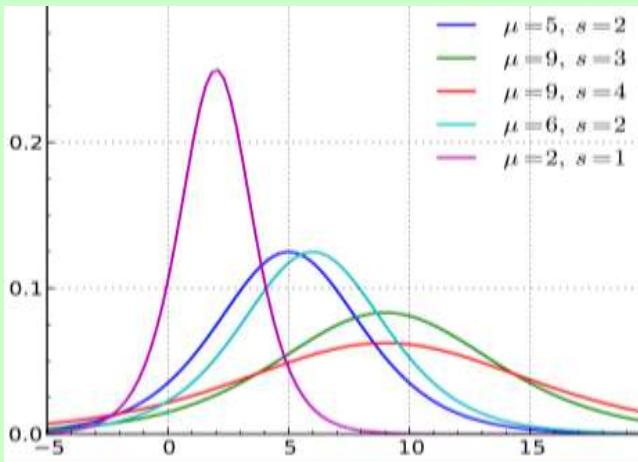
**Logis:** Logistic distribution with an arbitrary *mean*  $\mu$  given in **I** and a *scale parameter*  $s$  in **J**.

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

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

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

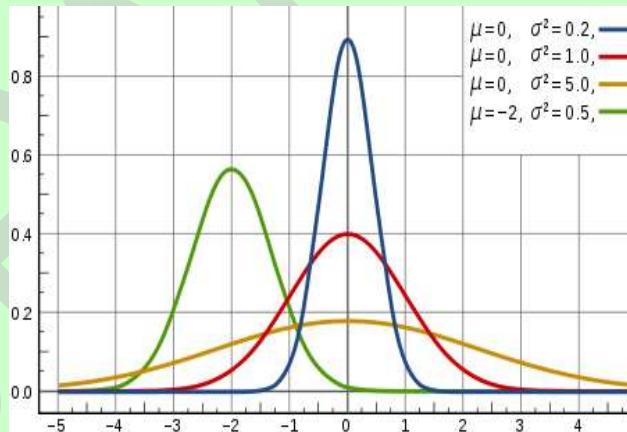
$$\text{LOGIS}^{-1} \text{ returns } F_{Lg}^{-1}(p) = \mu + s \ln\left(\frac{p}{1-p}\right).$$



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  $\sigma=1$ ) represents the *standardized normal 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

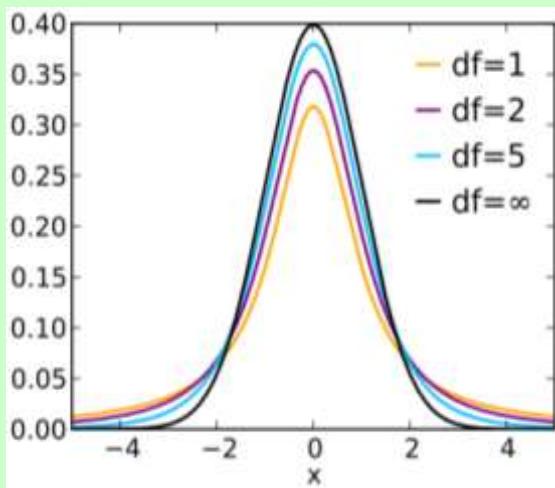
NORML<sub>A</sub> returns  $F_N(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$  with  $\Phi(z)$  denoting the *standardized normal CDF* (cf. the *error function* on p. 254).

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 diagram shows its *PDFs* plotted for different *degrees of freedom*. For  $df \rightarrow \infty$ , the shoulders of  $t(x)$  shrink and it approaches the *PDF* of the *standardized normal distribution* (compare the red curve at NORML on p. 227).



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.

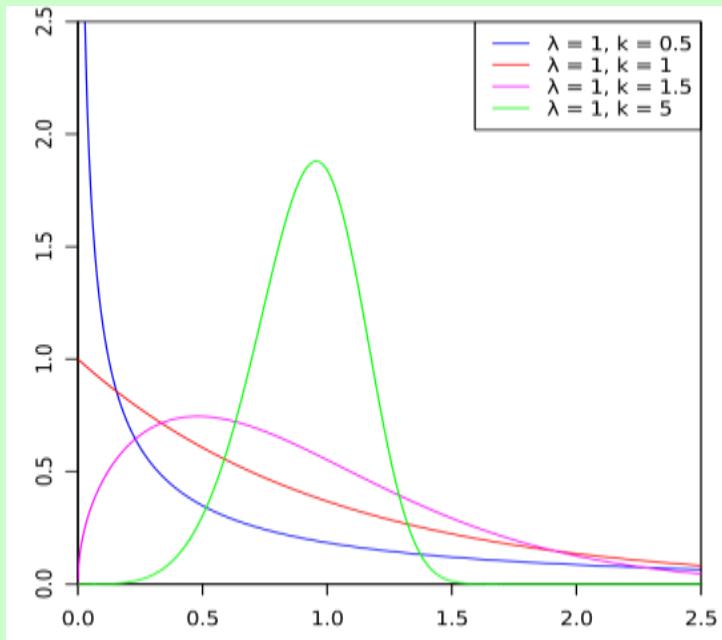
WEIBL<sub>A</sub> returns  $F_W(t) = 1 - e^{-(t/T)^b}$

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

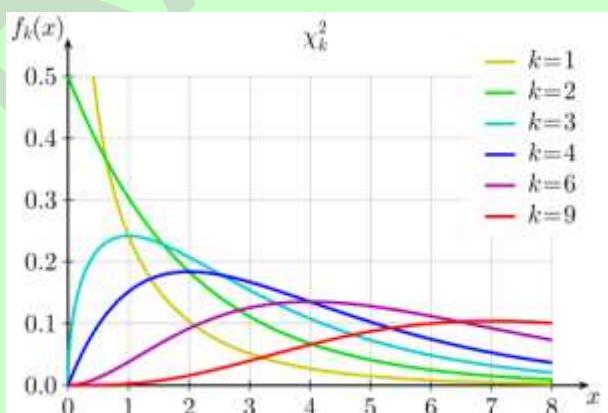
Read here for more information:

<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).



$\chi^2(x)$ : 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 graph 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 Curve Fitting

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

- For samples drawn out of a *normally distributed* (additive) process, the expected value is the *arithmetic mean* (or *average*) of the sample values and its uncertainty is given by its *standard error* (see  $\bar{x}$  and  $s_m$ ).
- For samples drawn out of a *log-normally distributed* (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.

Generally, the statistical model shall be chosen that matches observations best – within their statistical errors.<sup>100</sup> Be assured not everything is *normal (Gaussian)* in real world.<sup>101</sup> Process characteristics can be detected (and should be checked well in advance of calculating e.g. means) using suitable tests – turn to applicable statistical reference literature.

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<sup>100</sup> In real-life cases, dramatic deviations from the model distribution are frequently found – then you cannot expect the calculated consequences matching reality any better.

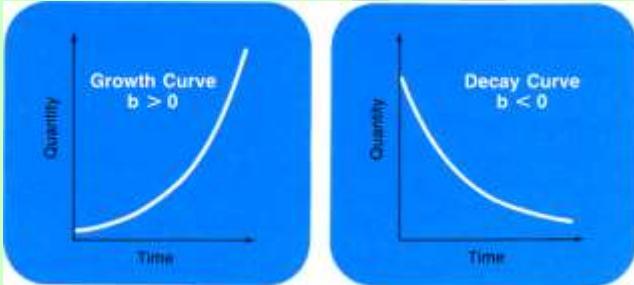
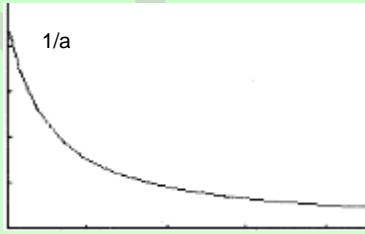
As mentioned in the main text, we recommend you look deeply into statistics textbooks to ensure you fully understand what you do with the functions provided in your *WP 43S*. The real world shows lots of sad examples where people full of good will caused large damages by applying tools they did not know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

<sup>101</sup> Since the *PDF* of a *normal* (a.k.a. *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.

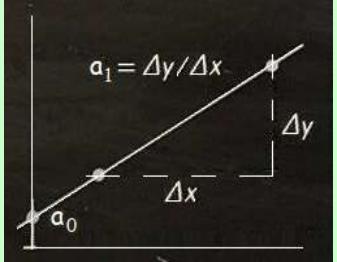
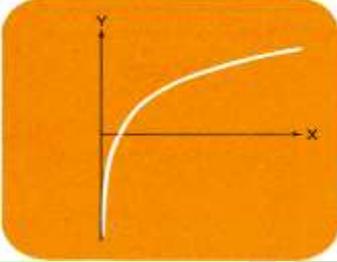
The following functions as named in the left column (sorted alphabetically) are all found in STAT:

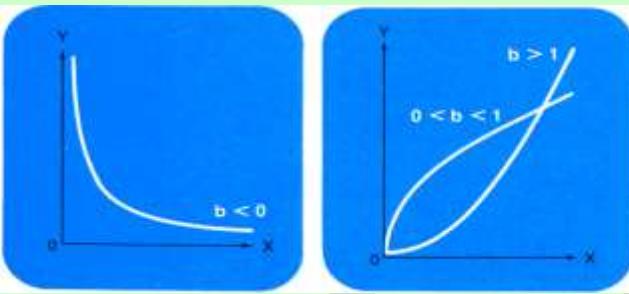
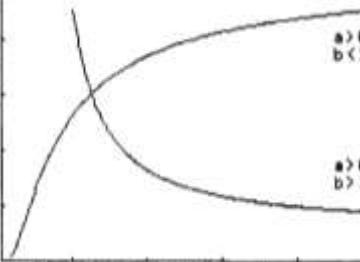
Name	Remarks (see pp. 12ff for general information)
CauchF	Selects a <i>Cauchy</i> (a.k.a. <i>Lorentz</i> , <i>Breit-Wigner</i> ) peak fit model $R(x) = \frac{1}{[a_0(x + a_1)^2 + a_2]}$ for least squares regression. <sup>102</sup> See p. 224 for shapes of such peaks.
CORR (r)	For any set of data points $(x_i, y_i)$ , the <i>coefficient of correlation</i> is $r = \frac{s_{xy}}{s_x s_y}$ . See $s_{XY}$ and $s$ below. For an arbitrary fit model $R(x)$ , $r^2 = 1 - \frac{\sum [R(x_i) - y_i]^2}{\sum (\bar{y} - y_i)^2}$ is its <i>coefficient of determination</i> indicating the fraction of the variation of the dependent data $y$ determined by the variation of the independent data $x$ . For $r^2 = 1$ , $y$ is fully determined by $x$ ; for $r^2 = 0$ , $y$ is completely independent of $x$ ; and e.g. $r^2 = 0.85$ means 85% of the variation of $y$ is due to $x$ . Note BESTF picks the fit model showing the maximum $r^2$ out of the models allowed. A two-parameter regression (like the majority of the fit models provided on your WP 43S) is said being (statistically) <i>significant</i> at a 99% <i>confidence level</i> if $\sqrt{\frac{r^2}{1 - r^2}(n - 2)} > t_{n-2}^{-1}(0.99)$ with the right side being the inverse of the <i>t distribution</i> for the <i>degrees of freedom</i> $n - 2$ (see p. 228).

<sup>102</sup> Note that *least squares regression* is best for data point errors in vertical direction  $y$  being significantly greater than the errors in horizontal direction  $x$ . See pp. 232ff for the formulas and more about the fit models provided.

Name	Remarks (see pp. 12ff for general information)
COV, $s_{XY}$	<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>and the <i>sample covariance</i> is</p> $s_{xy} = \frac{1}{n(n-1)} \left( n \sum x_i y_i - \sum x_i \sum y_i \right).$
ExpF	<p>Selects the exponential curve fit model <math>R(x) = a_0 e^{a_1 x}</math> for least squares regression.<sup>102</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 example).<sup>103</sup></p> 
GaussF	<p>Selects a <i>Gauss peak</i> fit model <math>R(x) = a_0 e^{\frac{(x-a_1)^2}{a_2}}</math> for least squares regression.<sup>102</sup> See p. 227 for the shapes of such peaks.</p>
HypF	 <p>Selects the hyperbolic fit model <math>R(x) = 1/(a_0 + a_1 x)</math> for least squares regression.<sup>102</sup></p>

<sup>103</sup> Color plots on this and the next page are taken from the *HP-27 manual*; therein,  $a$  equals  $a_0$  and  $b$  equals  $a_1$ , on your *WP 43S*.

Name	Remarks (see pp. 12ff for general information)
LinF	 <p>Selects the linear fit model <math>R(x) = a_0 + a_1 x</math> for least squares regression.<sup>102</sup> Generally, this will be a good choice if the measured data follow a straight line, raising or falling (but compare ORTHOF).</p>
LogF	 <p>Selects the logarithmic curve fit model <math>R(x) = a_0 + a_1 \ln(x)</math> for least squares regression.<sup>102</sup> Generally, this will be a good choice if the measured data follow a curve looking like drawn at left.</p>
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> at a 99% <i>confidence level</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> (cf. p. 228).</p>
OrthoF	<p>Selects the linear fit model <math>R(x) = a_0 + a_1 x</math> like LINF but assuming data point errors in <math>x</math> are equal to those in <math>y</math> (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. 236ff for more and the OM for application examples.</p>
ParabF	<p>Selects a parabolic fit model <math>R(x) = a_0 + a_1 x + a_2 x^2</math> for least squares regression.<sup>102</sup></p>

Name	Remarks (see pp. 12ff for general information)
PowerF	Selects the power curve fit model $R(x) = a_0 x^{a_1}$ for least squares regression. <sup>102</sup> Generally, this will be a good choice if measured data follow the shape of one of the curves pictured here (look for Tower of Pisa in the OM). <sup>103</sup> 
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>102</sup></p>
$s$ , $s_m$	The <i>sample standard deviation (SD)</i> is the positive square root of the <i>sample variance</i>
	$s_x^2 = \frac{1}{n(n-1)} \left[ n \sum x_i^2 - \left( \sum x_i \right)^2 \right] = \frac{1}{n-1} \left( \sum x_i^2 - n \bar{x}^2 \right)$ <p>And the <i>standard error</i> (i.e. the <i>SD</i> of the <i>mean <math>\bar{x}</math></i>) is <math>s_m = s / \sqrt{n}</math></p>
$s_w$ , $s_{mw}$	The <i>sample SD</i> for <u>weighted</u> data (where the weight $y_i$ of each data point $x_i$ was entered via <b><math>\Sigma+</math></b> ) is
	$s_w = \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i (\sum y_i - 1)}}$

Name	Remarks (see pp. 12ff for general information)
	And the corresponding <i>standard error</i> (the <i>SD</i> of the <i>mean</i> $\bar{x}_w$ ) is $s_{mw} = \frac{1}{\sum y_i} \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i - 1}}$
$s_{XY}$	See COV above.
$\bar{x}$	The <i>arithmetic mean</i> is calculated as $\bar{x} = \frac{1}{n} \sum x_i$
$\bar{x}_G$	The <i>geometric mean</i> is calculated as $\bar{x}_G = \sqrt[n]{\prod x_i} = e^{[\frac{1}{n} \sum \ln(x_i)]}$
$\bar{x}_H$	The <i>harmonic mean</i> is calculated as $\bar{x}_H = n / \sum \frac{1}{x_i}$
$\bar{x}_{RMS}$	The <i>quadratic mean</i> is calculated as $\bar{x}_{RMS} = \sqrt{\frac{1}{n} \sum x_i^2}$
$\bar{x}_w$	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 $\bar{x}_w = \sum x_i y_i / \sum y_i$
$\varepsilon$	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.

Name	Remarks (see pp. 12ff for general information)
$\varepsilon_m$	The scattering factor $\varepsilon_m$ of the geometric mean (compare $s_m$ ) is $\varepsilon_m = \varepsilon^{1/\sqrt{n}}$
$\varepsilon_p$	The scattering factor $\varepsilon_p$ for a population of <i>log-normally distributed</i> data is calculated via: $\ln(\varepsilon_p) = \sqrt{\frac{n-1}{n}} \ln(\varepsilon)$ Compare $\sigma$ .
$\sigma$	The SD of a population of <i>normally distributed</i> data is calculated via $\sigma = \sqrt{\frac{n-1}{n}} s$
$\sigma_w$	The SD of the population for <u>weighted</u> data (where the weight $y_i$ of each data point $x_i$ was entered via $(\Sigma+)$ ) is $\sigma_w = \sqrt{\frac{\sum y_i (x_i - \bar{x}_w)^2}{\sum y_i}}$

## 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 the parameters of a fit curve thereafter:

1. It accumulates the 22 sums listed on pp. 86ff and increments the number of data points  $n$ . Some of these 22 sums may turn non-numeric for negative entries – just do not care.
2. The subsequent evaluation will depend on the fit model you select (cf. pp. 232ff):
  - 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

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

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

The so-called *standard error of estimate*, which may be helpful for testing the slope and forecasts (see pp. 97ff in the *HP-21S OM*), is computed using

$$s_{y|x} = \sqrt{\frac{n-1}{n-2} (s_y^2 - a_1^2 s_x^2)}$$

- 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. 237 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. 237 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. 237 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

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

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

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

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:

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

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

- 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).

The output of L.R. is formatted like this, allowing for up to 12 significant digits displayed for each model parameter:

Linear	$a_1 = -312.345\ 678\ 901$
$y = a_0 + a_1 x$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Exponential	$a_1 = -12.345\ 678\ 901$
$y = a_0 e^{(a_1 x)}$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Power	$a_1 = -12.345\ 678\ 901$
$y = a_0 x^{a_1}$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Logarithmic	$a_1 = -12.345\ 678\ 901$
$y = a_0 + a_1 \ln(x)$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Hyperbolic	$a_1 = -12.345\ 678\ 901$
$y = (a_0 + a_1 x)^{-1}$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$

Root	$a_1 = -12.345\ 678\ 901$
$y = a_0 a_1^{(1/x)}$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Parabolic	$a_2 = -2.345\ 678\ 901\ 2$
$y =$	$a_1 = -12.345\ 678\ 901$
$a_0 + a_1 x + a_2 x^2$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Gauss peak	$a_2 = -2.345\ 678\ 901\ 2$
$\ln(y) =$	$a_1 = -12.345\ 678\ 901$
$a_0 + (x - a_1)^2 / a_2$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Cauchy peak	$a_2 = -2.345\ 678\ 901\ 2$
$1/y =$	$a_1 = -12.345\ 678\ 901$
$a_0 (a_1 + x)^2 + a_2$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$
Orthogonal	$a_1 = -312.345\ 678\ 901$
$y = a_0 + a_1 x$	$a_0 = -1.234\ 567\ 8 \times 10^{-3}$

## Error Propagation in Calculations

Experimental data are always attended with errors (cf. footnote 44), 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 is

$$\Delta R = f(x_1 \pm \Delta x_1, \dots, x_n \pm \Delta x_n) - f(x_1, \dots, x_n)$$

$$= \pm \sqrt{\left(\frac{df}{dx_1}\right)^2 \Delta x_1^2 + \cdots + \left(\frac{df}{dx_n}\right)^2 \Delta x_n^2}$$

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

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

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

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

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

---


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

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

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

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  $R = f(x_1, x_2, \dots, x_n)$ .
3. Let it compute  $R_1 = f(x_1 + \Delta x_1, x_2, \dots, x_n)$  and  $\Delta R_1 = R_1 - R$ .

- Let it compute  $R_2 = f(x_1, x_2 + \Delta x_2, \dots, x_n)$  and  $\Delta R_2 = R_2 - R$ .
- Repeat the last step for each remaining parameter.

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

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

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 1-dimensional problems of the kind

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

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

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

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

$$f_1 \approx f_0 + \left(\frac{df}{dt}\right)_0 \Delta t \text{ and } \left(\frac{df}{dt}\right)_1 \approx \left(\frac{df}{dt}\right)_0 + a\Delta t ,$$

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

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

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

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

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

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

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

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

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

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. 245, we will get the following new set:

$$\frac{df}{dt_{1/2}} \approx \frac{df}{dt_0} + \left[ a - b \left(\frac{df}{dt}\right)_0^2 \right] \frac{\Delta t}{2}$$

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

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

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

$$\begin{aligned} \left(\frac{df}{dt}\right)_{1/2} &\approx \left(\frac{df}{dt}\right)_0 + \left[a - b \left(\frac{df}{dt}\right)_0^2\right] \frac{\Delta t}{2} \\ f_1 &\approx f_0 + \left(\frac{df}{dt}\right)_{1/2} \quad \text{and} \quad \left(\frac{df}{dt}\right)_{3/2} \approx \left(\frac{df}{dt}\right)_{1/2} + \left[a - b \left(\frac{df}{dt}\right)_{1/2}^2\right] \Delta t \\ f_2 &\approx f_1 + \left(\frac{df}{dt}\right)_{3/2} \Delta t, \quad \text{etc.} \end{aligned}$$

This half-step method as explained above can be applied easily to all ordinary differential equations of 2<sup>nd</sup> order which can be written like

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

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

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

For solving a 2-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  $y$ :

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

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

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

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

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

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

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

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

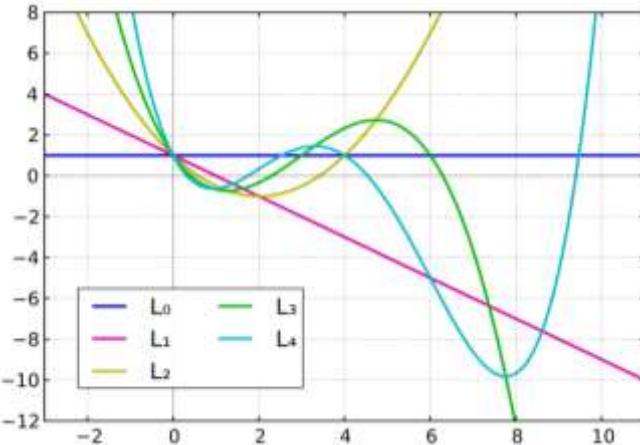
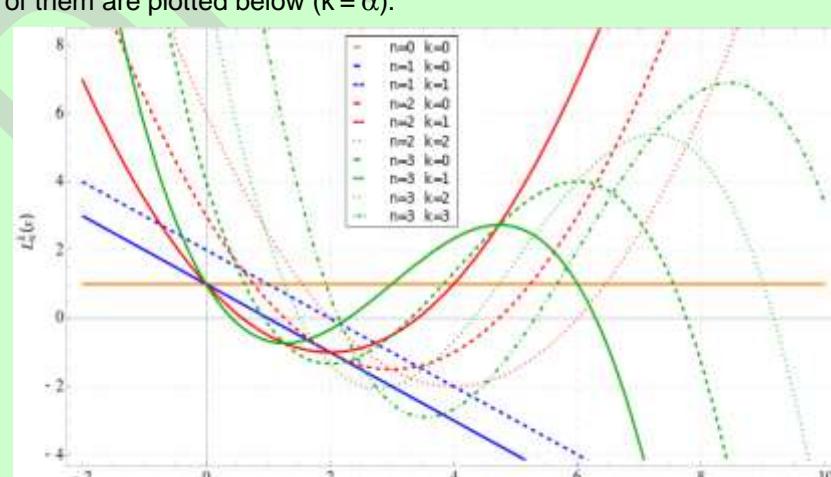
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## Orthogonal Polynomials

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

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

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

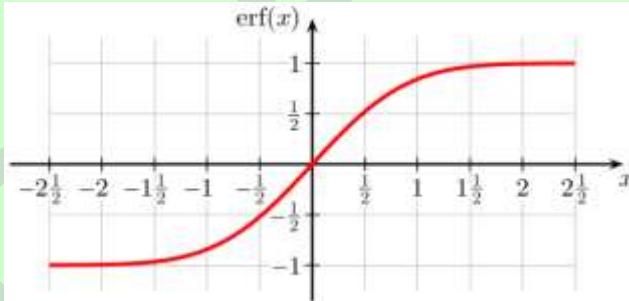
Name	Remarks (see pp. 12ff for general information)
$L_m$	<p><b>Laguerre polynomials</b> (compare <math>L_{n\alpha}</math> below):</p> $L_n(x) = \frac{e^x}{n!} \cdot \frac{d^n}{dx^n} (x^n e^{-x}) = L_n^{(0)}(x)$ with $n$ in $\mathbb{Y}$ , solving the differential equation $x \cdot f''(x) + (1-x) \cdot f'(x) + n \cdot f(x) = 0$ . <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 <math>\mathbb{Y}</math>, 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> $T_n(x) = \begin{cases} \cos(n \arccos(x)) & \text{for } -1 \leq x \leq 1 \\ \cosh(n \operatorname{arcosh}(x)) & \text{for } x > 1 \\ (-1)^n \cosh(n \operatorname{arcosh}(-x)) & \text{for } x < -1 \end{cases} \quad \text{with } n \text{ in } \mathbb{Y}, \text{ solving}$ <p>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)
$U_n$	<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>

## Even More Mathematical Functions

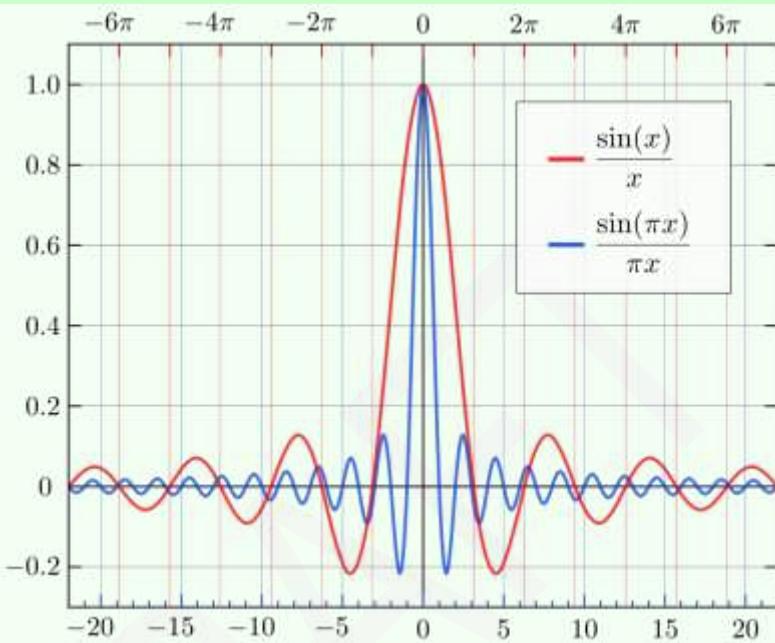
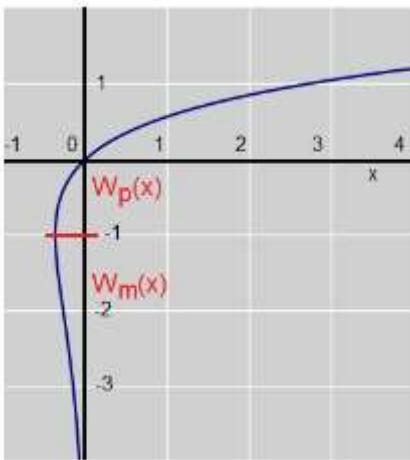
All the following functions are found in X.FN. Some of them are for pure mathematics only but were useful at some stages of the WP 34S or WP 43S projects, so we made them accessible for the public.

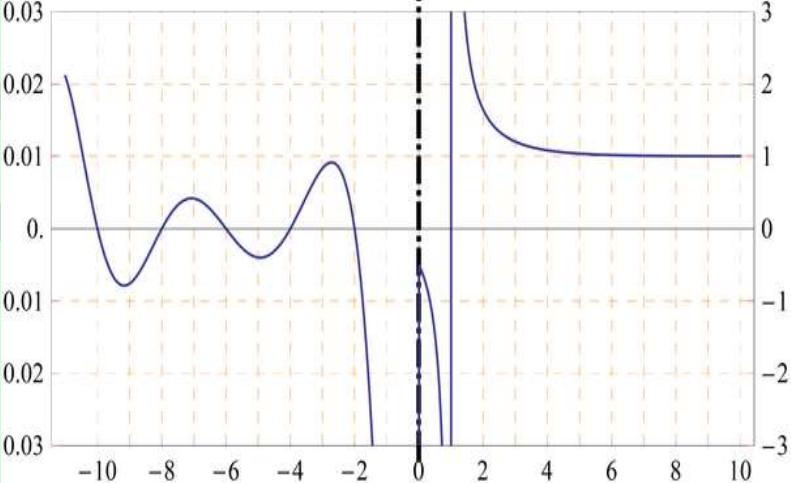
Name	Remarks (see pp. 12ff for general information)
AGM	Returns the <i>arithmetic-geometric mean</i> . Find more about it here: <a href="http://mathworld.wolfram.com/Arithmetic-GeometricMean.html">http://mathworld.wolfram.com/Arithmetic-GeometricMean.html</a> .
erf	<p>Returns the <i>error function</i> <math>\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt</math>.</p> <p>Note that</p>  <p><math>\text{erf}\left(\frac{x}{\sqrt{2}}\right) = 2 \Phi(x) - 1</math> with <math>\Phi(x)</math> representing the <i>standardized normal CDF</i> as described on p. 227.</p> <p>Beyond statistics, the <i>error function</i> may be helpful in heat conduction and diffusion problems, for instance.</p>
erfc	This command returns the <i>complementary error function</i> $\text{erfc}(x) = 1 - \text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-t^2} dt$ . This function is related to the <i>error probability</i> of the <i>standardized normal distribution</i> .

Name	Remarks (see pp. 12ff for general information)
$g_d$ , $g_d^{-1}$	<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</i> of this function is <math>g_d^{-1}(x) = \int_0^x \frac{d\xi}{\cos(\xi)}</math>.</p> <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>\beta_x(x, y, z) / B(y, z)</math></p> <p>with <math>\beta_x(x, y, z) = \int_0^x \tau^{y-1} (1-\tau)^{z-1} d\tau</math> being the <i>incomplete Beta function</i> and <math>B(y, z)</math> being <i>Euler's Beta function</i> (see p. 85 and <a href="https://en.wikipedia.org/wiki/Beta_function">https://en.wikipedia.org/wiki/Beta_function</a>).</p>
$I\Gamma_p$	<p>Returns the <i>regularized Gamma function</i> <math>P(x, y) = \frac{\gamma(x, y)}{\Gamma(x)}</math></p> <p>See <math>\gamma_{XY}</math> below for <math>\gamma(x, y)</math> and p. 85 for <math>\Gamma(x)</math>.</p>
$I\Gamma_q$	<p>Returns the <i>regularized Gamma function</i> <math>Q(x, y) = \frac{\Gamma_u(x, y)}{\Gamma(x)}</math></p> <p>See <math>\Gamma_{XY}</math> below for <math>\Gamma_u(x, y)</math> and p. 85 for <math>\Gamma(x)</math>.</p>

See here for more:  
[https://en.wikipedia.org/wikiln  
complete\\_gamma\\_function](https://en.wikipedia.org/wikiln_complete_gamma_function)

Name	Remarks (see pp. 12ff for general information)
$J_y(x)$	<p>Generally, the <i>Bessel functions</i> solve the differential equation</p> $x^2 f''(x) + x f'(x) + (x^2 - \nu^2) f(x) = 0 \quad \text{with } \nu \in \mathbb{C}.$ <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)
sinc, sinc $\pi$	 <p>The graph shows two functions: <math>\frac{\sin(x)}{x}</math> (red line) and <math>\frac{\sin(\pi x)}{\pi x}</math> (blue line). The x-axis is labeled with values <math>-6\pi, -4\pi, -2\pi, 0, 2\pi, 4\pi, 6\pi</math>. The y-axis ranges from -0.2 to 1.0. The red curve has a sharp vertical asymptote at <math>x=0</math> and oscillates around the x-axis. The blue curve has a smooth peak at <math>x=0</math> reaching a value of 1.0 and also oscillates around the x-axis.</p>
$W_p$ , $W_m$	<p>Return Lambert's <math>W</math> 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>(x, y) = (-1/e, -1)</math>. The graph 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>  <p>The graph shows the real branches of the Lambert W function. The x-axis ranges from -1 to 4, and the y-axis ranges from -3 to 1. A vertical black line at <math>x = -1/e \approx -0.368</math> separates the two branches. The upper branch, labeled <math>W_p(x)</math>, starts at approximately <math>(-0.368, -1)</math> and increases monotonically towards positive infinity as <math>x</math> increases. The lower branch, labeled <math>W_m(x)</math>, starts at approximately <math>(-0.368, -1)</math> and decreases monotonically towards negative infinity as <math>x</math> increases.</p>

Name	Remarks (see pp. 12ff for general information)
$\gamma_{xy}$	Returns the <i>lower incomplete Gamma function</i> $\gamma(x, y) = \int_0^y t^{x-1} e^{-t} dt$ . Required for $I\Gamma_p$ above.
$\Gamma_{xy}$	Returns the <i>upper incomplete Gamma function</i> $\Gamma_u(x, y) = \int_y^\infty t^{x-1} e^{-t} dt$ . Required for $I\Gamma_q$ above.
$\zeta(x)$	Returns <i>Riemann's Zeta</i> for <i>real</i> arguments, with $\zeta(x) = \sum_{n=1}^{\infty} \frac{1}{n^x}$ for $x > 1$ , and its analytical continuation for $x < 1$ : $\zeta(x) = 2^x \pi^{x-1} \sin\left(\frac{\pi}{2}x\right) \cdot \Gamma(1-x) \cdot \zeta(1-x).$ Note the different vertical scales for negative and positive $x$ in the plot below. And $\sqrt{6 \zeta(2)} = \pi$ .  <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 provided 1976/77 already on the *Commodore M55* pocket calculator (featuring 55 keys).

Beyond what is printed in this appendix, you will also find lots of information about the special functions implemented in your *WP 43S* in the internet. Generally, *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. 221ff) is a competent source. And *Mathworld* (quoted on pp. 254ff) or *WolframAlpha* 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-yyyy-mm-dd.exe
2. Click **Next**
3. Enter the installation folder **C:\msys64** 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). Alternatively, you can enter **make rebuild** and skip step 15.
15. **make** to build the *WP 43S* simulator.
16. **./wp43s.exe** 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:\msys64\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 the *name* of each and every *item* provided, be it a command, constant (# ...), menu or submenu (M unless trailed by a colon), predefined label (L) or register/variable (V), reserved character (c), or system flag (S). The *names* of *items* are sorted here as they are in your WP 43S:

$^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$	16	arctan	19	BITS	22	CLPALL	25
$^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$	16	artanh	19	$\text{B}_n$	22	CLR (M)	25
$10^x$	16	ASIN	19	$\text{B}_n^*$	22	CLREGS	25
1COMPL	16	ASLIFT (S)	106	BS?	22	CLSTK	25
$1/x$	17	ASR	19	$\text{Btu} \rightarrow \text{J}$	22	CLX	26
2COMPL	17	ASSIGN	19	C (V)	99	CLΣ	26
$2^x$	17	ATAN	20	cal $\rightarrow$ J	23	CNST	26
$3\sqrt{x}$	17	atm $\rightarrow$ Pa	21	CARRY (S)	105	COMB	26
A (V)	99	AUTOFF (S)	106	CASE	23	CONJ	26
ABS	17	AUTXEQ (S)	106	CATALOG	23	CONST (M)	26
$\text{ac}_{\text{us}} \rightarrow \text{m}^2$	17	au $\rightarrow$ m	21	Cauch $^{-1}$	24	CONVG	26
$\text{ac} \rightarrow \text{m}^2$	17	A:	20	Cauch $_{\Delta}$	24	CORR	27
ACC (V)	99	B (V)	99	Cauch $_{\Delta}$	24	cos	27
ACOS	17	BACK	20	Cauch:	24	cosh	27
ADM (V)	99	bar $\rightarrow$ Pa	20	CauchF	24	COV	27
ADV	17	BATT?	20	Cauch $_p$	24	CPX (M)	27
AGM	17	bbl $\rightarrow$ m $^3$	20	CB	24	CPXj (S)	104
AGRAPH	17	BC?	20	CEIL	24	CPXRES (S)	104
ALL	18	BEEP	21	CF	24	CPXS (M)	27
ALLENG (S)	106	BeginP	21	CHARS (M)	24	CPX?	27
ALPHA (S)	105	BestF	22	CLALL	24	CROSS	28
ALP.IN (S)	107	BestF?	22	CLCVAR	25	ct $\rightarrow$ kg	28
AND	18	Binom $_{\Delta}$	22	CLFALL	25	cwt $\rightarrow$ kg	28
ANGLES (M)	18	Binom $^{-1}$	22	CLK (M)	25	CX $\rightarrow$ RE	28
arccos	18	Binom $_{\Delta}$	22	CLLCD	25	D (V)	99
arcosh	19	Binom:	22	CLMENU	25	DATE	28
arcsin	19	Binom $_p$	22	CLP	25	DATES (M)	28

DATE→	28	EIGVAL	32	FF	35	GCD	37
DAY	29	EIGVEC	32	FIB	35	$g_d$	37
DBLR	29	END	32	FILL	35	$g_d^{-1}$	37
DBLx	29	ENDP	32	FIN (M)	35	Geom <sub>p</sub>	38
DBL/	29	ENG	32	FIX	35	Geom <sub>△</sub>	38
dB→fr	29	ENORM	32	FLAGS (M)	35	Geom <sub>△</sub>	38
dB→pr	29	ENTER†	33	FLASH (M)	35	Geom <sup>-1</sup>	38
DEC	29	ENTRY?	33	FLASH?	35	Geom:	38
DECIM. (S)	106	EQN (M)	33	FLOOR	35	$gl_{us} \rightarrow m^3$	38
DECOMP	29	EQ.DEL	33	fm.→m	35	$gl_{uk} \rightarrow m^3$	38
DEG	29	EQ.EDI	33	FP	36	GRAD	38
DEG→	29	EQ.NEW	33	$F_p(x)$	36	GRAD→	38
DELITM	29	erf	33	FP?	36	GRAMOD (V)	100
DENANY (S)	104	erfc	33	fr→dB	36	GROW (S)	106
DENFIX (S)	105	ERR	33	FRACT (S)	104	GTO	38
DENMAX	30	EVEN?	33	FS?	36	GTO.	39
DENMAX (V)	99	e <sup>x</sup>	33	FS?C	36	$ha \rightarrow m^2$	39
DET	30	EXITALL	33	FS?F	36	$H_n$	39
DIGITS (M)	30	EXP (M)	34	FS?S	36	$H_{nP}$	39
DISP (M)	30	ExpF	34	ft.→m	36	$hp_E \rightarrow W$	39
DMY (S)	104	Expon	34	ft <sub>us</sub> →m	36	$hp_M \rightarrow W$	39
DOT	30	Expon <sub>e</sub>	34	FV (V)	100	$hp_{uk} \rightarrow W$	39
DROP	30	Expon <sub>p</sub>	34	fz <sub>uk</sub> →m <sup>3</sup>	36	Hyper <sub>p</sub>	39
DROPy	30	Expon <sup>-1</sup>	34	fz <sub>us</sub> →m <sup>3</sup>	36	Hyper <sub>△</sub>	39
DSE	30	Expon:	34	$F_\Delta(x)$	36	Hyper <sub>△</sub>	39
DSL	31	EXPT	34	$F_\Delta(x)$	36	Hyper <sup>-1</sup>	39
DSTACK	31	e <sup>x-1</sup>	34	F <sup>-1</sup> (p)	36	Hyper:	40
DSZ	31	E:	34	F:	36	HypF	40
D.MS	31	FB	34	f' (M)	36	I (V)	100
D.MS→	31	FBR	34	f'(x)	37	IDIV	40
D.MS→D	31	FC?	34	f'' (M)	36	IDIVR	40
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D→J	32	FC?S	35	GAP	37	Im	40
D→R	32	FCNS (M)	35	GaussF	37	INC	40

INDEX	40	kg $\rightarrow$ ct	44	LOADR	47	Mat_B (V)	101
INFO (M)	40	kg $\rightarrow$ cwt	44	LOADSS	47	Mat_X	50
INPUT	41	kg $\rightarrow$ lb.	44	LOADV	48	Mat_X (V)	101
INT?	41	kg $\rightarrow$ oz	44	LOAD $\Sigma$	48	max	50
INTING (S)	107	kg $\rightarrow$ scw	44	LocR	48	MDY (S)	104
INTS (M)	41	kg $\rightarrow$ sto	44	LocR?	48	MEM?	50
INVRT	41	kg $\rightarrow$ s.t	44	LOG <sub>10</sub>	48	MENU	50
in. $\rightarrow$ m	41	kg $\rightarrow$ ton	44	LOG <sub>2</sub>	48	MENUS (M)	50
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ISM (V)	100	LASTx	45	Logis <sub><math>\Delta</math></sub>	48	mmH $\rightarrow$ Pa	51
ISZ	42	lb. $\rightarrow$ kg	45	Logis <sup>-1</sup>	48	MOD	51
I <sub>xyz</sub>	42	lbf $\rightarrow$ N	45	Logis:	48	MODE (M)	51
I $\Gamma_p$	42	lbft $\rightarrow$ Nm	45	LOG <sub>xy</sub>	48	MONTH	51
I $\Gamma_q$	42	LBL	45	LOOP (M)	48	MSG	51
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I-	42	LCM	45	ly $\rightarrow$ m	49	MUL $\pi$	51
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i%/ $a$ (V)	100	LEAP?	46	L.R.	49	MVAR	51
J (V)	100	LgNrm <sub>p</sub>	46	m <sup>2</sup> $\rightarrow$ ac	49	MyMenu	51
J <sub>y</sub> (x)	43	LgNrm <sub><math>\Delta</math></sub>	46	m <sup>2</sup> $\rightarrow$ ac <sub>us</sub>	49	My $\alpha$ (M)	51
J+	42	LgNrm <sub><math>\Delta</math></sub>	46	m <sup>2</sup> $\rightarrow$ ha	49	M.DELR	52
J-	42	LgNrm <sup>-1</sup>	46	m <sup>3</sup> $\rightarrow$ bbl	49	M.DIM	52
J/G	42	LgNrm:	46	m <sup>3</sup> $\rightarrow$ fz <sub>UK</sub>	49	M.DIM?	52
J/G?	42	LinF	46	m <sup>3</sup> $\rightarrow$ fz <sub>US</sub>	49	M.DY	52
J $\rightarrow$ Btu	43	LJ	46	m <sup>3</sup> $\rightarrow$ gl <sub>UK</sub>	49	M.EDI	52
J $\rightarrow$ cal	43	L <sub>m</sub>	46	m <sup>3</sup> $\rightarrow$ gl <sub>US</sub>	49	M.EDIN	52
J $\rightarrow$ D	43	L <sub><math>m\alpha</math></sub>	46	MANT	49	M.EDIT (M)	52
J $\rightarrow$ Wh	43	LN	46	MASKL	50	M.GET	52
K (V)	100	LN $\beta$	47	MASKR	50	M.GOTO	53
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KEYG	44	LN(1+x)	47	MATR?	50	M.INSR	53
KEYX	44	LOAD	47	MATX (M)	50	M.LU	53
KEY?	44	LOADP	47	Mat_A (V)	101	M.NEW	53

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M.RZR	53	NPER (V)	101	POLAR (S)	104	RCLS	61
M.SIMQ (M)	53	NUM.IN (S)	107	PopLR	58	RCL+	62
M.SQR?	54	nΣ	56	PowerF	58	RCL-	62
M.WRAP	54	N→lbf	56	PRCL	58	RCLx	62
m:	54	ODD?	56	PRIME?	59	RCL/	62
m→au	54	OFF	56	PRINT (M)	59	RCL↑	62
m→fm.	54	OR	56	PRINT (S)	105	RCL↓	62
m→ft <sub>US</sub>	54	OrthoF	56	PROB (M)	59	RDP	62
m→ft.	54	ORTHOG (M)	56	PROG (M)	59	Re	62
m→in.	54	OVERFL (S)	105	PROGS (M)	59	REAL?	62
m→ly	54	oz→kg	56	PROPFR (S)	104	REALDF (V)	102
m→mi.	54	ParabF	56	PRTACT (S)	107	REALS (M)	62
m→nmi.	54	PARTS (M)	56	pr→dB	59	RECV	62
m→pc	54	PAUSE	57	psi→Pa	59	REGS (V)	102
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Nm→lbf	55	PLOT	58	RANGE	60	ROUNDI	65
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SETDAT	69		STOCFG	73	TONE	76	Weibl:	79
SETEUR	69		STOEL	73	ton→kg	76	WHO?	79
SETIND	69		STOIJ	73	TOP?	76	Wh→J	79
SETJPN	69		STOP	73	tor→Pa	77	$W_m$	80
SETSIG	69		STOS	73	$t_p(x)$	77	$W_p$	80
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SETUK	69		STO-	74	TRANS	77	WSIZE?	80
SETUSA	69		STO×	74	TRI (M)	77	$W^{-1}$	80
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SHOW	70		STO↑	74	TVM (M)	77	$W \rightarrow hp_E$	80
SIGN	70		sto→kg	74	$t_{Δ}(x)$	77	$W \rightarrow hp_M$	80
SIGNMT	70		STO↓	74	$t_{Δ}(x)$	77	X (V)	102
SIM_EQ	70		STRING	(M) 74	$t^{-1}(p)$	77	$\hat{x}$	81
sin	70		STRI?	74	t:	77	$\bar{x}$	81
sinc	70		SUM	74	$t \gtrless$	77	$x^2$	81
sinh	71		$s_w$	74	ULP?	77	$x^3$	81

XEQ	81	Y.MD	84	$\Sigma \ln^2 x$	88	/	91
$\bar{x}_G$	81	$y \bar{z}$	84	$\Sigma \ln^2 y$	88	${}^{\wedge} \text{MOD}$	91
$\bar{x}_H$	81	Z (V)	102	$\Sigma \ln x$	88	$\rightarrow (c)$	91
xIN	81	$z \bar{z}$	84	$\Sigma \ln xy$	88	$\rightarrow \text{DATE}$	91
$x_{\max}$	81	$\alpha \text{CAP (S)}$	105	$\Sigma \ln y$	88	$\rightarrow \text{DEG}$	91
$x_{\min}$	81	$\alpha \text{INTL (M)}$	84	$\Sigma \ln y/x$	88	$\rightarrow \text{D.MS}$	91
XNOR	81	$\alpha \text{LENG?}$	84	$\Sigma_n$	88	$\rightarrow \text{GRAD}$	91
XOR	81	$\alpha \text{MATH (M)}$	85	$\sigma_w$	88	$\rightarrow \text{HR}$	92
xOUT	82	$\alpha \text{POS?}$	85	$\Sigma x$	88	$\rightarrow \text{H.MS}$	92
$\bar{x}_{\text{RMS}}$	82	$\alpha \text{RL}$	85	$\Sigma x^2$	88	$\rightarrow \text{INT}$	92
$\bar{x}_w$	82	$\alpha \text{RR}$	85	$\Sigma x^2 y$	88	$\rightarrow \text{MUL}\pi$	92
$\bar{\bar{y}}$	82	$\alpha \text{SL}$	85	$\Sigma x^2/y$	88	$\rightarrow \text{POL}$	92
$x!$	82	$\alpha \text{SR}$	85	$\Sigma x^3$	88	$\rightarrow \text{RAD}$	92
X.FN (M)	82	$\alpha \cdot (M)$	85	$\Sigma x^4$	88	$\rightarrow \text{REAL}$	93
x:	82	$\alpha . \text{FN (M)}$	85	$\Sigma x \ln y$	88	$\rightarrow \text{REC}$	93
$x \rightarrow \text{DATE}$	83	$A \dots \Omega (M)$	85	$\Sigma xy$	88	$\uparrow \text{Lim (V)}$	102
$x \rightarrow \alpha$	83	$\alpha \rightarrow x$	86	$\Sigma y$	89	$\downarrow \text{Lim (V)}$	102
$x \bar{z}$	83	$\beta(x,y)$	86	$\Sigma y^2$	89	$\bar{z}$	93
$x \bar{z} y$	83	$\Gamma_{xy}$	86	$\Sigma y \ln x$	89	$ M $	94
$x < ?$	83	$\gamma_{xy}$	86	$\Sigma +$	89	$ x $	94
$x \leq ?$	83	$\Gamma(x)$	86	$\Sigma -$	89	$  $	94
$x = ?$	83	$\delta x (L)$	86	$\chi^2_p(x)$	90	$\%$	94
$x \neq ?$	83	$\Delta \%$	86	$\chi^2_{\Delta}(x)$	90	$\% \text{MRR}$	94
$x \approx ?$	83	$\varepsilon$	86	$\chi^2_{\Delta}(x)$	90	$\% T$	95
$x \geq ?$	83	$\varepsilon_m$	87	$\chi^2:$	90	$\% \Sigma$	95
$x > ?$	83	$\varepsilon_p$	87	$(\chi^2)^{-1}$	90	$\% +MG$	95
$x = +0?$	83	$\zeta(x)$	87	$(-1)^x$	90	$\sqrt{x}$	95
$x = -0?$	83	$\pi$	87	$[M]^T$	90	$\int$	95
Y (V)	102	$\Pi_n$	87	$[M]^{-1}$	90	$\int f(M)$	96
$\hat{y}$	84	$\Sigma (M)$	87	$+$	90	$\int f dx (M)$	96
yd. $\rightarrow$ m	84	$\sigma$	87	$+/-$	90	$\not{=}$	96
YEAR	84	$\Sigma 1/x$	87	$\pm \infty?$	91	$\not{=} (M)$	96
year $\rightarrow$ s	84	$\Sigma 1/x^2$	87	$-$	91	$\blacksquare \text{ADV}$	96
YMD (S)	104	$\Sigma 1/y$	87	$\times$	91	$\blacksquare \text{CHAR}$	96
$y^x$	84	$\Sigma 1/y^2$	87	$\times \text{MOD}$	91	$\blacksquare \text{DLAY}$	96

LCD	96	# $F_\delta$	133	# $M_\odot$	135	# $\gamma_{EM}$	137
MODE	97	# $G$	133	# $N_A$	135	# $\gamma_p$	137
PROG	97	# $G_0$	133	# NaN	135	# $\Delta v_{Cs}$	137
r	97	# $G_c$	133	# $p_0$	135	# $\varepsilon_0$	137
REGS	97	# $g_e$	134	# $R$	135	# $\lambda_c$	138
STK	98	# $GM_\oplus$	134	# $r_e$	136	# $\lambda_{Cn}$	138
TAB	98	# $g_\oplus$	134	# $R_K$	136	# $\lambda_{Cp}$	138
USER	98	# $h$	134	# $R_{Moon}$	136	# $\mu_0$	138
WIDTH	98	# $\hbar$	134	# $R_\infty$	136	# $\mu_B$	138
$\Sigma$	98	# $k$	134	# $R_\odot$	136	# $\mu_e$	138
#	98	# $K_J$	134	# $R_\oplus$	136	# $\mu_e/\mu_B$	138
#	98	# $I_{PL}$	134	# Sa	136	# $\mu_n$	138
# a	132	# $m_e$	134	# Sb	136	# $\mu_p$	138
# $a_0$	132	# $M_{Moon}$	134	# $Se^2$	136	# $\mu_u$	138
# $a_{Moon}$	132	# $m_n$	134	# $Se'^2$	136	# $\mu_\mu$	138
# $a_\oplus$	133	# $m_n/m_p$	135	# $Sf^{-1}$	136	# $\sigma_B$	139
# c	133	# $m_p$	135	# $T_0$	136	# $\Phi$	139
# $c_1$	133	# $m_p/m_e$	135	# $T_p$	136	# $\Phi_0$	139
# $c_2$	133	# $m_{PL}$	135	# $t_{PL}$	137	# $\omega$	139
# e	133	# $m_u$	135	# $V_m$	137	# $-\infty$	139
# $e_E$	133	# $m_u c^2$	135	# $Z_0$	137	# $\infty$	139
# F	133	# $m_\mu$	135	# $\alpha$	137	# B	98
# $F_\alpha$	133	# $M_\oplus$	135	# $\gamma$	137	# DEC (V)	103

## **APPENDIX J: RELEASE NOTES**

	Date	Release notes
0	29.11.12	<b>Official project start with first publication of the 43S concept and a layout on one of the forums of the Museum of HP Calculators (<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> Though there are found far older traces of a '43S' denoting a 'Super HP-42S', though in various more or less fictional cases – pure vapourware™.
0.1	2.2.14 23.5.15	Manual setup based on the one of WP 34S. Passed to <i>Jake Schwartz</i> , <i>Eric Smith</i> , and <i>Richard Ottosen</i> for first information.
0.2	3.10.15	Update based on Jake's feedback and further thoughts, distributed to <i>Eric</i> , <i>Jake</i> , <i>Marcus</i> , and <i>Pauli</i> .
0.3	21.3.16	Split the manual in three; moved LBL onto the keyboard, renamed STOM to STOCFG, RCLM to RCLCFG, SERR to $s_m$ , and SERR <sub>w</sub> to $s_{mw}$ ; refined the <i>Key Response Table</i> . Passed to <i>Michael</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		<b>Changed keyboard layout.</b> Replaced the labels BST by <b>≡Δ</b> , SST by <b>≡V</b> , and UNDO by <b>↶</b> ; added some <i>alpha input mode</i> reminders on the keyboard. Added AGRAPH, CLLCD, EQ.xxx, <b>HYP</b> , J/G, M.GOTO, ORTHOF, PIXEL, POINT, TDISP, and <b>USER</b> . Moved the background considerations out of <i>ReM App. D</i> . Introduced <b>K</b> as <i>alpha register</i> for alphanumeric constants in programs. Removed <i>fraction data type</i> . Extended <i>items</i> from 6 to 7 characters to match HP-42S.

Date	Release notes
2.4.18	Specified <i>data types</i> more precisely in <i>ReM App. D</i> . Reduced the maximum number of <i>local registers</i> from 888 to 100. Deleted JG1582 and JG1752. Renamed two commands for TVM. Replaced the heading apostrophe for <i>menu names</i> . Put <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	<p>Changed keyboard layout: introduced <u>TRG</u> containing trigonometric functions, removed <u>HYP</u> into <u>EXP</u> and <math>\blacksquare\pi</math> to g-shifted <math>\blacksquare\theta</math>, 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.</p> <p>Corrected errors and inconsistencies. Added one more example. Moved the key response table into an appendix.</p>
7.5.18	
20.9.18	
0.9	<p>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 <u><math>\blacksquare\chi</math></u> to match <i>HP-42S</i>. Added a chapter about curve fitting. Modified functionalities of <u>ENTER</u>↑ and <math>\blacksquare\leftarrow</math>. Expanded <i>App. K</i>. Renamed DOUBLE to →DP. Added →SP and conversions of <i>quarts</i>. Rearranged <u>X.FN</u>. Replaced <u>USR</u> by <u>UM</u>. Changed keyboard moving <u>UM</u>, <u><math>\blacksquare X</math></u>, and <u>TRI</u>. Moved <math>\blacksquare</math> to <math>\blacksquare f</math> <u>R/S</u>. 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.</p>
3.1.19	
0.10	<p>Returned <i>angle data type</i> and <math>\alpha</math>SR. Added IDIVR and VANGLE. Refined FP, IP, IMPFRC, PROFRC, SDIGS?, →DP, →HR, →INT, →REAL, →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 <u><math>\alpha</math></u>. 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 <math>\pm\infty</math> and NaN. Modified RBR and the menu for STO and RCL. Removed <math>\blacksquare</math> from the keyboard. Renamed <math>X_u</math> to <math>X_e</math> for the distributions.</p>
3.3.19	

	Date	Release notes
0.11	8.5.19	Changed keyboard making <b>CC</b> primary and user mode shifted, removing $x^2$ , $x\bar{x}$ , and DSP, adding $ x $ , DROP, and SHOW, and moving some shifted labels. Modified <u>BITS</u> , CLREGS, CNST, CPX, DISP, EXP, INTS, MODE, PARTS, SHOW, STAT, $\underline{U}\rightarrow$ , $\alpha$ MATH, the division matrix, <i>data type</i> conversions, and the <i>Quick Reference Guide</i> . Added conversions of <i>barrels</i> , <i>carats</i> , and <i>fathoms</i> . Deleted DSP. – Separated predefined variables. Refined Sect. 6. Added $\bar{x}_H$ , $\bar{x}_{RMS}$ , nine statistical sums and five curve fit models. Split <u>STAT</u> in <u>STAT</u> and <u>SUMS</u> ; renamed RMDR to RMD, $L_n$ to $L_m$ , $L_{na}$ to $L_{ma}$ , $\Pi$ to $\Pi_n$ , $\Sigma$ to $\Sigma_n$ , and some constants to avoid search ambiguities. Refined App. J, Sect. 3 and 4, $\rightarrow$ INT, CLR, and the functions of $\Delta$ and $\nabla$ . Put <u>SUMS</u> instead of RMD on the keyboard, moved <u>ADV</u> , <u>BITS</u> , <u>CATALOG</u> , <u>EQN</u> , <u>FILL</u> , <u>INTS</u> , <u>MATX</u> , <u>MODE</u> , <u>PROB</u> , <u>RTN</u> , <u>SHOW</u> , <u>STAT</u> , and <u><math>\alpha</math>.FN</u> . Rearranged A... $\Omega$ and Sect. 2 of the OM.
0.12	16.10.19	Rearranged the appendices of the ReM 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 <i>short integer</i> input. Expanded App. D. Specified maximum size of <i>long integers</i> . 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>TRL</u> , and <u>X.FN</u> . Rearranged Section 1 of the OM. Added some internal <i>data types</i> to App. B; reduced the range of <i>long integer</i> results and DP real inputs to $10^{\pm 999}$ . Defined the domains of $e^{-1}$ , IDIVR, $LN(1+x)$ , MOD, and RMD according to the HP-42S; modified PLOT and $\Sigma+$ . Refined the <i>Addressing Tables</i> . Added a <i>data type</i> matrix for IDIVR. Refined the <i>Special Results</i> 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><math>\alpha</math>o</u> , <u>SHOW</u> , and <u>STATUS</u> . Refined the sorting order of <i>items</i> , ALL, CX $\rightarrow$ RE, MEM?, RE $\rightarrow$ CX, RBR, RM, SLVQ, and $\underline{U}\rightarrow$ . Started filling App. F and G. Refined App. 2. Added a <i>long integer</i> example, CPXR?, LZ?, $\Delta v_{Cs}$ , conversions of <i>hectares</i> , and a proposal for system status information.
0.14	7.3.20	Introduced <i>system flags</i> for status information. Split <u>I/O</u> . Added <u>CATALOG</u> / <u>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> , $\underline{U}\rightarrow$ and $\underline{\Delta}\rightarrow$ , moving <u>CPX</u> , <u>FILL</u> , <u>RBR</u> , <u>R<math>\uparrow</math></u> , <u>USER</u> , <u><math>\alpha</math>.FN</u> , <u><math>\alpha</math>INTL</u> , $\sqrt{x}$ , and $\bar{x}$ , displaying <u>PRINT</u> , <u>RMD</u> , <u>STATUS</u> , $x^2$ , and ' $\wedge$ ', and removing <u>c/d</u> , $\bar{x}$ , $\rightarrow$ SP, and $\rightarrow$ DP. Renamed <u>DISP</u> to <u>DSP</u> and <u>SUMS</u> to $\Sigma$ , changed $\underline{\square}$ to $\underline{\square}$ . Refined the addressing tables and catalog access, <u>a b/c</u> , <u>ADV</u> , <u>BATT?</u> ,

	Date	Release notes
		<u>BITS</u> , <u>CATALOG'CHARS</u> and ' <u>MENUS</u> ', CLALL, CLFALL, CPX, EXP, GAP, INTS, I/O, MODE, NEIGHB, PARTS, PRIME?, P.FN, SHOW, STAT, STK, X.FN, qINTL, and q•. Deleted all 16-digit (i.e. SP) data types as well as A...Z 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.
0.15  14.6.20		Added BESTF?, RANGE, RANGE?, <u>REGIST</u> , SNAP, and s(a), as well as errors 28 and 31 – 35. Changed DSZ and ISZ to comply with HP-16C. <b>Changed keyboard shifting N, O, P, and Q, swapping ? and Z, moving CNST, CPX, FLAGS, RBR, RTN, R↑, VIEW, and □, removing :, and adding MOD, ✓, and SNAP. Renamed DSP to DISP, CNST to CONST</b> , CONST to CNST, ASL.BLK to ASLIFT, SSIZE to SSIZE8, TDM to TDM24, and the left and right sided probabilities. Refined ASSIGN, <u>CATALOG</u> , CNST, <u>DISP</u> , <u>INFO</u> , NEXTP, PRIME?, PROB, RBR, RESET, SHOW, SINC, <u>STAT</u> , U→, VIEW, x=+0?, x=-0?, y*, a→x, Ȣ, pp. 54 – 57 and 205 – 207 (and consequences) as well as <i>Section 6</i> of the OM, pp. 108 – 117, App. B, C, and E of the ReM, and some looping and statistical explanations. Reduced the maximum number of <i>local registers</i> from 100 to 99. Changed ALLSCI to ALLENG and RECTN to POLAR. Added <i>data type</i> matrices for powers. Corrected.
0.16  3.11.20		Added torque and mmHg conversions, ISM, LOADV, x <sub>max</sub> and x <sub>min</sub> . Added UNDO to the <u>IOI</u> . Refined I/O and the descriptions of LOAD, LOADSS, RESET, and UNDO. Marked the not-undoable <i>items</i> in the <u>IOI</u> . Renamed the constants according to the OM and kicked them out of the <u>IOI</u> . Added usb. Refined <i>Basic Kinds of Program Steps</i> , App. E and F. Changed bit numbering from 1...64 to 0...63. Renamed SMODE? to ISM?. Refined IM, RE, SINC, TRI, WSIZE, X.FN and the labels of torque conversions. Added SINCrr and more vintage pictures. Expanded App. G. Refined the power matrix. Corrected.
0.17  8.3.21		Empty menus show up. Refined Ȣ, AUTOFF, BATT?, <u>BITS</u> , CLFALL, CLP, CLREGS, DSZ, e <sup>x</sup> , FP, GTO., IP, ISZ, J/G, LOAD, LOCR, LOCR?, LN, MEM?, M.EDI, M.EDIN, NaN?, RCLEL, RDP, RSD, SAVE, SDL, SDR, TDISP, WSIZE, x=+0?, x=-0?, Ȣy, y <sup>x</sup> , Σ+, Σ-, √x, □r, labels in U→, the distributions, the DT matrices, Sect. 3 and 4 and App. 1, as well as App. B, E, F, and I. Renamed ST.X etc. to X etc. Increased the number of local flags to 32. Added Chinese units of length and area to

	Date	Release notes
		U→. Deleted M.OLD, added DELITM, J/G?, and ☒x. Moved 'no' from <input checked="" type="checkbox"/> to <input type="checkbox"/> . Corrected.

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 view* is limited by a dashed line this indicates it is a *multi-view menu* and or can be used to browse the additional views of this *menu*. To execute a softkey in the lowest row, press the corresponding . To execute one in 2<sup>nd</sup> or 3<sup>rd</sup> row, press the corresponding headed by or , respectively.

## 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 **GP registers** (00 ... 99). Furthermore, there are **I**, **J**, and **K** serving special purposes in matrix handling (see p. Q-7), probability distributions (see p. Q-8), and programming but may be used globally otherwise. Also **A**, **B**, **C**, and **D** may be used this way unless being part of **stack**. Each **register** may contain any type of data. **STO nn** stores a copy of  $x$  into **Rnn**, **RCL nn** recalls a copy of the contents of **Rnn** into **X**, and **xz nn** swaps  $x$  and the contents of **Rnn**.

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

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

**Programs** consist of ≥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. Q-6 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. Any number you enter without using **.(dot)**, **E**, **CC**, or **#** is taken as a long integer of base 10.

**Real numbers:** Any number you enter using **.(dot)** 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 (CF POLAR and press **1.23 CC 4.56 +/- ENTER↑**) or its magnitude and phase like  $-7.89 \angle 120^\circ$  in polar mode (SF POLAR and press **7.89 +/- CC 120 ENTER↑**).

**Angles:** Any real number input trailed by **d.ms** is interpreted as an *angle* in *sexagesimal degrees*. Angles may be entered as well in *decimal degrees*, *radians*, *multiples of  $\pi$* , or *grades*. 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. Q-7 f.

**Short integers:** Any purely numeric input trailed by **#** and number 2 ... 16 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 (or text) strings:** Enter *alpha input mode (AIM)* by pressing **@**. Data entered in AIM become an *alphanumeric string* when closed (unless they are function parameters). All available Latin letters (incl. accented ones) are found in **f A**. Greek letters are accessed via **g** plus the corresponding Latin letter (see calculator backside). 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 *n*, CF *n* Set (or clear) the flag specified.

DEG Selects *degrees* as angular display mode (ADM).

RAD Selects *radians* as ADM.

GRAD Selects *grades*, a.k.a. *gon*, as ADM.

MULπ Selects *multiples of π* as ADM.

RM *n* Sets rounding mode.

SETSIG *n* Sets calculator precision (1 ... 34 significant digits).

DENMAX *n* Sets the maximum denominator for calculating with fractions.

SYSTEM Returns the calculator to the DMCP system for updating.

## DISPLAY FORMATS

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

FIX *n* Fixed number of *n* decimals.

SCI *n*, ENG *n* Scientific (or engineering) notation.

ALL *n* Displays all digits present as far as possible.

ROUND Rounds a *time*, real, or complex *x* to current display format.

ROUNDI Rounds to next integer.

RDP *n* Rounds *x* to *n* decimal places (1 ... 99, think of FIX)

RSD *n* Rounds *x* to *n* significant digits (1 ... 34, think of SCI).

SDL *n*, SDR *n* Shifts digits left (right) by *n* decimal positions.

CHINA, EUROPE, INDIA, JAPAN, UK, USA Set local display preferences.

GAP *n* Selects a digit group gap inserted after every *n* digits.

RANGE *n* Sets the maximum exponent to be displayed for real numbers

RANGE? Returns the range setting

DSTACK *n* Sets the number of stack registers to be displayed (1 ... 4).

## PROGRAMMING

### Program Entry

- |                            |   |
|----------------------------|---|
| <b>P/R</b>                 | toggles <i>program entry mode</i> .                                     |
| <b>GTO</b> [ ]             | moves the <i>program pointer</i> to a new program space.                |
| <b>GTO</b> [ ] <b>nnnn</b> | moves it to step number <b>nnnn</b> within the <i>current program</i> . |
| [ ]                        | moves it to previous step   |
| [ ]                        | moves it to next step   |
|                            | deletes the <i>current program step</i> entirely.                       |
| <b>EXIT</b>                | exits <i>program entry mode</i> .                                       |

### 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. Q-4).

**Global labels** can be accessed from anywhere in memory (thus, they should be unique). Global labels are alphanumeric and  $\leq 7$  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 current routine only.

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

When a binary test step is executed, the program step immediately following it 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 ccccc.fffii with ccccc being the current counter value, fff the final counter value, and ii the increment (or decrement) size (default is 1); DSZ and ISZ count to 0 in steps of 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). The example pictured 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 *Integrator* (see pp. Q-10f) or by VARMNU within a program. Each label in this *menu* represents a variable. While this *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*.

## EXECUTING FUNCTIONS AND PROGRAMS

Any function or program can be executed via **XEQ** **α 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 in the current program only.

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

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

**Run/Stop key:** Press **R/S** to run the current program beginning with the current step or to stop the 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 also be searched alphabetically. Avoid using function names twice!

## 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 finish 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** **α 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 keying in an actual parameter, you can specify the variable or *register* containing the parameter. Just press the *softkey* **→**. E.g. to display the contents of the variable or *register* specified in **R12**, key in **VIEW** **→ 12**. This works with *stack registers* as well.

## CLEARING AND DELETING

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

- |  |   |
|--|---|
| CLS  | Clears all statistical data.  |
| CLP  | Clears (deletes) the <i>current program</i> .                                   |
| CF <i>n</i>  | Clears <i>flag n</i> .  |
| CLMENU   | Clears the <i>programmable menu</i> .   |
| CLCVAR   | Clears all variables used in the <i>current program</i> .                       |
| CLX  | Clears <i>stack register X</i> .  |
| CLREGS   | Clears all <i>registers</i> (except the <i>stack</i> and statistical data).     |
| CLPALL   | Clears (deletes) all programs in <i>RAM</i> .                                   |
| CLFALL   | Clears all numbered user <i>flags</i> .   |
| CLLCD  | Clears the <i>LCD</i> above and to the right of pixel <i>x, y</i> .             |
| CLSTK  | Clears the entire <i>stack</i> (i.e. fills all its <i>registers</i> with zero). |
| CLALL  | Clears almost everything but the modes set.                                     |
| RESET  | Resets the <i>WP 43S</i> to <i>startup default configuration</i> .              |
| DELITM <b>CATALOG</b> VARS ... <input type="checkbox"/>  | deletes the user variable selected.   |
| DELITM <b>CATALOG</b> MENUS ... <input type="checkbox"/> | deletes the user <i>menu</i> selected.  |
| DELITM <b>CATALOG</b> PROGS ... <input type="checkbox"/> | deletes the user program selected.  |

## 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 named 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 first element in 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  $(A)\vec{X} = \vec{B}$ :

- Enter **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** and **Mat\_B**.
- 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	RANI#			$\Gamma(x)$
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:	Binom <sub>p</sub>		Binom <sub>▲</sub>	Binom <sub>△</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#.  
 RANI# Returns a random integer number between  $x$  and  $y$ .  
 $\Gamma(x)$  Returns the *Gamma function* value of  $x$ .

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

- Binom:** Binomial d. ( $i = p_0$  = gross probability of success,  $j = n$  = sample size)  
**Cauch:** Cauchy-Lorentz (a.k.a. Breit-Wigner) d. ( $i$  = location,  $j$  = shape)  
**Expon:** Exponential d. ( $i$  = rate)  
**F:** Fisher's F d. ( $i$  = degrees of freedom 1 ( $dof_1$ ),  $j$  =  $dof_2$ )  
**Geom:** Geometric d. ( $i = p_0$ )  
**Hyper:** Hyperbolic d. ( $i = p_0$ ,  $j = n$ ,  $k$  = batch size)  
**LgNrm:** Log-normal d. ( $i = \mu$ ,  $j = \sigma$ )  
**Logis:** Logistic d. ( $i = \mu$ ,  $j$  = scale parameter)  
**NBin:** Negative Binomial d. ( $i = p_0$ ,  $j = n$ )  
**Norml:** Normal d. ( $i = \mu$ ,  $j = \sigma$ )  
**Poiss:** Poisson d. ( $i = n p_0$  = Poisson parameter)  
**t:** Student's t d. ( $i$  = dof)  
**Weibl:** Weibull d. ( $i$  = shape,  $j$  = characteristic lifetime)  
 **$\chi^2$ :** 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<sub>▲</sub>** the *cumulated d. function*, **Norml<sub>△</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 input in **X** ( $0 \leq x \leq 1$ ).

## STATISTICS

Statistical data are accumulated in 23 dedicated summation *registers*, kept 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 errors or remove erroneous data,

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

## Data Evaluation and Analysis

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

$\bar{x}$ , 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.

$\bar{x}_H$ ,  $\bar{x}_{RMS}$ ,  $x_{max}$ ,  $x_{min}$  Harmonic and quadratic means, max. and min. values.

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

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).

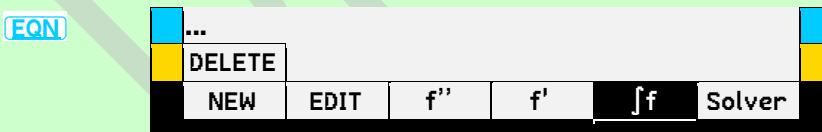
r	Returns the correlation coefficient.
$s_{xy}$ , cov	Return the sample or population covariance.
$\hat{x}, \hat{y}$	Return the forecast for x or y according to the fit model selected.
LinF	Linear fit model: $y = a_0 + a_1x$ .
ExpF	Exponential fit model: $\ln(y) = \ln(a_0) + a_1x$ or $y = a_0 e^{a_1 x}$ .
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. Note that ORTHOF is not part of the fit model 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 [ $c, b, a, \dots$ ]. 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. Q-4).

**$\Sigma_n$  label** calculates the sum of the terms given by the routine specified, using the loop control number given in **X** (cf. p. Q-4).

**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**.

**∫fd 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 (**↓LIM**), the upper limit (**↑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	
<b>[INTS]</b>	DBL /	DBLR	DBL ×	$\wedge$ MOD	CEIL	GCD	
	IDIV	RMD	MOD	$\times$ MOD	FLOOR	LCM	
	A	B	C	D	E	F	

A ... F	Digits for input of short integers of bases >10.							
IDIV	<b>R</b> <b>Z</b>	Integer divide – works also for real numbers ( <b>R</b> ) and long integers ( <b>Z</b> ).						
RMD, MOD	<b>R</b> <b>Z</b>	Remainder and modulo.						
$\times$ MOD	<b>R</b> <b>Z</b>	Returns $(z \cdot y) \bmod x$ .						
$\wedge$ MOD	<b>R</b> <b>Z</b>	Returns $(z^y) \bmod x$ .						
FLOOR	<b>R</b>	Returns the greatest integer $\leq x$ .						
CEIL	<b>R</b>	Returns the smallest integer $\geq x$ .						
LCM	<b>Z</b>	Returns the least common multiple of $x$ and $y$ .						
GCD	<b>Z</b>	Returns the greatest common divisor of $x$ and $y$ .						
DBL /, DBLR, DBL×	Double word length commands for division, remainder, and multiplication.							
1COMPL, 2COMPL	Sets 1's (2's) complement mode.							
UNSIGN	Sets unsigned mode.							
SIGNMT	Sets sign-and-mantissa mode.							
WSIZE	Sets the word size to 1 ... 64 bits.							

	1COMPL	2COMPL	UNSIGN	SIGNMT		WSIZE
BITS	LJ				RJ	
	SL	RL	RLC	RRC	RR	SR
	A	B	C	D	E	F
	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** Creates a mask of  $x$  bits on the left (or right) side.

MIRROR Reflects all bits.

Arithm. shifts  $x$  to the right by  $n$  places = divides  $x$  by  $2^n$ .

**SB, FB, or CB, #n**      This command is the rightmost 16 places of an address byte. It sets, flips, or clears bit #*n* in *x* (counting starts with #0).

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

<code>BOV, BOV</code>	Checks if bit $m$ in $x$ is set (or clear)
<code>#B</code>	Returns the number of bits set in $x$

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

**SL, SR,  $n$**  Shifts  $x$  left (or right) by  $n$  places.  
**RL, RR,  $n$**  Rotates  $x$  left (or right) by  $n$  places.

<b>RL, RR <math>n</math></b>	Rotates $x$ left (or right) by $n$ places
<b>RC, RRC <math>n</math></b>	Rotates $x$ left (or right) by $n$ places

**RLC, RRC *n*** Rotates *x* left (or right) by *n* places through Carry.  
**LDC, RDC** Adjusts the bit position to the left (right).

**LJ, RJ** Adjusts the bits set in  $x$  to the left (or right).

# 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					
				aLENG?	aPOS?	
	x→a	aRL	aRR	aSL	aSR	a→x

`x → a s` Converts a code  $x$  to the corresponding character and appends it to the string in `s`.

`aRL, aRR` **s** Rotates the string in **s** by *x* characters to the left (or right).

**qSL, qSR *s*** Deletes the first (or last) *x* characters of the string in *s*.

**q → x s** Pushes the code of the first character in **s** on the stack.

gl.ENG? **s** Pushes the length of the string in **s** on the stack

<code>LEN(<i>s</i>)</code>	Returns the length of the string in <i>s</i> on the stack.
<code>qPOS? <i>s</i> <i>x</i></code>	Returns the position where substring <i>x</i> begins in the string in <i>s</i> .

**FPR** Displays all characters defined in both fonts.



# BACKGROUND CONSIDERATIONS AND FACTS

This section is for recording and explaining some of the boundary conditions considered and 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; and a bit of the product philosophy may be found here, too.

## Accessing Items

The hardware offers 43 keys for some 740 *items*. Subtract six for the *softkeys*. Space for primary functions is quickly occupied – the respective functions are mostly set.

Obvious primary functions are the digits **0** ... **9**, **.**, **ENTER↑**, **x<sup>y</sup>**, **±**, **E**, **⬅**, **+**, **-**, **x**, **/**, **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 will need a primary **CC**.

Other functions may be debated: **R↓**, **1/x**, **y<sup>x</sup>**, **x<sup>2</sup>**, **✓x**, **e<sup>x</sup>**, **ln**, **10<sup>x</sup>**, **lg**, **sin**, **cos**, and **tan** are the most popular – twelve candidates for seven key tops left. Either **x<sup>2</sup>** or **✓x** shall be primary (we chose **x<sup>2</sup>** since a shifted **✓x** is of little use); and we can ditch **10<sup>x</sup>** and **lg** when we have **e<sup>x</sup>** and **ln** primary. So the six functions **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 **✓x**, **10<sup>x</sup>**, and **lg** 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 three functions, we made all **g**-shifted and put **✓x** also in the unshifted row of **EXP** since it is the most popular of these.

*WP 43S* features 33 *menus* on its keyboard. Of these, **CATALOG**, **CONST**, **U→**, and the three alpha character *menus* shall be separated since they follow special rules. Each of the other 27 *menus* offers six unshifted locations for its most popular *items*. Selecting these can be easy (like in **ADV**, **LOOP**, **STK**, or **TRI**) or more difficult (like in **INFO**, **P.FN**, or **X.FN**).

Unshifted softkeys are (cf. pp. 119ff):

<u>ADV</u>	SOLVE	SLVQ	$f'(x)$	$\Pi_n$	$\Sigma_n$	$\int f dx$
<u>BITS</u>	AND	OR	XOR	NOT	MASKL	MASKR
<u>CLK</u>	DATE	$\rightarrow$ DATE	DATE $\rightarrow$	WDAY	TIME	$x \rightarrow$ DATE
<u>CLR</u>	CLΣ	CLP	CF	CLMENU	CLCVAR	CLX
<u>CPX</u>	dot	cross	UNITV	Re	conj	Re $\Rightarrow$ Im
<u>DISP</u>	FIX	SCI	ENG	ALL	ROUNDI	ROUND
<u>EQN</u>	NEW	EDIT	$f''$	$f'$	$\int f$	Solver
<u>EXP</u>	$x^3$	$\sqrt[3]{y}$	$\log_x y$	lb x	$2^x$	$\sqrt{x}$
<u>FIN</u>	%	%MRR	%T	%Σ	%+MG	TVM
<u>FLAGS</u>	SF	FS?	FF	STATUS	FC?	CF
<u>INFO</u>	SSIZE?	MEM?	RM?	ISM?	WSIZE?	KTYP?
<u>INTS</u>	A	B	C	D	E	F
<u>I/O</u>	LOAD	LOADP	LOADR	LOADSS	LOADV	LOADΣ
<u>LOOP</u>	DSE	DSZ	DSL	ISE	ISZ	ISG
<u>MATX</u>	NEW	$[M]^{-1}$	M	$[M]^T$	SIM EQ	EDIT
<u>MODE</u>	SF	DEG	RAD	GRAD	MULπ	CF
<u>PARTS</u>	IP	FP	MANT	EXPT	sign	DECOMP
<u>PRINT</u>	$\blacksquare x$	$\blacksquare r$	$\blacksquare \Sigma$	$\blacksquare$ ADV	$\blacksquare$ LCD	$\blacksquare$ PROG
<u>PROB</u>	Norml:	t:	$C_{yx}$	$P_{yx}$	F:	$\chi^2$ :
<u>P.FN</u>	INPUT	END	ERR	TICKS	PAUSE	P.FN2
<u>STAT</u>	$\Sigma +$	$\bar{x}$	s	g	$s_m$	SUM
<u>STK</u>	$x \gtrless$	$y \gtrless$	$z \gtrless$	$t \gtrless$	$\gtrless$	DROPy
<u>TEST</u>	$x < ?$	$x \leq ?$	$x = ?$	$x \neq ?$	$x \geq ?$	$x > ?$
<u>TRI</u>	sin	arcsin	cos	arccos	tan	arctan

<u>U→</u>	E:	P:	year→s	F&p:	m:	x:
X.FN	AGM	B <sub>n</sub>	B <sub>n</sub> *	erf	erfc	Orthog
α.FN	x→α	αRL	αRR	αSL	αSR	α→x
Σ	n	Σx	Σx <sup>2</sup>	Σxy	Σy <sup>2</sup>	Σy
→	→DEG	→RAD	→GRAD		→D.MS	→MULπ

All these functions can be accessed via a single keystroke if and when their *menu* is open, else via three keystrokes. Thus, repeating any unshifted *softkey* as a shifted label on the keyboard is of limited value; and there are just two cases where this is done ( $\sqrt{x}$  and  $\sqrt[4]{x}$  as well as STATUS and **STATUS**).

|x| and ↵ are also featured as shifted softkeys: accessing |x| or ↵ needs two keystrokes while |x| and ↵ require four maximum (and two if the *menu* is open). In consequence, |x| and ↵ are actually not needed in any *menu* but are left in the related menus Cpx and PARTS since space is available there so far.

See also *Layouting* on pp. B-18f.

## Alpha Register

For long I thought we could do without a dedicated *alpha register* since each and every *register* is capable holding an *alphanumeric 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 it (cf. the OM, Section 3).

## Angles

Originally, a separate *DT* 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 *DT* 4 returned with v0.10 for sake of keeping algebraic operations simple and avoiding dedicated 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 *grades*). 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 need for high precision storage of  $\pi$  for modulo calculations and reduction of rounding errors. And *radians* are inevitable since Taylor series for trigonometric functions are written for angular input in *radians*. So, internally, *angles* are tagged *reals* now.

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 (see <https://forum.swissmicros.com/viewtopic.php?f=2&t=350#p4349> ). *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 planned to be kept for many years in a way that programs written for both calculators could have run on the *WP 43S* as well (except matrix operations and some flag allocations). It became difficult with the full implementation of the *DT* concept and had to be eventually abandoned officially when introducing named *system flags* with v0.14. On the other hand, we were allowed to eliminate some *HP-42S* bugs this way (e.g. the *Matrix Editor* pushing 0 on the stack).

Nevertheless, *names* of *items* were kept as close as possible to the *names* users are used to unless there were striking reasons for better *names*. Extra entries are provided catching traditional *names*.

## Calculation Internals

General powers in  $\mathbb{R}$  and  $\mathbb{C}$  are calculated as  $y^x = e^{x \ln(y)}$  and general roots as  $\sqrt[x]{y} = e^{\frac{\ln(y)}{x}}$  for all values of  $x$  except the integers 2 and 3. For odd ('integer') roots of  $y < 0$ ,  $\sqrt[x]{y} = -e^{\frac{\ln(-y)}{x}}$ ; here, 'integer' includes DT 1 and 10 and reals with zero fractional part. Some special results in [App. B](#) can be deduced from these calculation paths.

Note that Free42 may calculate even powers differently (as a series of multiplications using repeated squaring), never employing more than 34 digits (see also p. B-22).

## 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*). Find them printed here to scale:

0 1 2 3 4 5 6 7 8 9	A B C D E F
0020 ! " # % ^ ' ( ) * + , - . /	
0030 0 1 2 3 4 5 6 7 8 9 : ; < = > ?	
0040 ☺ ABCDEFGHI JKLMNO	
0050 PQRSTUVWXYZ[ ☺ ] ^ _	
0060 ☻ abcdefghijklmno	
Numeric font. Press ↴ or EXIT	1/16
0070 pqrstuvwxyz ☺ ~ ☺	
0080 ° ± 2 3 ☺ . ☺ ☺ ☺ ☺ ☺	
0090 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0100 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0110 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0120 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0130 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0370 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0380 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0390 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0400 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0410 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	

0 1 2 3 4 5 6 7 8 9	A B C D E F
0020 ! " # \$ % & ' ( ) ^ + , - . /	
0030 0 1 2 3 4 5 6 7 8 9 : ; < = > ?	
0040 ☺ A B C D E F G H I J K L M N O	
0050 P Q R S T U V W X Y Z [ ☺ ] ^ _	
0060 ☻ a b c d e f g h i j k l m n o	
0070 p q r s t u v w x y z {   } ~ ☺	
0080 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0090 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0100 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0110 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0120 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0130 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0370 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0380 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0390 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0400 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	
0410 ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺ ☺	

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
1D60	×	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2000	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2010	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2060	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2070	0	1	-1	E	4	5	6	7	8	9	+	-	█	█	█	█	
2080	0	1	2	3	4	5	6	7	8	9	+	-	*	█	█	█	
2090	π	e	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2100	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
21C0	→	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2210	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2220	█	4	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2240	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2260	#	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2390	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
23A0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
2420	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	
2460	I	2	3	4	5	6	7	8	9	0	1	11	12	13	14	15	16
2480	█	█	█	█	█	█	█	█	█	0	1	2	3	4	5	6	
2490	9	10	█	█	█	█	█	█	█	a	b	c	d	█	█	█	
24A0	f	g	h	█	█	█	█	█	█	r	T	█	█	█	█	█	
24B0	u	v	w	x	y	z	A	B	C	D	E	F	G	H	I	J	
24C0	K	L	M	N	O	P	R	S	T	U	V	W	X	Y	Z	█	

	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
03B0	୦	ା	ର	ୟ	ତ୍ୟ	ୱେ	୩	୭	୧	କ	ଳ	ମ	ନ୍ୟ	୯	୦	୯
03C0	ପ୍ର	୫	୯	୯	୯	୯	୯	୯	୯	୯	୯	୯	୯	୯	୯	୯
1D60	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2000	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2010	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2020	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2060	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2070	0	1	-1	E	4	5	6	7	8	9	+	-	█	█	█	█
2080	0	1	2	3	4	5	6	7	8	9	+	-	*	█	█	█
2090	π	e	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2100	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2110	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2120	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2190	←	↑	→	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓	↑	↓
21C0	→	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
21E0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2200	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2210	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2220	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2230	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2240	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2250	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2260	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
2290	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
23A0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
23B0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
23C0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
23D0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
23E0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
23F0	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2430	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
2460	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2490	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█
24A0	e	f	g	h	i	j	k	l	m	n	o	p	q	s	█	█
24B0	u	v	w	x	y	z	A	B	C	D	E	F	G	H	I	J
24C0	K	L	M	N	H	O	P	R	R	S	T	U	V	W	X	Y
2710	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█

The so-called ‘numeric’ font uses a matrix of up to 16 × 32 px (variable width, fixed height). Therein, the punctuation space (2008<sub>16</sub>, 8 px wide) is employed for separating groups of digits in longer 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 here 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 CONST.

Optionally, narrower digits can be used in *complex numbers*, matrices, or *short integers* of small base where space may be scarce (see pp. B-8ff).

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 ( $4, 10_{10}, 27_{10}$ ) 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 here with their hex addresses and widths). Using them, any spacing is feasible.

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

Afrikaans, aymara, Bahasa Indonesia, Bahasa Melayu/Malaysia, Basa Jawa, Basa Sunda, Bhāsa Bali, bosanski, català, Cebuano (Bisayan), čeština, Cymraeg, dansk, Deutsch, eesti, Ελληνικά, English, español, euskara, Filipino, français, Gaeilge, galego, Hiligaynon, hrvatski,

	Code	px
Standard space	$20_{16}$	10
m space	$2003_{16}$	12
m/3 space	$2003_{16}$	4
m/4 space	$2003_{16}$	3
m/6 space	$2003_{16}$	2
Figure space	$2003_{16}$	8
Punctuation sp.	$2003_{16}$	4
Hair space	$2003_{16}$	1

Ilokano, italiano, Kiswahili, kreyòl (ayisien), kurdî, lietuvių, magyar, Malagasy, Nāhuatl (Mexicatlatolli), nederlands, nihongo (rōmaji), norsk, O'zbek tili, polski, português, quechua (runasimi), română, shqip, slovenščina, slovensky, srpski, suomi, svenska, Tagalog, tatarça, Türkçe, Türkmen dili, Vlaams, walon, Waray, and zhōngwén (hànyǔ pīnyīn).

This makes the *WP 43S* the most versatile multilingual calculator available worldwide. If you know of further living languages covered (with  $\geq 1$  million speakers) beyond the ones listed here, please tell us.

Turn to the *OM* for examples where and how these characters are used. See here two sample strings in either font, printed approximately to a common realistic scale:

$$\begin{array}{ll} -1.602\ 22 \times 10^{-19} \text{ C} & -1.602\ 22 \cdot 10^{-19} \text{ C} \\ -1.602\ 22 \times 10^{-19} \text{ As} & -1.602\ 22 \cdot 10^{-19} \text{ As} \end{array}$$

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.

## 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.

For reasons of mathematical tradition, rectangular notation is found most frequently. We used it for storing *complex numbers* in the *WP 34S*. Thus, it is used for the *WP 43S* as well, but care must be taken at **complex infinities**:

Since infinities may be counted as numeric data being part of the *real number* range (see p. 167), also complex infinities may be part of the *complex number* plane the *WP 43S* operates on. Coming from rectangular notation, there are eight 'complex infinities' possible only, listed here aside to their equivalents in polar notation:

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

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

**Calculating with infinities**, any finite number 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 have to deal with the eight cases listed above only as long as you build your complex calculations on Cartesian notation (see footnote 82 for additional information). With polar notation, on the other hand, an infinite number of complex infinities would have to be treated.

Note, however, that polar notation is advantageous for complex powers and roots: the  $n^{\text{th}}$  root of a *complex number* ( $r$ ;  $\varphi$ ) in polar notation will return  $(\sqrt[n]{r}; \varphi/n)$ . Hence, e.g.  $\sqrt[3]{(\infty; 180^\circ)} = (\infty; 60^\circ)$ , corresponding to the Cartesian point  $\infty \times (1 + i\sqrt{3})$  which the calculator will display as  $\infty + i \times \infty$ , converted following the calculation rules – but mathematically wrong; and  $\sqrt[6]{(\infty; 180^\circ)} = (\infty; 30^\circ)$ , corresponding to the Cartesian point  $\infty \times (\sqrt{3} + i)$ , would return  $\infty + i \times \infty$  as well.

Integer powers of  $(r; \varphi)$ , on the other hand, will return  $(r^n; \varphi \times n)$ . E.g.  $\infty + i \times \infty = (\infty; 45^\circ)$  squared shall return  $(\infty; 90^\circ) = 0 + i \times \infty$ . Naïve pedestrian's approach:  $(\infty + i \times \infty)(\infty + i \times \infty) = \infty - \infty + 2i \times \infty = 0 + i \times \infty$ . Note the two  $\infty$  are exactly identical here; but  $\infty - \infty$  is generally defined as NaN for good reasons, so the properly calculated result will deviate from the truth here, too.

Thus, the odds are high that roots and powers of *complex numbers* near the far edge of complex plane will return incorrect data, in particular if specified in polar notation. These errors seem to be inevitable.

## Display Limits

Due to the character sizes and their design (cf. pp. B-5f), 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. Note that 1 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. – With SHOW, any *real number* can be displayed with 34-digits precision in a single row:

2020-01-06 17:28 Cls.4^r /max 64:2 A S  
-1.428 571 428 571 428 571 428 571 428 571 429 $\times 10^{-235}$   
-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 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  $+j\times$  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

$$-4.234\ 567\ 89+j\times4.234\ 567\ 89,$$

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):

$$-4.234\times10^{-925}+i\times4.234\times10^{-925}$$

Using 8 px wide multiplication dots instead, only  $1 + 15 + 12 + 8 + 1 = 37$  px are necessary for  $+i\times$ . We can display one decimal more now since  $15 + 2 \times (5 \times 16 + 3 \times 8 + 16 + 4 \times 13) + 37 + 1 = 397$  px:

$$-4,234\ 5\cdot10^{-925}+i\cdot4,234\ 5\cdot10^{-925}$$

Alternatively, 13 px wide narrow digits allow for 4 decimals even with multiplication crosses, while 5 decimals are viable with multiplication dots:

$$-6.234\ 5\times10^{-925}+i\times6.234\ 5\times10^{-925},$$

$$-6.234\ 56\cdot10^{-925}+i\cdot6.234\ 56\cdot10^{-925}$$

With SHOW, any *complex number* can be displayed with 34 digits precision in two rows:

2020-01-06 17:15 CL<sub>E</sub> /max 64:2 A  $\overline{4}$  S  
 $-8.403\ 361\ 344\ 537\ 815\ 126\ 050\ 420\ 168\ 067\ 229\times10^{-126}$   
 $-i\times5.882\ 352\ 941\ 176\ 470\ 588\ 235\ 294\ 117\ 647\ 059\times10^{-158}$

$$\begin{aligned} &-1.\times10^{-33} \\ &-8.403\times10^{-126}-i\times5.882\times10^{-158} \end{aligned}$$

**Complex numbers** in **polar notation** need  $4 + 16 + 4 = 24$  px for  $\overline{4}$  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 ↵ -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  $-200^g$  to  $+200^g$  in *gon* (see Section 2 of the OM). Hence, the angular parts can be displayed without exponents always. This allows for a minimum of 4 decimals for *degrees* and *gon*:

-4.234 5 $\times 10^{-925}$  ↵ -120.234 5°.

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

-4.234 56 $\times 10^{-925}$  ↵ -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  $(1 + 15 + 21 \times 16 + 6 \times 8 = 400$  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 up to 296 digits (see e.g. the prime number  $2.8\dots \times 10^{295}$  shown below with all its digits). Only

the most significant 294 digits will be displayed of an integer  $\geq 10^{297}$ , however, with ellipses added at its end. You can get all of its digits with the simulator only (cf. App. E on pp. 207ff).

For unsigned ***short integers***, up to 21 bits may be shown in the usual 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 narrower 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:

111, 110, 01, 11, 1, 11, 111, 110, 01, 11, 1, 11, 111, 110, 01, 11, 1, 11, 110, 0002 .

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	<i>21 bits</i>	<i>25 bits</i>	<i>44 bits</i>	<i>64 bits</i>
3	<i>31 bits</i>	<i>38 bits</i>		
4	<i>38 bits</i>	<i>44 bits</i>		
5	<i>46 bits</i>	<i>55 bits</i>		
6	<i>51 bits</i>	<i>62 bits</i>		
7	<i>56 bits</i>			
8	<i>57 bits</i>		<i>64 bits</i>	
> 8	<i>64 bits</i>			

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

$$\begin{bmatrix} -6,609 \cdot 10^{-19} & -6,609 \cdot 10^{-19} & -1,609 \cdot 10^{-19} & -1,609 \cdot 10^{-19} \end{bmatrix}$$

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

$$\begin{bmatrix} -6.609 \cdot 2 \cdot 10^{-19} & -6.609 \cdot 2 \cdot 10^{-19} & -1.609 \cdot 2 \cdot 10^{-19} & -1.609 \cdot 2 \cdot 10^{-19} \end{bmatrix}$$

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

$$\begin{bmatrix} \dots & -6,609 \cdot 2 \cdot 10^{-19} & -6,609 \cdot 2 \cdot 10^{-19} & -1,609 \cdot 2 \cdot 10^{-19} & \dots \end{bmatrix}.$$

allowing to display a section of three elements in SCI 4 format. Using multiplication crosses will cost one decimal.

Vertically, each such matrix row requires 20 px as other small font strings do. Thus, 5 matrix rows ( $5 \times 20 + 4 = 104$  px) can be put in the space taken by 3 standard numeric rows ( $3 \times 32 + 2 \times 5 = 106$  px). So, a  $5 \times 4$  real matrix can be displayed entirely always, using SCI 3 in worst case.

In consequence, any chosen  $3 \times 3$  section out of a real matrix of arbitrary size can be shown in SCI 3 minimum with surrounding ellipses. In FIX format, 8 decimals can be displayed always.

In analogy, for a **complex matrix** of arbitrary size any chosen  $3 \times 2$  section can be displayed in FIX 6 format maximum with surrounding ellipses like

```
[... -6.609 226+i·6.609 226 -1.609 226+i·1.609 226 ...]
```

while displaying complex matrix elements featuring large exponents may become inconvenient very soon, regardless of the symbols used:

```
[... -6.60E-199+i·6.60E-199 -1.60E-199+i·1.60E-199 ...] .
```

Also displaying an arbitrary  $3 \times 3$  section out of a larger complex matrix is viable up to FIX 3 as long as the numbers stay in a reasonable range:

```
[... -6,609+i·6,609 -6,609+i·1,609 -1,609+i·1,609 ...] .
```

One row of **alphanumeric text** will typically take some 40 characters. The actual number will vary depending on their individual widths as mentioned above.

The *status bar* is a good example for such an alphanumeric row: Loaded to maximum, it might look like

```
2017-05-08 23:49 RLE4π /3 546f 64:00 A ☰☐♦☒☐
```

containing 45 characters.

Putting the alphabet in a row allows for

```
abcdefghijklmnopqrstuvwxyz ABCDEFGHIJKLMNOP
```

i.e. 41 characters.

Echoing command input requires up to 16 characters (the 17<sup>th</sup> will close input) for a 7-character command indirectly addressing a 7-character variable entered in A/M. This can be done in either font.

Command and variable *names* in menus are discussed in the last paragraph of next chapter. Although seven characters are allowed for such *names*, six may well fill the screen space available there already. Thus, it is recommended to keep such *names* as short as possible, though meaningful.

## Display Segmentation

The *LCD* of the *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 pixel 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:

- Each regular alphanumeric row (e.g. for labels, status, a text string, or a program step) requires 20 px vertically (cf. pp. B-5f). There shall be at least one row of blank pixels separating it from the next row of data.
- Hence, each *menu* row takes (counting bottom-up)  $1 + 20 + 1 + 1 = 23$  px (the first pixel is for separation from the black frame, the last for its upper frame line). Thus, three *menu* rows require 69 px. In U, extra-high labels may appear: 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 remain free on the screen so far.
- Each regular numeric output requires 32 px vertically (cf. p. B-5) plus 4 px separating it from the next such output row. Thus, for 4 rows we need  $4 \times 32 + 3 \times 4 = 140$  px. Since there are 4 px above them already, we put the remaining 7 px below this block.
- If there is a short *text string* in an arbitrary *stack register*, its base line should be positioned where the base line of the respective numeric output would have been.
- With a *text string* in **X** needing two rows,  $1 + 20 + 1 + 20 + 1 = 43$  px are required vertically matching the  $7 + 32 + 4 = 43$  px available for the lowest numeric row. Longer *strings* will need *SHOW* to be shown entirely.

- In *PEM*, on the other hand,  $147 = 7 \times (20 + 1)$  px correspond to a block of 7 alphanumeric program rows.
- With *SHOW*, also pure numeric output may require more than one row – the small font will be used there as well. Thus, up to 7 rows of small digits are possible again. Cf. pp. 69 and B-12.

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. Users should avoid such ambiguities.

## Echo and Fallback

Almost all key presses are echoed and fall back to NOP. Softkeys shall not be echoed since *WYS/WYG* applies there always. Furthermore, some functionalities, wherever they may be assigned to, are not echoed (and hence cannot fall back) since

- 1) they are harmless (EXIT, UP, DOWN) or
- 2) reverting or exiting them is a no-brainer (UP, DOWN, P/R, all *menu* calls) requiring no more than one keystroke.

With the presence of UNDO (see p. B-30), the necessity of fallback to NOP becomes debatable overall; there is some benefit remaining in *user mode* as long as an overlay matching the actual assignments is not available – and UNDO is shifted in *startup default configuration*.

## 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 behind each operator like +, -, ·, ×, /, and ! (except  $\hat{}$ ); 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  $C_{xy}$ ) and triadic operations in analogy – their arguments shall be separated by blank spaces inserted via **R/S**.

Terminating the *Equation Editor*, numeric exponents are automatically converted from e.g.  $xy^{23}$  to  $xy^{23}$ . For easier handling, this will be reverted when editing such an equation again.

## Layouting

After drawing many fictional calculators just for fun, we gained our real-world layout experience with the *WP 34S*. Based on this and seeing a forthcoming better display than the very limited one of the *HP-20b/30b* at the horizon, I conducted a poll on the forum of the *Museum of HP Calculators* about the community's general preferences for the placement of the four basic arithmetic operators on a hypothetical portrait *RPN* pocket calculator (<https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234505>). In return, I published the basic concept and first layout of the *WP 43S* (<https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234685>) in 2012-11 (the picture overleaf shows my last draft before said post, wishfully assuming the good old slanted keys of the Seventies). Instead of resurrecting an old calculator or copying an existing layout, we wanted to create a new, optimized pocket calculator based on our experience.

Even after years, the order and location of the four basic arithmetic operators on the keyboard may become subject to repeated vivid discussions. All the early *HP pocket* calculators (from the world's first scientific pocket calculator, the *HP-35* of 1972, up to the *HP-41C*, *CV*, and *CX*) presented them beneath

**ENTER↑** in the order **-, +, ×, ÷** (top down); though actually no one knows the reason for this old sorting order anymore. With the launch of the Voyagers in 1981, these operators had to be moved and *HP* abandoned its proprietary sequence for pocket calculators turning to the common order **+, -, ×, ÷** (bottom up). The poll of 2012-11 resulted in a majority for placing the operators beneath **ENTER↑** for ergonomic reasons.

Everything after the first layout of 2012-11 was and is just patient refinement and careful tuning of the basic idea, just row two of the keys changed significantly due to increasing support of complex numbers and the shifted functions wandered around. The layout even survived an hardware switch – we were waiting for *Eric Smith's* and late *Richard Ottosen's* so-called *Reptiles* (see the *HHC* meetings until 2015) still when *Michael* mailed me the concept of his and *David's* *DM42* in March 2016.

Actually, development of the *DM42* overtook the *WP 43S* – it was launched late in spring 2017 as a resurrection of the *HP-42S* while *Pauli* and me were looking for willing software engineers and actual support beyond friendly words still in vain. Despite its popularity in the community, the lack of qualified manpower for coding *WP 43S* was the lasting bottleneck in our project since 2012. It was overcome not earlier than 2021.



## Menus

The community does not like deep *menus*: it prefers the *HP-32SII* to the *HP-32S*. On the other hand, it wants a large function set. So *menus* become inevitable but shall be designed carefully.

*Menu* size corresponds to keystroke efficiency; optimum for our user interface 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 functionality. Besides its (in)visibility, a function presented in the unshifted row of the top *menu view* is more efficient than a shifted function presented on the keyboard – if used more than just once (cf. pp. B-1ff).

Generally, I separated status setting from ‘acting’ operations in different *menu* 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 (cf. also pp. 136f). So we can conclude that the *real number* range supported (cf. p. 162) suffices by far for solving what has to be solved. Saving display space gave reason for RANGE.

For sake of consistency, maximum numbers within different *DTs* 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*.

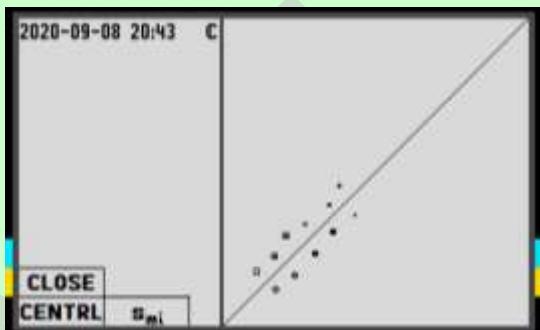
Note the number range determines the precision required for calculating accurately (see p. B-22).

## 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 experimental 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, see below). 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. – Although axis and diagonal can be created using AGRAPH and PIXEL alone, four characters are provided in the small font for ‘drawing’ the vertical axis and the  $45^\circ$  line:



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 (see below). For POINT, some of the graphic control modes of HP-42S shall be implemented in analogy (the table below is copied from the HP-42S OM, p. 137):

Flag 34	Flag 35	How the AGRAPH Image is Displayed
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.

Settings 1 (= 0, 0) and 3 (= 1, 0) herein should suffice for our plotting (cf. GRAMOD on p. 99).

The necessary *softkey* functions could be as follow. Some background calculations will be required. Setting 1 in the table above will do while plotting:

- PLOT shall set up the plot screen and plot the data points all at once:

Let  $x_{min}$  and  $x_{max}$  be the minimum and maximum values for  $x$  and  $y_{min}$  and  $y_{max}$  be the same for  $y$ . Then the diagram shall extend in either direction from  $d_{min} = \min(x_{min}; y_{min}) - \delta$  to  $d_{max} = \max(x_{max}; y_{max}) + \delta$  with  $\delta = [\max(x_{max}; y_{max}) - \min(x_{min}; y_{min})] \times 0.05$ . All data points  $(x_i; y_i)$  shall then be projected into the screen area between  $(d_{min}; d_{min}) = (161; 1)$  and  $(d_{max}; d_{max}) = (400; 240)$  and be plotted there.

- CENTRL shall fit the center line and plot it for checking deviations from the  $45^\circ$  line: Set ORTHOF and let L.R. fit the regression line through the original data points; then display this line in the diagram area properly.
- $s_{mi}$  shall calculate the minimum experimental standard deviation of the measuring instrument from the variances of the data and push it on the stack, displayed at left end of X:

$$s_{mi}^2 = s_x^2 s_y^2 \frac{1 - r^2}{s_x^2 + r^2 s_y^2}$$

- CLOSE shall clear and close the plot screen, returning to normal display.

It may be beneficial to define a general origin for graphics at a location deviating from pixel (1; 1) (i.e. the bottom left corner of the LCD) – the point (161; 1) 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’ left for up to six *softkeys*. Any user may do his own in the quadratic drawing area then, using the commands AGRAPH, CENTRL, CLLCD, CLOSE, PIXEL, PLOT, and POINT. Though this may come in further future...

## Precision and Accuracy

As mentioned above more than once, there are inevitable errors in each numeric 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 (cf. footnote 74).

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 one digit precision is lost 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 (cf. footnote 74). Consequently, *WP 43S* also works with 39 digits internally most times and rounds results to 34 digits. *SLVQ* calculates using 72 digits. The statistical summation registers are 75 digits wide (used also for the initial steps of variance calculation). Range reductions for trigonometric functions use many more digits (cf. pp. B-3f).

Luckily, real-world problems are usually many orders of magnitude less precisely defined than the internal precision of the *WP 43S*. Compare also the precisions in the set of physical and astronomical constants provided (cf. pp. 127ff).

## Prefixes

Prefixes  and  passed without any discussion for more than six years until 2019-06. Alternatively, prefixes  and  could have been chosen but their typography leaves less freedom for placing the corresponding golden and blue labels.

## Sorting in Detail

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

Note that sorting is a two-step procedure: step 1 sorts the text 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. Applying this algorithm, a section of CATALOG'FCNS looks like e.g. **s**, **SAVE**, **SB**, **SCI**, **SCIOVR**, **scw→kg**, ..., **SLVQ**, **s<sub>m</sub>**, **s<sub>mw</sub>**, **SOLVE**, ...

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

—	0020	2003	2004	...	2008	200a	— 2423
0	0030	220e	00b0	0 2070	0 2080		
1	0031	1 2027	½ 00bc	¼ 00bd	1 2071	1 2081	1 2460
2	0032	2 00b2	2 2082	2 2461			
3	0033	3 00b3	3 2083	3 2462	¾ 221b		
4	0034	4 2074	4 2084	4 2463			
5	0035	5 2075	5 2085	5 2464			
6	0036	6 2076	6 2086	6 2465			
7	0037	7 2077	7 2087	7 2466			
8	0038	8 2078	8 2088	8 2467			
9	0039	9 2079	9 2089	9 2468			
10	2491	10 2469					
11	246a						
12	246b						
13	246c						
14	246d						
15	246e						
16	246f						
A	0041	a 0061	ä 00aa	À 24b6	á 2090	à 249c	
		À 00c0	à 00e0	Á 00c1	á 00e1	Ã 00c2	â 00e2
		Ã 00c3	ă 00e3	Ä 00c4	ä 00e4	Å 00c5	å 00e5
		Æ 00c6	æ 00e6	Ā 0100	ā 0101	Ā 0102	ă 0103
						À 0104	ä 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>đ</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>Ě</b> 00c8	<b>ě</b> 00e8
	<b>é</b> 00c9	<b>é</b> 00e9	<b>Ě</b> 00ca	<b>ě</b> 00ea	<b>Ě</b> 00cb	<b>ě</b> 00eb
	<b>ē</b> 0112	<b>ē</b> 0113	<b>Ě</b> 0114	<b>ě</b> 0115	<b>Ě</b> 0116	<b>ě</b> 0117
	<b>Ę</b> 0118	<b>ę</b> 0119	<b>Ę</b> 011a	<b>ę</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>H</b> 24bd	<b>h</b> 2095	
					<b>ń</b> 0127	<b>ń</b> 210f
<b>I</b> 0049	<b>i</b> 0069	<b>I</b> 24be	<b>i</b> 24a4	<b>ǐ</b> 00cc	<b>ǐ</b> 00ec	
	<b>í</b> 00cd	<b>í</b> 00ed	<b>ǐ</b> 00ce	<b>í</b> 00ee	<b>ǐ</b> 00cf	<b>í</b> 00ef
	<b>Ī</b> 012a	<b>ī</b> 012b	<b>Ǐ</b> 012c	<b>ǐ</b> 012d	<b>Ǐ</b> 012e	<b>ǐ</b> 012f
					<b>ǐ</b> 0130	<b>í</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>Ň</b> 00d1	<b>ň</b> 00f1
	<b>Ń</b> 0143	<b>ń</b> 0144	<b>Ň</b> 0147	<b>ń</b> 0148	<b>Ń</b> 2115	
<b>o</b> 004f	<b>o</b> 006f	<b>o</b> 00ba	<b>o</b> 00a9	<b>o</b> 24c4	<b>o</b> 24aa	<b>o</b> 2092
	<b>ò</b> 00d2	<b>ò</b> 00f2	<b>ó</b> 00d3	<b>ó</b> 00f3	<b>ò</b> 00d4	<b>ó</b> 00f4
	<b>ő</b> 00d5	<b>ő</b> 00f5	<b>ö</b> 00d6	<b>ö</b> 00f6	<b>ő</b> 00d8	<b>ő</b> 00f8
	<b>ō</b> 014c	<b>ō</b> 014d	<b>ǒ</b> 014e	<b>ǒ</b> 014f	<b>œ</b> 0152	<b>œ</b> 0153
<b>P</b> 0050	<b>p</b> 0070	<b>P</b> 24c5	<b>p</b> 24ab	<b>p</b> 209a		

<b>Q</b> 0051	<b>q</b> 0071	<b>q</b> 24c6	<b>q</b> 24ac	<b>Q</b> 211a			
<b>R</b> 0052	<b>r</b> 0072	<b>r</b> 24ad	<b>r</b> 24c7	<b>R</b> 0154	<b>r</b> 0155		
				<b>R</b> 0158	<b>r</b> 0159	<b>R</b> 211d	
<b>S</b> 0053	<b>s</b> 0073	<b>s</b> 24c8	<b>s</b> 24ae	<b>s</b> 209b	<b>S</b> 015a	<b>s</b> 015b	
	<b>ſ</b> 015e	<b>ſ</b> 015f	<b>ſ</b> 0160	<b>ſ</b> 0161	<b>þ</b> 00df		
<b>T</b> 0054	<b>t</b> 0074	<b>T</b> 24af	<b>T</b> 22a4	<b>t</b> 24c9	<b>t</b> 209c		
			<b>T</b> 0162	<b>þ</b> 0163	<b>þ</b> 0164	<b>þ</b> 0165	
<b>U</b> 0055	<b>u</b> 0075	<b>u</b> 24ca	<b>u</b> 24b0	<b>u</b> 1d64	<b>Ü</b> 00d9	<b>ü</b> 00f9	
	<b>ú</b> 00da	<b>ú</b> 00fa	<b>ú</b> 00db	<b>ú</b> 00fb	<b>Ü</b> 00dc	<b>ü</b> 00fc	
	<b>ő</b> 0168	<b>ő</b> 0169	<b>ő</b> 016a	<b>ő</b> 016b	<b>ő</b> 016c	<b>ő</b> 016d	
			<b>ő</b> 016e	<b>ő</b> 016f	<b>ő</b> 0172	<b>ő</b> 0173	
<b>V</b> 0056	<b>v</b> 0076	<b>v</b> 24cb	<b>v</b> 24b1				
<b>W</b> 0057	<b>w</b> 0077	<b>w</b> 24cc	<b>w</b> 24b2	<b>ŵ</b> 0174	<b>ŵ</b> 0175		
<b>X</b> 0058	<b>x</b> 0078	<b>x</b> 1d61	<b>x</b> 24cd	<b>x</b> 24b3	<b>x</b> 2093		
			<b>ẍ</b> 0379	<b>ẍ</b> 0378	<b>ẍ</b> 037f	<b>ẅ</b> 221c	
<b>Y</b> 0059	<b>y</b> 0079	<b>ȝ</b> 24ce	<b>y</b> 24b4	<b>ÿ</b> 00dd	<b>ý</b> 00fd		
	<b>ÿ</b> 0176	<b>ȝ</b> 0177	<b>ÿ</b> 0178	<b>ÿ</b> 00ff	<b>ÿ</b> 0233	<b>ý</b> 0232	
<b>Z</b> 005a	<b>z</b> 007a	<b>ȝ</b> 24cf	<b>z</b> 24b5	<b>ž</b> 0179	<b>ž</b> 017a	<b>ž</b> 017b	
			<b>ž</b> 017c	<b>ž</b> 017d	<b>ž</b> 017e	<b>ž</b> 2124	
<b>Α</b> 0391	<b>α</b> 03b1	<b>α</b> 2065	<b>ά</b> 03ac				
<b>Β</b> 0392	<b>β</b> 03b2						
<b>Γ</b> 0393	<b>γ</b> 03b3						
<b>Δ</b> 0394	<b>δ</b> 03b4	<b>δ</b> 2066					
<b>Ε</b> 0395	<b>ε</b> 03b5	<b>έ</b> 03ad					
<b>Ζ</b> 0396	<b>ζ</b> 03b6						
<b>Η</b> 0397	<b>η</b> 03b7	<b>ή</b> 03ae					
<b>Θ</b> 0398	<b>θ</b> 03b8						
<b>Ι</b> 0399	<b>ι</b> 03b9	<b>ί</b> 03af	<b>ϊ</b> 03aa	<b>ΐ</b> 03ca	<b>ΐ</b> 0390		

<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>ό</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>T</b> 03a4	<b>τ</b> 03c4	
<b>Υ</b> 03a5	<b>υ</b> 03c5	<b>ύ</b> 03cd <b>Ύ</b> 03ab <b>ϋ</b> 03cb <b>ΰ</b> 03b0
<b>Φ</b> 03a6	<b>φ</b> 03c6	
<b>X</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	23a4   23a5 ] 23a6
{ 007b	} 007d	
▲ 2430	▲ 2431	▲ 2432    ▲ 2433
+ 002b	+ 207a	+ 208a    ± 00b1
- 002d	- 207b	-1 2072    - 208b    ± 2213
× 00d7	× 00b7	• 2219    • 2218    * 002a    * 208f
/ 002f	\ 005c	
^ 005e		
, 002c	, 2429	
. 002e	. 2428	... 2026
! 0021	! 00a1	

?	003f	⸮	00bf										
:	003a	:	2236	÷	00f7								
;	003b												
'	0027	‘	2018	’	2019	,	201a	‘	201b	104			
”	0022	“	201c	”	201d	,,	201e	“	201f	« 00ab	» 00bb		
@	0040												
-	005f	„	2427										
~	007e												
→	2192	↗	21c0										
←	2190	↖	21cd										
↑	2191	↑	21e7	▲	21c9	↑	242b						
↓	2193	↓	21e9	▼	21cb								
↗	21c4												
↙	2195												
☰	21cc												
¬	00ac												
ѧ	2227	ყ	2228	ყ	22bb	Ա	22bc	Վ	22bd				
&	0026												
	007c		2223		2224		2225		2226				
«	226a	◀	003c	◀	2264	≡	2261	=	2254	= 003d	≈ 2243		
		≈	2248	≡	2258	△	2259	≠	2260	≥ 2265	> 003e		
										» 226b			
%	0025	\$	0024	€	20ac	¢	00a2	£	00a3	¥	00a5	₪ 00a7	
✓	221a	♾	221d										
♾	221e	♾	209e	♾	209f								
ʃ	222b	ʃ	222c	ʃ	222d	ƒ	222e	ƒ	222f	ƒ	2230		

<sup>104</sup> Look up [https://de.wikipedia.org/wiki/Anführungszeichen#Andere\\_Sprachen](https://de.wikipedia.org/wiki/Anführungszeichen#Andere_Sprachen) or [https://en.wikipedia.org/wiki/Quotation\\_mark#Summary\\_table](https://en.wikipedia.org/wiki/Quotation_mark#Summary_table) for properly using these characters in different languages.

⌚ 2299	⌚ 229a	⌚ 2068	
⊕ 2295	⊕ 2069		
Ἑ 221f	Ἱ 22a5		
ἢ 2220	ἢ 2221	ἢ 2222	
ὢ 2308	ὢ 2309		
ὢ 230a	ὢ 230b		
ὤ 2399	ὤ 231b	ὤ 231a	ὤ 242a
ὤ 242c	ὤ 242f	ὤ 2434	
# 0023			
Ὡ 242d	Ὡ 242e		
Ὡ 2200	Ὡ 2202	Ὡ 2203	Ὡ 2204
	Ὡ 2208	Ὡ 2209	Ὡ 220b
Ὡ 2421	Ὡ 2422	Ὡ 2425	Ὡ 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 as well as 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 support of special actions, 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 keeping them as they were on the vintage *HP RPN* pocket calculators up to the *HP-42S* (and *WP 34S* and *WP 31S*):

Only **ENTER↑**, **CLX**, **Σ+**, and **Σ-** disable **ASL**, all other functions enable it. But compare **INPUT** on p. 40 as well as **M.EDI** and **M.EDIN** on p. 51.

## 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 state as it was before executing last command. Until 2020, we assumed that such a complete **UNDO** was viable in *WP 43S* as well, but the overhead turned out forbidding.

Since

- any user *flags* altered inadvertently can be reverted easily and
- any wide-reaching clear commands (CLREGS, CLFALL, CLPALL, etc.) ask for confirmation before executing,

we implemented UNDO recalling not only the *stack* but also the summation *registers* and system *flags* as they were before executing last command, for better user experience (this specification also allows for undoing  $\Sigma-$ ).

DRAFT

## For Your Convenience

Please find here the display frame of your *WP 43S* as we designed it (printed to scale), and below its virtual keyboard in alpha input mode (*AIM*) plus a branching helper.

Overleaf, its original keys and keyplate are printed to scale. You will also find there an explanatory picture taken from the back of an *HP-16C* (with C denoting CARRY and G standing for OVERFL).

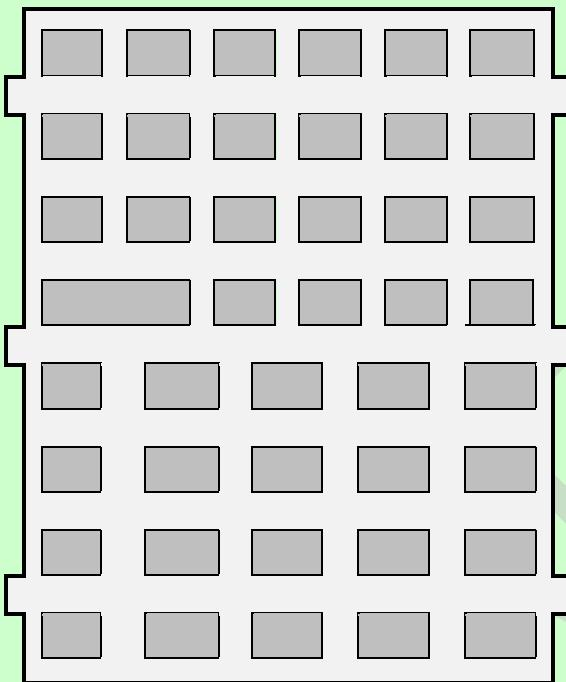
Choose your favorites, cut them out, and use them with your *WP 43S*. If you bought it complete and flashed, keys and keyplate shall be printed properly on its top face and the picture shown here at right is on its rear for your reference.





	C	G	
$+$	x	x	
$-$	--	x	
$\times$	x	x	$\text{RMD} \neq 0 \rightarrow C$
$\div$	x	--	$\text{RMD} \neq 0 \rightarrow C$
$\sqrt{x}$	x	--	$\text{RMD} \neq 0 \rightarrow C$
$\text{CHS ABS}$	--	x	
$\text{DBL } X$	--	o	$y = x * (X \& Y)$
$\text{DBL } Z$	x	o	$(Y \& Z) \div x \rightarrow X ; \text{RMD} \neq 0 \rightarrow C$
$\text{SL}$	x	--	$\square \leftarrow \square \rightarrow \square \rightarrow o$
$\text{SR}$	x	--	$o \rightarrow \square \rightarrow \square \rightarrow \square$
$\text{ASR}$	x	--	$\square \rightarrow \square \rightarrow \square \rightarrow \square$
$\text{RL}$	x	--	$\square \leftarrow \square \rightarrow \square \rightarrow \square$
$\text{RR}$	x	--	$\square \rightarrow \square \leftarrow \square \rightarrow \square$
$\text{RLC}$	x	--	$\square \leftarrow \square \rightarrow \square \rightarrow \square$
$\text{RRC}$	x	--	$\square \rightarrow \square \leftarrow \square \rightarrow \square$

Template for a quick overlay (almost to scale – see point 3 below):



1. Print out on standard copy paper ( $80 \text{ g/m}^2$ ). Fill in labels where, if, and as required.
2. Laminate with 80 mics stock (result is a thickness of about 0.25 mm).
3. Cut out voids for keys and perimeter. Attention: Tabs (a.k.a. tongues) as drawn are too wide and too long, cut smaller.