

WP43S REFERENCE MANUAL

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

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

DRAFT

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The pictures on p. 157 and bottom of p. 158 were kindly supplied by *SwissMicros* as well as the drawing on p. 208, the picture on p. 204 by *Martin Lorang*. The plots in Appendix H are based on material found in *Wikipedia*. The other pictures, diagrams, and graphics were created by the author.

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

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

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

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

Statement of Corporate Objectives
Hewlett-Packard

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WELCOME!

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

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

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

Enjoy!

Walter Bonin

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Print Conventions and Common Abbreviations

Throughout this manual, standard text font is Arial. Emphasis is added by underlining or **bold** printing. Calculator COMMANDS, MENUS, PREDEFINED VARIABLES and SYSTEM FLAGS are generally called by their *names*, printed capitalized in running text (*menus* underlined). **Quoted text is printed blue** (as well as [translator's footnotes](#)). **Specific terms, titles, trademarks, names or abbreviations** are printed in italics, [hyperlinks](#) in blue underlined italics. The latter will beam you to its target in the .pdf file – it cannot work in a printed copy for obvious reasons; thus such a link generally refers to a page number, to the [Table of Contents](#)

, or to a fully specified external address.

- Bold italic Arial letters such as *n* are used for variables; bold normal letters for constant **sample values** (e.g. labels, numbers, or characters).
- Courier is used for file names, binary and hexadecimal codes, and describing numeric formats.
- Times New Roman regular letters are for unit symbols and for mathematical functions. Italics are for *unit names* in running text.
- Times New Roman **bold** capitals are used for **REGISTER ADDRESSES**, lower case bold italics for *register contents*. So e.g. the value *y* lives in *register Y* and *r45* in *R45*. Overall stack contents are generally quoted in the order [*x, y, z, ...*]. We keep the term *register* for the space where an individual object is stored, although the actual size of such a *register* may vary widely following the size of the object stored therein.
- This **KEY** font (created by *Luiz Vieira* of Brasil) is taken for references to calculator keys, including **SOFTKEYS** in general. For shifted operations like **GTO** or **LBL**, the respective color is used. **Alphanumeric** and numeric calculator outputs (like 1.234×10^{-56} or $7,089 \cdot 10^{-12}$) are printed as you see them on the calculator screen.
- We will use decimal points in most parts of this manual (but you may set your WP 43S to decimal commas as well, of course). Although that point is less visible than a comma, 'comma people' seem to be

more tolerant against points used as radix marks than vice versa (based on the number of complaints read).

All this holds unless stated otherwise locally.

The following abbreviations are used throughout this manual:

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

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

BCD = binary coded decimal.

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

DP = double precision.

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

HP = Hewlett-Packard.

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

LCD = liquid crystal display.

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

OM = Owner's Manual.

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

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

px = pixels.

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

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

SP = single precision.

SRS = subroutine return stack (see *App. B* on pp. 161ff).

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

Some more abbreviations may be used and explained locally.

SECTION 1: INDEX OF ITEMS (I/O)

All the *items* provided on your *WP 43S* (more than 850) are listed below with their *names* (as they are printed in routines) in column 1 and the keystrokes necessary to call them. Most *items* shall be picked from *menus* (see pp. 117ff).¹

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

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



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

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

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

² These labels are not required to be unique, be they printed or displayed.

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

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

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

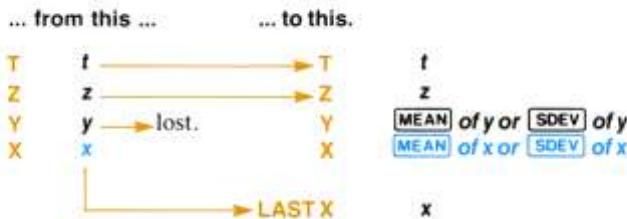
For the vast majority of operations, remarks start with a number:

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

Note some functions overwrite two *stack* levels instead of pushing two values on it: e.g. →POL and →REC, as you may have expected.⁴

⁴ On the *HP-42S*, however, also statistical functions returning two values do that – while the *Spices* (e.g. *HP-34C*) and *Voyagers* (e.g. *HP-15C*) push both results on the stack instead as you expect from *RPN* calculators. For your information, the picture below shows what the *HP-55*, *HP-19C/29C*, *HP-67/97*, *HP-41C*, and *HP-42S* do there:

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



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

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

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

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

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

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

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

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

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

Note that for any command XYZ requiring one trailing input parameter, you can enter XYZ → ST.X and it will take its parameter from X instead – like a good old traditional *RPN* command.

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

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

The *data types* a particular function operates on are listed in { } under “remarks” if there are restrictions – cf. App. B on pp. 161ff. Most bit and integer functions operate on *short integers* only (*data type* 10). The other functions typically work with more kinds of objects. Functions stating *data types* 8* or 9* instead of 8 or 9 operate on each *matrix element* instead of the entire matrix (as explained in *Section 2* of the OM). Wherever operations return *data types* differing from their input, the output types are listed as well.⁷

⁵ Some reasoning why *automatic stack lift* is disabled for these four:

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

⁶ We did not compare the *RPL* calculators of the last three decades or the *HP Prime*. They are exceeding the realm of shirt pocket calculators.

⁷ This applies for °C→°F, for instance: For SP (DP) real input, output will stay SP (DP) real. For integer input, however, output will be SP real.

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

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---|---|--|
| $^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$ | $^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$ etc. | (1) {2, 11}; {1} → {2} Convert temperatures. See pp. 140ff. |
| 10^x | | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} Returns 10^x , the inverse of $\lg(x)$. |
| 1COMPL | 1COMPL ... | (0) Sets 1's complement mode for operations on <i>short integers</i> . Indicated in the status bar. See Sect. 2 of the OM. |
| $\frac{1}{2}$ | | (-1) {} → {2} Trivial but helpful constant for iterations. |
| $\frac{1}{x}$ | | (1) {2, 3, 8*, 9*, 11, 12}; {1} → {2} Inverts the number x or all elements of the matrix x . |
| 2COMPL | 2COMPL ... | (0) Sets 2's complement mode for operations on <i>short integers</i> . Indicated in the status bar. See Sect. 2 of the OM. |
| 2^x | | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} Returns 2^x . |
| $\sqrt[3]{x}$ | | (1) {1, 2, 3, 8*, 9*, 10, 11, 12}; ({1} → {2}) Returns the cube root of x . Roots of non-cube <i>long integers</i> will return reals. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------------|---|--|
| a | g CNST a | (-1) {} → {2} Gregorian year in days and Bohr radius in meter. |
| a_0 | g CNST a_0 | |
| ABS | f CAT. FCNS ABS | Points to x on p. 98. Maintained for backward compatibility only. |
| ACOS | f CATALOG FCNS ACOS | Points to arccos on p. 18. |
| $ac \rightarrow m^2$ | g U f A: acre → m² | (1) {2, 11}; {1} → {2} |
| $ac_{us} \rightarrow m^2$ | g U f A: acre_{us} → m² | Convert areas. See pp. 140ff. |
| ADV | f ADV | Menu. See p. 123. |
| AGM | g X.FN AGM | (2) {2, 3, 11, 12}; {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. 242 for more. |
| AGRAPH | g P.FN P.FN2 g AGRAPH s | (0) Alpha graphics. Displays a graphics image. Each character in the source s specifies an 8-dot-1-column pattern. The X- and Y-registers specify the pixel location of the bottom left point of this column. $1 \leq x \leq 400$ and $1 \leq y \leq 232$ are valid (but see App. K). So one row (8 px high) starting in column 1 may need up to 400 characters to specify – the more blank space is found therein the less characters may be required for describing it entirely. Cf. <i>HP-42S Owner's Manual</i> , pp. 135 – 140, and <i>HP-42S Programming Examples and Techniques</i> , pp. 214 – 223. |
| ALL | g DISP ALL n | (0) Sets the numeric display format to show all decimals of real or complex SP or DP numbers whenever displayable (trailing decimal zeros will not be shown). ALL 00 works like ALL in HP-42S almost. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------------------------|--|---|
| | | For $x \geq 10^{16}$ (or earlier for complex numbers), however, display will switch to SCI or ENG ... with the maximum number of necessary decimals displayable using the large font (see ALLSCI). The same will happen if $x < 10^{-n}$ and more than 16 digits are required to show x entirely (see examples in Section 2 of the OM). The limits differ in RBR – see p. 62. |
| a_{Moon} | g [CNST] a_{Moon} | (-1) {} → {2} Semi-major axis of the Moon's orbit around the earth in meter. |
| AND | f [BITS] AND | (2) {10} Works bitwise as in HP-16C (see the OM, Sect. 2). (2) {1, 2, 11} → {1} Works like AND in HP-28S, i.e. x and y are interpreted before executing this operation. Zero is ‘false’; any other real number is ‘true’. |
| ANGLES | f [CAT.] VARS ANGLES | Submenu of tagged angular variables defined at execution time. See pp. 117f. |
| \arccos | [TRI] arccos | (1) {3, 8*, 9*, 12}; {1, 2, 11} → {4}; Returns the tagged angle $\arccos(x)$. ⁸ |
| arcosh | g [EXP] g arcosh [TRI] g arcosh | (1) {2, 3, 8*, 9*, 11, 12} Returns $\operatorname{arcosh}(x)$. |
| \arcsin | [TRI] arcsin | (1) {3, 8*, 9*, 12}; {1, 2, 11} → {4}; Returns the tagged angle $\arcsin(x)$. ⁹ |

⁸ Precisely, ARCCOS returns the principal value of $\arccos(x)$, i.e. a real part $\in [0, \pi]$ in 4^r , or $\in [0^\circ, 180^\circ]$ in 4° or $4''$, or $\in [0^g, 200^g]$ in 4^g , or $\in [0, 1]$ in 4π . Cf. ISO/IEC 9899.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|-------------------------|---|
| arctan | TRI arctan | (1) {3, 8*, 9*, 12}; {1, 2, 11} → {4}; Returns the tagged angle $\text{arctan}(x)$. ¹⁰ |
| arsinh | g EXP g arsinh | (1) {2, 3, 8*, 9*, 11, 12} |
| | TRI g arsinh | Returns $\text{arsinh}(x)$. |
| artanh | g EXP g artanh | (1) {2, 3, 8*, 9*, 11, 12} |
| | TRI g artanh | Returns $\text{artanh}(x)$. |
| ASIN | f CATALOG FCNS ASIN | Points to arcsin above. Maintained for backward compatibility only. |
| ASR | f BITS f ASR n | (1) {10} Works like n (≤ 63) consecutive ASR commands in HP-16C, corresponding to a division of x by 2^n . ASR 0 executes as NOP, but loads L. See Sect. 2 of the OM. |
| ASSIGN | f ASN item, location | (0) Assigns an item (i.e. a function, a menu, a label, or a character) to a specified sequence of keystrokes, corresponding to a specific location on the keyboard or in a menu. See Section 6 of the OM. |
| ATAN | f CATALOG FCNS ATAN | Points to arctan above. Maintained for backward compatibility only. |
| atm→Pa | g U F&p: f atm→Pa | (1) {2, 11}; {1} → {2} |
| au→m | g U x: au→m | Convert pressures and distances. See pp. 140ff. |

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

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------|--|--|
| A...Z | f CATALOG CHARS A...Z | Submenu of Latin letters. See pp. 117ff. |
| A: | g U→ f A: | Submenu. See p. 140. |
| a _⊕ | g CNST a _⊕ | (-1) {} → {2} Semi-major axis of the Earth's orbit around the sun in <i>meter</i> . |
| BACK | g P.FN P.FN2 g BACK n | (0) Jumps <i>n</i> steps backwards ($0 \leq n \leq 255$) in a program. E.g. BACK 1 goes to the previous program step. If BACK attempts to cross an END, an error is thrown. Reaching step 000 stops program execution and lights . Cf. SKIP. ATTENTION: 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 | g U→ F&p: bar→Pa | (1) {2, 11}; {1} → {2} Converts pressures. See pp. 140ff. |
| BATT? | g INFO f BATT? | (-1) {} → {2} Measures the battery voltage in the range between 1.9V and 3.4V and returns this value. |
| bbl→m ³ | g U→ f V: f barrel → m ³ | (1) {2, 11}; {1} → {2} Converts volumes. See pp. 140ff. |
| BC? | f BITS g BC? n | (-1) {10} Tests if the specified bit in <i>x</i> is clear. |
| BEEP | g I/O BEEP | (0) Sounds a sequence of four tones. See also TONE. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------|--|--|
| BeginP | g [FIN] TVM f Begin | (0) Sets “Begin” mode in <i>TVM</i> : payments occur at the beginning of each period. Typical for savings plans and leasing. Cf. ENDP. |
| BestF | f [STAT] ▼ BestF <i>n</i> | <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 <i>BEST</i> in <i>HP-42S</i>).</p> <p>Relevant for L.R., CORR, COV, s_{xy}, \hat{x}, and \hat{y}. You can accelerate computation of these functions significantly by excluding fit models making no sense for your data (e.g. for physical or technical reasons). The parameter <i>n</i> carries this information. Each fit model corresponds to a number as listed:</p> <ul style="list-style-type: none"> • LINF 1 • EXPF 2 • LOGF 4 • POWERF 8 • ROOTF 16 • HYPF 32 • PARABF 64 • CAUCHF 128 • GAUSSF 256 <p>Take the numbers of all models you can exclude and sum them up – the result is <i>n</i>.</p> <p>Example: Excluding the three 3-parameter models results in $n = 64 + 128 + 256 = 448$. So call BESTF 448 to look for the best-fitting 2-parameter model..</p> <p>Note ORTHOF is <u>not</u> part of the set of models under investigation. See pp. 212ff for more.</p> |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------------|------------------------------|--|
| Binom | g PROB | (1) {2, 11} |
| Binom_e | g Binom: | <i>Binomial distribution</i> with the number of successes g in X , the probability of a success p₀ in I , and the sample size n in J . See p. 212 for more. |
| Binom_p | Binom etc. | Binom^{-1} returns the maximum number of successes m for a given probability p in X , p₀ in I and n in J . |
| Binom: | g PROB g Binom: | Submenu. See p. 126. |
| BITS | f BITS | Menu. See p. 121. |
| B_n | g X.FN B_n | (1) {1, 2, 11} |
| B_n* | g X.FN B_n* | B_n and B_n^* return the Bernoulli number for an integer $n > 0$ given in X , working with different definitions (see both formulas on p. 210). |
| BS? | f BITS g BS? n | (0) {10} Tests if the specified bit in x is set. |
| Btu→J | g U→ E: Btu→J | (1) {2, 11}; {1} → {2} Converts energies. See pp. 140ff. |
| c | g CNST c etc. | (-1) {} → {2} |
| c₁ | | Speed of light in vacuum in <i>meter per second</i> ; |
| c₂ | | first and second radiation constants in <i>Planck's Law</i> (see p. 133). |
| cal→J | g U→ E: cal→J | (1) {2, 11}; {1} → {2} Converts energies. See pp. 140ff. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------|--|--|
| CASE | g P.FN P.FN2 g CASE S | <p>(0) Works like SKIP below but takes the number of steps to skip from s.</p> <p>Example: Assume a program section:</p> <pre> ... 100 CASE 12 101 GTO 01 102 GTO 02 103 GTO 07 104 GTO 05 105 LBL 01 ... 132 LBL 02 ... 153 LBL 05 ... 234 LBL 07 ... </pre> <p>In execution of this program, $r12$ will be checked in step 100: if $r12 \leq 1$ then the program will proceed to step 101 and continue with a jump to step 105, for $r12 = 2$ the program will go to step 102, etc., resulting in a nice controlled dispatcher for $1 \leq r12 \leq 4$.</p> <p>ATTENTION: CASE might surprise you for $r12 > 4$ 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 manually maintain all those statements individually.</p> |
| CATALOG | f CATALOG | <i>Catalog</i> of everything. See pp. 117ff. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------------|--|---|
| Cauch | g PROB f Cauch: Cauch etc. | (1) {2, 11} <i>Cauchy-Lorentz</i> (a.k.a. <i>Lorentz</i> or <i>Breit-Wigner</i>) distribution with the location x_0 specified in I and the shape γ in J . See p. 215 for more. |
| Cauch_e | | |
| Cauch_p | | |
| Cauch⁻¹ | | Cauch ⁻¹ returns x for a given probability p in X , with x_0 in I and γ in J . |
| Cauch: | g PROB f Cauch: | Submenu . See p. 126. |
| CauchF | f STAT ▾ f CauchF | (0) Selects the Cauchy (a.k.a. Lorentz) peak fit model. Relevant for CORR, COV, L.R., s_{xy} , \hat{x} , and \hat{y} . See pp. 221ff for more. |
| 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, 11} → {1} Returns the smallest integer $\geq x$. Cf. FLOOR. |
| CF | g FLAGS 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. 117ff. |
| CLALL | g CLR g CLall | (0) Clears all registers, user flags, variables, and programs in RAM. Modes will stay as they are. Cf. CLCVAR, CLFALL, CLPALL, CLREGS, CLSTK, and RESET. |
| CLCVAR | g CLR CLCVAR | (0) Clears all variables used in the <i>current program</i> , i.e. sets all such real and complex variables to 0.. , all integer ones to 0 , all time variables to 0:00:00 , all date variables to January 1st of year 0 , all character strings to zero length, and all the elements of all matrix variables used to zero. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------|--|---|
| CLFALL | g FLAGS g CLFall g CLR f CLFall | (0) Clears all global and local user <i>flags</i> . Compare CF. |
| CLK | g CLK | Menu . See p. 117. |
| CLLCD | g CLR f CLLCD | (0) Clears the <i>LCD</i> in the rectangular window north and west of the point <i>x, y</i> . I.e. all pixels $\geq x$ and $\geq y$ are cleared. |
| CLMENU | g CLR CLMENU g P.FN P.FN2 ... | (0) Clears all <i>menu</i> key definitions for the programmable <i>menu</i> . See MENU. |
| CLP | g CLR CLP | (0) Clears the <i>current program</i> in RAM or FM. Freed memory is returned to the pool of free space. |
| CLPALL | g CLR f CLPall | (0) Clears all programs in RAM. Cf. CLP. |
| CLR | g CLR | Menu . See p. 123. |
| CLREGS | g CLR f CLREGS | (0) Clears all global and local general purpose <i>registers</i> allocated (see also LOCR), i.e. sets all these registers to 0. The contents of the stack and L are kept. |
| CLSTK | g CLR f CLSTK 0 g FILL | Clears all <i>stack registers</i> currently allocated (i.e. either X ... T or X ... D). All other <i>register</i> contents are kept. Cf. CLREGS. |
| CLX | g CLR CLX ⬅ | (1) Clears <i>register X</i> , disabling <i>automatic stack lift</i> . The shortcut works for closed x only. Cf. CLREGS. |
| CLΣ | f STAT g CLΣ g CLR CLΣ | (0) Clears the statistical summation <i>registers</i> and releases the memory allocated for them (see p. 164). |
| CNST | g CNST | Menu . See CONST below and pp. 140ff. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|------------------------------------|---|
| COMB | g PROB C_{yx} | (2) {1} Returns the number of possible <u>subsets</u> of x items taken out of a set of y items (i.e. choose x out of y). No item occurs more than once in a subset, and <u>different orders</u> of the same x items are <u>not counted</u> separately. Cf. PERM. |
| | | (2) {2, 3, 11, 12} See pp. 210ff for the formula. |
| CONJ | g CPX conj | (1) {3, 9*, 12} Returns the complex conjugate of x . |
| CONST | g P.FN f CONST n | (-1) {} → {2} Returns the constant stored at position n in <u>CNST</u> (see pp. 131ff). Allows for indirectly addressing these constants. |
| CONVG? | g TEST g CONVG? r | (0) {2, 11} Checks for convergence by comparing x and y as determined by the lowest five bits of r . a) The very lowest two bits set the tolerance limit: $0 = 10^{-14}, \ 1 = 10^{-24}, \ 2 = 10^{-32}$. b) The next two bits determine the comparison mode using the tolerance limit set: $0 = \text{compare the numbers } x \text{ and } y \text{ relatively},$ $1 = \text{compare them absolutely}.$ c) The top bit tells how special numbers are treated: $0 = \text{NaN and } \pm\infty \text{ are considered converged},$ $1 = \text{they are not considered converged}.$ Now, $r = a + 4b + 16c$. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|--|--|
| CORR | f STAT ▲ r | (-1) {} → {2} Returns the <i>coefficient of correlation</i> for the current statistical data and curve fit model. See pp. 221ff for more. |
| COS | TRI cos | (1) {2, 3, 8*, 9*, 11, 12}; {1, 4} → {2} Returns the cosine of the angle in X (see Section 2 of the OM for details). |
| cosh | g EXP g cosh | (1) {2, 3, 8*, 9*, 11, 12} |
| | TRI g cosh | Returns the hyperbolic cosine of x. |
| COV | f STAT ▲ f cov | (-1) {} → {2} Returns the population covariance for the two data sets entered via (Σ+) , depending on the curve fit model selected. See s_{xy} for the sample covariance and pp. 212ff for more. |
| CPX | g CPX | Menu. See p. 124. |
| CPXS | f CAT. VARS CPXS | Submenu of complex variables defined at execution time. See pp. 117f. |
| CPX? | g TEST ▲ CPX? | (0) Checks if x is complex. Returns true if X contains data of type 3, 9, or 12 with nonzero imaginary part. |
| CROSS | f MATX f cross | (2) {8} Requires two real 2D or 3D vectors in X and Y and returns their cross product. Crossing of 2D vectors works as for complex numbers. |
| | g CPX cross | (2) {3} → {2}; {12} → {11} When two complex numbers are crossed, your WP 43S simply returns a real number that is equal to the signed magnitude of the resulting moment vector. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------|--|---|
| ct→kg | g [U→] m: f carat → kg | (1) {2, 11}; {1} → {2} |
| cwt→kg | g [U→] m: cwt→kg | Convert masses. See pp. 140ff. |
| CX→RE | CC (works in run mode only) g [CPX] f CX→RE | <p>(-1) {3} → {2}; {9} → {8}; {12} → {11}</p> <p>Cuts a closed complex object x, putting either</p> <ul style="list-style-type: none"> (for L) its real part in \mathbf{Y} and its imaginary part in \mathbf{X} or (for \odot) magnitude in \mathbf{Y} and phase in \mathbf{X}. |
| DATE | g [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 Sect. 2 of the OM). |
| DATES | f [CATALOG] VARS f [DATES] | <i>Submenu</i> of <i>date</i> variables defined at execution time. See pp. 117f. |
| DATE→ | g [CLK] DATE→ | (-2) {2, 6, 11} → {1} Assumes x containing a <i>date</i> in the format selected (or a real number in corresponding format) and pushes its three components as integers on the <i>stack</i> . Reversible by →DATE. |
| DAY | g [CLK] f DAY | (1) {2, 6, 11} → {1} Assumes x containing a <i>date</i> in the format selected (or a real number in corresponding format) and extracts the day. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|---|---|
| DBLR | g INTS g DBLR etc. | (10) Double word length commands for remainder, multiplication and division. ¹¹ |
| DBLx | | DBLR and DBL / accept a double size dividend in Y and Z (most significant bits in Y), the divisor in X as usual, and return the result in X . |
| DBL/ | | DBLx takes x and y as factors as usual but returns the product in X and Y (most significant bits in X). |
| DBL? | g TEST ▲ f DBL? | (0) Checks if x contains a double precision real or complex number. |
| dB→fr | g U→ ▲ dB → field ratio | (1) {2, 11}; {1} → {2} |
| dB→pr | g U→ ▲ dB → power ratio | Convert ratios. See pp. 140ff. |
| DEC | f LOOP f DEC r | (0) {1, 2, 10, 11} Decrements r by 1. Does not load L even for target address X . |
| DECOMP | f PARTS DECOMP | (-1) {1, 2, 11} → {1} Decomposes x (after converting it to an <i>improper fraction</i> , if applicable), returning a stack [<i>denominator</i> (x), <i>numerator</i> (x), ...]. Reversible by division. Example: If X contains 2.25 then DECOMP will return $x = 4$ and $y = 9$. |
| DEG | g MODE DEG | (0) Sets the <i>ADM</i> to <i>decimal degrees</i> . Indicated in the status bar. |
| DEG→ | f L→ f DEG→ | (1) {1, 2, 11} → {4} Converts angles as described on p. 148. |

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|-------------------------------|--|
| DENMAX | g MODE DENMAX | (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. Indicated in the status bar. For $x = 1$, the current DENMAX setting is recalled, replacing x . |
| DET | f CATALOG FCNS DET | Points to M explained on p. 98. Maintained for backward compatibility only. |
| DIGITS | f CAT. DIGITS | Submenu of digits. See pp. 117f. |
| DISP | g DISP | Menu. See p. 124. |
| DOT | g CPX dot | (2) {3} → {2}; {12} → {11} Returns $Re(x) \cdot Re(y) + Im(x) \cdot Im(y)$ |
| | f MATX f dot | (2) {8} → {2}; {9} → {3} Requires two matrices in x and y and returns their dot (scalar) product. The dot product is defined as the sum of the products of the corresponding elements in both matrices. Note both matrices must be of the same size; else DOT will throw an error. See the OM, Sect. 2. |
| DROP | g DROP↓ | Drops x ... from the stack. See Section 1 of the OM for details. |
| DROPy | g STK DROPy | Drops y |
| DSE | f LOOP DSE r | (0) {1, 2, 10, 11} Given $cccccc.ffffii$ in the source, DSE decrements r by ii , skipping next program step if then $cccccc \leq ffff$. 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 destination address X . Note that neither $ffff$ nor ii can be negative, and DSE is only sensible with $cccccc > 0$. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|--|--|
| DSL |  | (0) {1, 2, 10, 11} 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 multi-level returns like SUM will work as described in the OM regardless of the number chosen for DSTACK. In any case, command input will be echoed directly below the <i>status bar</i> . This command is for old-school calculator users who may feel distracted by a multitude of <i>stack registers</i> displayed changing simultaneously. |
| DSZ |  | (0) {1, 2, 10, 11} Decrements r by 1 and skips the next step if $ r < 1$ thereafter. Does not load L even for target address X. Cf. HP-29C, HP-67, HP-16C. |
| D.MS |  (for closed input) | (0) Sets the ADM to <i>sexagesimal degrees</i> . Indicated in the status bar. |
| D.MS→ |  | (1) {1, 2, 11} → {4} |
| D.MS→D |  | Convert angles as described on pp. 148f. |
| D.MY |  | (0) Sets the format dd.mm.yyyy for <i>dates</i> . |
| D→D.MS |  | (1) {1, 2, 11} → {4} Converts angles as described on p. 148. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|------------|--|
| D→J | | (1) {2, 6, 11} → {1} Assumes x containing a <i>date</i> in the format selected (or a real number in corresponding format) and converts it to a <i>Julian day number</i> ¹² according to J/G setting. |
| D→R | | (1) {1, 2, 11} → {4} Converts angles as described on p. 148. |
| e | | (-1) {} → {2} |
| e_E | | Elementary charge in <i>coulomb</i> and Euler's e . |
| EIGVAL | | (-1) {8, 9} Evaluates the matrix x and pushes a diagonal matrix containing its eigenvalues on the stack. |
| EIGVEC | | (-1) {8, 9} Evaluates the matrix x and pushes a matrix containing its eigenvectors on the stack. |
| END | | (0) Last command in a program and terminal for searching local labels as described in the OM, Section 3. Works like RTN in all other aspects. |
| ENDP | | (0) Sets "End" mode in TVM: payments occur at the end of each period. Typical for loans and investments. Cf. BEGINP. |
| ENG | | (0) Sets engineer's display format (see Section 2 of the OM). |

¹² Translator's note: *Julian day number* translates to "Julianisches Datum" in German and «jour Julien» in French. See the corresponding articles in Wikipedia for more.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|-----------------------------------|--|
| ENORM | f [MATX] g ENORM | (1) {8, 9} → {2} Calculates the Euclidean norm of the matrix in X . The Euclidean norm is defined as the square root of the sum of squares of all matrix elements. Works like FNRM on HP-42S. For a vector, ENORM returns its length. Cf. $ x $ on p. 98. |
| ENTER↑ | ENTER↑ | (-1) Separates two entries in input. Copies x into Y , disabling <i>automatic stack lift</i> . See p. 114 and the OM (Section 1) for details. |
| ENTRY? | g TEST g ENTRY? | (0) Checks the (internal) entry flag. It is set if: <ul style="list-style-type: none"> any character is entered in AIM, or any command is accepted for entry (be it via ENTER↑, a function key, or R/S with a partial command line). Useful in routines, e.g. after PAUSE. |
| EQN | g EQN | Menu. See p. 124. |
| EQ.DEL | g EQN f DELETE | Deletes an equation. |
| EQ.EDI | g EQN EDIT | Opens the <i>Equation Editor</i> to edit an existing equation. |
| EQ.NEW | g EQN NEW | Opens the <i>Equation Editor</i> to enter a new equation. |
| erf | g X.FN erf etc. | (1) {2, 11}; {1} → {2} |
| erfc | | Returns the error function or its complement. See pp. 242ff for more. |
| ERR | g P.FN ERR n | (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. 175ff for the respective error codes. Cf. MSG. |

See Section 4 of
the OM.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------|--------------------------------|--|
| EVEN? | g TEST f EVEN? | (0) Checks if x is integer and even. |
| e^x | e^x | (1) {2, 3, 8*, 9*, 11, 12}; {1, 10} → {2} Returns e^x . |
| EXITALL | g P.FN P.FN2 EXITall | (0) Exits all menus. |
| EXP | g EXP | Menu. See p. 124. |
| ExpF | f STAT ▾ ExpF | (0) Selects the exponential curve fit model. Relevant for CORR, COV, L.R., s_{XY} , \hat{x} , and \hat{y} . See pp. 212ff for more. |
| Expon | g PROB | (1) {2, 11} |
| Expon _e | f Expon: Expon etc. | <i>Exponential distribution</i> with the rate λ in J. See pp. 212ff for more. |
| Expon _p | | |
| Expon ⁻¹ | | Expon ⁻¹ returns the survival time t_s for a given probability p in X, with λ in J. |
| Expon: | g PROB f Expon: | Submenu. See p. 126. |
| EXPT | f PARTS EXPT | (1) {1, 2, 11} → {1} Returns the exponent h of the number $x = m \cdot 10^h$ displayed. Cf. MANT. |
| e^{x-1} | g EXP f e^{x-1} | (1) {2, 8*, 11} For $x \approx 0$, this returns a more accurate result for the fractional part than e^x does. |
| E: | g U→ E: | Submenu. See p. 140. |
| F | g CNST F | (-1) {} → {2} Faraday constant in coulomb per mol. |
| FB | f BITS g FB n | (1) {10} Inverts ('flips') the specified bit in x . |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------------|---|--|
| FBR | g a.FN g FBR | (0) Font browser. Shows all characters implemented in the 2 fonts designed for your WP 43S. |
| FCNS | f CAT. FCNS | Submenu of provided functions. See pp. 117ff. |
| FC? | g FLAGS FC? n | (0) Tests if the specified <i>flag</i> is clear. |
| FC?C | g FLAGS f FC?C n etc. | (0) Tests if the specified <i>flag</i> is clear. Clears, flips, or sets this <i>flag</i> after testing, respectively. |
| FC?F | | |
| FC?S | | |
| $F_e(x)$ | g PROB F: F_e(x) etc. | (1) {2, 11} <i>Fisher's F distribution.</i> $F_e(x)$ equals $Q(F)$ on HP-21S. The degrees of freedom are specified in I and J . See pp. 212ff for more. |
| $F_p(x)$ | | |
| $F(x)$ | | |
| $F^{-1}(p)$ | | |
| FF | g FLAGS FF n | (0) Flips the <i>flag</i> specified. |
| FIB | g X.FN f FIB | (1) {1} Returns the Fibonacci number (see pp. 210f). (1) {2, 3, 11, 12} Returns the extended Fibonacci number. |
| FILL | g FILL | Copies <i>x</i> to all stack registers. |
| FIN | g FIN | Menu. See p. 124. |
| FIX | g DISP FIX n | (0) Sets fixed point display format (see the OM, Sect. 2). |
| FLAGS | g FLAGS | Menu. See p. 124. |
| FLASH | f CATALOG PROGS FLASH | Submenu of global labels defined at execution time. See pp. 117f. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------------------------|---|---|
| FLASH? | FLASH? | (-1) {} → {1} Returns the number of free words in FM (1 word = 2 bytes). |
| FLOOR | FLOOR | (1) {8*}; {1, 2, 11} → {1} Returns the greatest integer ≤ x . Cf. CEIL. |
| fm.→m | fathom → m | (1) {2, 11}; {1} → {2} Converts distances. See pp. 140ff. |
| FP | FP | (1) {1, 2, 8*, 10, 11} Returns the fractional part of x . Cf. IP. |
| FP? | FP? | (0) Tests x for having a fractional part ≠ 0 . |
| fr→dB | field ratio→dB | (1) {2, 11}; {1} → {2} Converts ratios. See pp. 140ff. |
| FS? | FS? | (0) Tests if the specified flag is set. |
| FS?C | | (0) Tests if the specified flag is set. Clears, flips, or sets this flag after testing, respectively. |
| FS?F | FS?C | |
| FS?S | etc. | |
| ft.→m | ft.→m | (1) {2, 11}; {1} → {2} |
| ft _{us} →m | survey foot _{us} → m | |
| fz _{uk} →m ³ | V: floz _{uk} → m ³ | |
| fz _{us} →m ³ | V: floz _{us} → m ³ | |
| F _α | F _α | (-1) {} → {2} |
| F _δ | etc. | Feigenbaum's α and δ . |
| F: | F: | Submenu. See p. 126. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|------------------------------------|--|
| f' | [g] [EQN] f' | Submenus for calculating the first or second derivative of a given equation. See the OM (Sect. 4) for more. |
| f'' | [g] [EQN] f'' | |
| f'(x) | [f] [ADV] f'(x) <u>lbl</u> | (1, 2, 11) → {2} f'(x) [f''(x)] returns the 1 st [2 nd] derivative of the function f(x) at position x. This f(x) must be specified in a routine starting with LBL <i>lbl</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) | [f] [ADV] [f] f''(x) <u>lbl</u> | ATTENTION: f'(x) and f''(x) fill all stack registers with x before calling the routine specified. |
| F&p: | [g] [U→] F&p: | Submenu. See p. 140. |
| G | [g] [CNST] G | (-1) {} → {2} Newtonian constant of gravitation in $m^3/kg\ s^2$; also called γ by other authors. |
| G ₀ | [g] [CNST] G ₀ | (-1) {} → {2} Conductance quantum in <i>siemens</i> . |
| GAP | [g] [DISP] ▲ [f] GAP n | (0) Defines the interval for inserting digit group separators in reals. For integers, the intervals are fixed to 4 digits for binary and 3 for any other base – except 4, 8, and 16 where the interval is 2. In input, gaps will always be inserted as chosen for reals. After GAP 0, no group separators will be displayed neither in reals nor integers at all. See Sect. 2 of the OM. |
| GaussF | [f] [STAT] ▼ [f] GaussF | (0) Selects the Gauß peak fit model. Relevant for CORR, COV, L.R., s _{XY} , x̂, and ŷ. See pp. 221ff for more. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------------|---|--|
| G_C | g [CNST] G_C | (-1) {} → {2} Catalan's (mathematical) constant. |
| GCD | g [INTS] g GCD | (2) {1; 10} Returns the Greatest Common Divisor of x and y . ¹³ This will always be positive. |
| g_d | g [X.FN] f g_d etc. | (1) {2, 3, 11, 12}; {1} → {2} Returns the Gudermannian function or its inverse. See p. 243 for details. |
| g_e | g [CNST] g_e | (-1) {} → {2} Landé's electron g-factor. |
| Geom | g [PROB] | (1) {2, 11} |
| Geom _e | g Geom: Geom etc. | Geometric distribution: The CDF returns the probability for a first success after $m = x$ Bernoulli experiments. The probability p_0 for a success in each such experiment must be specified in J. See pp. 212ff for more. |
| Geom _p | | |
| Geom ⁻¹ | | Geom ⁻¹ returns the number of failures f before 1 st success for given probabilities p in X, p_0 in J. |
| Geom: | g [PROB] f Geom: | Submenu. See p. 126. |
| $gl_{uk \rightarrow m^3}$ | g [U→] f V: gl_{uk}→m³ | (1) {2, 11}; {1} → {2} |
| $gl_{us \rightarrow m^3}$ | etc. | Convert volumes. See pp. 140ff. |
| GM_{\oplus} | g [CNST] GM_⊕ | (-1) {} → {2} Newtonian constant of gravitation times the Earth's mass with its atmosphere included according to WGS84. ¹⁴ Displayed in m^3 / s^2 . |

¹³ See also LCM. Remember school?

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------|-----------------------------|---|
| GRAD | g MODE GRAD | (0) Sets the <i>ADM</i> to <i>grad/gon</i> . ¹⁵ Indicated in the status bar. |
| GRAD→ | f L→ f GRAD→ | (1) {2, 11}; {1} → {2} Converts angles as described on pp. 148f. |
| GTO | f GTO labl | (0) In <i>PEM</i> , inserts an unconditional branch to <i>labl</i> . Else positions the program pointer to <i>labl</i> . |
| GTO. | f GTO . n | to step <i>n</i> (specify up to four digits until becoming unambiguous in used program memory). |
| | f GTO . labl | to the global label specified. |
| | f GTO . ▲ | directly after previous END, going to the top of <i>current program</i> (see Sect. 3 of the OM). |
| | f GTO . ▼ | directly after <i>next</i> END, going to the top of <i>next program</i> . |
| | f GTO . . | to the end of used program memory in <i>RAM</i> (i.e. to the final END statement). |
| g_{\oplus} | g CNST g_⊕ | (-1) {} → {2} Standard earth acceleration in m/s^2 . |

¹⁴ See http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html.

¹⁵ This angular unit is also known as *gradian* in the English language.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------|---------------------------------------|---|
| h | g [CNST] h | (-1) {} → {2} Planck constant in joule-second. |
| ha→m ² | g [U↔] f A: ha → m² | (1) {2, 11}; {1} → {2} Converts areas. See pp. 140ff. |
| H _n | g [X.FN] Orthog H_n | (2) {2, 11}; {1} → {2} |
| H _{np} | ... Orthog f H_{np} | Hermite polynomials for probability (H _n) and physics (H _{np}). See p. 237 for details. |
| hp _E →W | g [U↔] P: hp_E→W | (1) {2, 11}; {1} → {2} Convert powers. See pp. 140ff. |
| hp _M →W | etc. | |
| hp _{uk} →W | | |
| Hyper | g [PROB] | (1) {2, 11} |
| Hyper _e | g Hyper: Hyper etc. | Hypergeometric distribution with the number of successes g in X , the probability of a success p_o in I , the sample size n in J , and the batch size n_o in K . See pp. 212ff for the formula. |
| Hyper _p | | Hyper ⁻¹ returns the maximum number of successes m for a given probability p in X , p_o in I , n in J , and n_o in K . |
| Hyper ⁻¹ | | |
| Hyper: | g [PROB] g Hyper: | Submenu. See p. 126. |
| HypF | f [STAT] ▾ f HypF | (0) Selects the hyperbolic fit model. Relevant for CORR, COV, L.R., s _{XY} , \hat{x} , and \hat{y} . See pp. 221ff for more. |
| ℏ | g [CNST] ℏ | (-1) {} → {2} $= \frac{h}{2\pi}$, reduced Planck constant (a.k.a. so-called Dirac constant) in joule-second. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|----------------------------------|---|
| IDIV | g INTS f IDIV | (2) {1, 10}; {2, 11} → {1} Integer division, working like f IP . See the OM, Sect. 2, for the <i>data type</i> of the quotient. |
| IDIVR | f CATALOG FCNS IDIVR | {1, 2, 10, 11} |
| | | Like IDIV but also returns the remainder in Y . See the OM, Section 2, for the resulting <i>data types</i> of quotient and remainder. |
| iHg→Pa | g U F&p: f in.Hg → Pa | (1) {2, 11}; {1} → {2} Converts pressures. See pp. 140ff. |
| Im | g CPX f Im | (1) {3} → {2}; {9} → {8}; {12} → {11} |
| | f PARTS g Im | Returns the imaginary part of <i>x</i> . Cf. RE. |
| INC | f LOOP f INC r | (0) {1, 2, 10, 11} Increments <i>r</i> by 1. Does not load L even for target address X . |
| INDEX | f MATX f INDEX name | (1) Indexes a named matrix. You can also index a matrix by editing it (see M.EDIT or M.EDIN). After exiting the <i>Matrix Editor</i> , the matrix is no longer indexed. See also <i>Matrix Utility Functions</i> in the HP-42S Owner's Manual, pp. 223ff. |
| INFO | g INFO | Menu . See p. 125. |
| INPUT | g P.FN INPUT r | Works in programs only: Recalls the content of the source specified into X , displays the name of the source along with <i>r</i> , and halts program execution, allowing you to enter or calculate a value; pressing R/S then stores <i>x</i> into said destination and continues program execution – pressing EXIT instead cancels INPUT, so R/S thereafter will continue with the source content as it was. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------|---------------|---|
| | | 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 | | See p. 125. |
| INT? | | (0) Tests <i>x</i> for being an integer, i.e. having a fractional part equal to zero. Cf. FP?. |
| INVRT | | Works like $[M]^{-1}$ on p. 98. Maintained for backward compatibility only. |
| in. \rightarrow m | \rightarrow | (1) {2, 11}; {1} \rightarrow {2} Converts distances. See pp. 140ff. |
| IP | | (1) {1, 8*10}; {2, 11} \rightarrow {1} Returns the integer part of <i>x</i> . Cf. FP. |
| ISE | | (0) {1, 2, 10, 11} Given ccccccc.ffffii in the source, ISE increments <i>r</i> by ii, skipping next program step if ccccccc \geq ffff then. If <i>r</i> has no fractional part then ffff = 0 and ii = 0. If ii = 0, ccccccc will be incremented by 1. ISE does not load L even for target address X. Note that neither ffff nor ii can be negative, but ccccccc can. |
| ISG | | (0) {1, 2, 10, 11} Works like ISE but skips if ccccccc > ffff. |
| ISZ | | (0) {1, 2, 10, 11} Increments <i>r</i> by 1, skipping next program step if then $ r < 1$. ISZ does not load L even for target address X. Cf. HP-29C, HP-67, and HP-16C. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------|---------------------------------|---|
| I _{xyz} | [g] X.FN [f] I _{xyz} | (3) {1, 2, 11} Returns the <i>regularized Beta function</i> . |
| IΓ _p | [g] X.FN [f] IΓ _p | (2) {1, 2, 11} |
| IΓ _q | etc. | Returns the <i>regularized Gamma function</i> (one of two kinds). |
| I+ | [f] MATX ▲ I+ | (1) Increments or decrements the row index of the indexed matrix. See INDEX and also J+, J-, RCLEL, STOEL, RCLIJ, and STOIJ. |
| I- | [f] MATX ▲ I- | |
| I/O | [g] I/O | Menu. See p. 125. |
| J _y (x) | [g] X.FN [g] J _y (x) | (2) {2, 11}; {1} → {2} J _y (x) returns the <i>Bessel function of first kind</i> and order y . See p. 244 for details. |
| J+ | [f] MATX ▲ J+ | (1) Increments or decrements the column index of the indexed matrix. If GROW is set and the pointers I and J are at the last element of the matrix, executing J+ creates a new row at the end of the matrix. See INDEX and also I+, I-, RCLEL, STOEL, RCLIJ, and STOIJ. |
| J- | [f] MATX ▲ J- | |
| J/G | [g] CLK ▲ [f] J/G | (0) {2, 6} Sets the date the Gregorian calendar was introduced in the region you are interested in. See <i>Dates</i> in Section 2 of the OM. |
| J→Btu | [g] U→ E: J→Btu | (1) {2, 11}; {1} → {2} |
| J→cal | etc. | Convert energies. See pp. 140ff. |
| J→D | [g] CLK [f] J→D | (1) {1} → {6} Takes x as a <i>Julian day number</i> ¹⁶ and converts |

¹⁶ Translator's note: *Julian day number* translates to "Julianisches Datum" in German and «jour Julien» in French. See the corresponding articles in Wikipedia for more information about these numbers.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|--|---|
| | | it to a common <i>date</i> according to J/G (see above) and the date format selected. |
| J→Wh | g U→ E: J→Wh | (1) {2, 11}; {1} → {2} Converts energies. See pp. 140ff. |
| k | g CNST k | (-1) {} → {2} <i>Boltzmann constant in joule per kelvin.</i> |
| KEY | | See KEYG and KEYX below. |
| KEYG | g P.FN P.FN2 KEYG key# , labl | Defines the label to be branched to (KEYG) or called (KEYX) when a particular <i>softkey</i> is pressed. KEYG and KEYX work in <i>PEM</i> only and will be translated to a program step KEY key# GTO labl or KEY key# XEQ labl , |
| KEYX | g P.FN P.FN2 KEYX key# , labl | respectively. Key numbers go from 1 to 18 with 1 corresponding to F1 , 9 to f F3 , and 14 to g F2 , for example. |
| KEY? | g TEST g KEY? r | (0) Tests if a key was pressed while a routine was running or paused. If <u>no</u> key was pressed in that interval, the next program step after KEY? will be executed; else it will be skipped and the code of said key will be stored in r . Key codes reflect the rows and columns on the keyboard (see the OM, Sect. 3; cf. GETKEY on HP-42S). |
| kg→ct | g U→ m: f kg → carat | (1) {2, 11}; {1} → {2} Convert masses. See pp. 140ff. |
| kg→cwt | g U→ m: kg → cwt etc. | |
| kg→lb. | | |
| kg→oz | | |
| kg→scw | g U→ m: f kg → sh.cwt | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------------|-----------------------------------|--|
| kg→sto | g [U→] m: f kg → stone | |
| kg→s.t | g [U→] m: ▲ kg → short ton | |
| kg→ton | g [U→] m: ▲ kg→ton | |
| kg→trz | g [U→] m: f kg → tr.oz | |
| K_J | g [CNST] K_J | (-1) {} → {2} Josephson constant in <i>hertz per volt.</i> |
| KTYP? | g [INFO] KTYP? r | (-1) {} → {1} Assumes a key code in the address specified (see KEY?), checks it, and returns its key type: <ul style="list-style-type: none">• 0 ... 9 if it corresponds to a digit 0 ... 9,• 10 if it corresponds to [, E, or +/−,• 11 if it corresponds to f or g,• 13 if it corresponds to a softkey, and• 12 if it corresponds to any other key. May help in user interaction with routines (see the OM, Section 3).. |
| LASTx | RCL L | (-1) See Sect. 1 of the OM. Actually, this command will be recorded as RCL L in routines. |
| lbf→N | g [U→] F&p: lbf→N | (1) {2, 11}; {1} → {2} Converts forces. See pp. 140ff. |
| LBL | g [LBL] labl | (0) Identifies programs and routines for execution and branching. Read more about labels and specifying them in Sect. 3 of the OM. |
| LBL? | g [TEST] g [LBL?] labl | (0) Tests for existence of the label specified, anywhere in program memory. See LBL for more. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------------|--|--|
| lb. \rightarrow kg | g U\rightarrow m: lb. \rightarrow kg | (1) {2, 11}; {1} \rightarrow {2} Converts masses. See pp. 140ff. |
| LCM | g INTS f LCM | (2) {1; 10} Returns the Least Common Multiple of x and y . ¹⁷ This will always be positive. |
| LEAP? | g TEST f LEAP? | (0) {2, 6, 11} Assumes x containing a date in the format selected (or a real number in corresponding format), extracts the year, and tests for a leap year. |
| LgNrm | g PROB | (1) {2, 11} |
| LgNrm _e | f LgNrm: LgNrm etc. | <i>Log-normal distribution</i> with $\mu = \ln \bar{x}_g$ specified in I and $\sigma = \ln \varepsilon$ in J . See \bar{x}_g and ε below and pp. 212ff for more. |
| LgNrm _p | | |
| LgNrm ⁻¹ | | LgNrm ⁻¹ returns x for a given probability p in X , with μ in I and σ in J . |
| LgNrm: | g PROB f LgNrm: | Submenu. See p. 126. |
| LinF | f STAT ▼ LinF | (0) Selects the linear fit model. Relevant for CORR, COV, L.R., s_{XY} , \hat{x} , and \hat{y} . See pp. 212ff for more. |

¹⁷ See also GCD. Remember school?

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------------------|------------|---|
| LJ | | <p>{10}</p> <p>Left justifies a bit pattern within its word size as in HP-16C: The stack will lift, placing the left-justified word in Y and the count of bit-shifts necessary to left justify the word in X.</p> <p>Example for word size 8: $1\ 0110_2$ LJ returns $x = 3$ and $y = 1011\ 0000_2$.</p> |
| L_m | | (2) {2, 11}; {1} → {2} |
| L_{max} | etc. | <i>Laguerre polynomials</i> and <i>Laguerre's generalized polynomials</i> . See pp. 227f for more. |
| LN | | <p>(1) {2, 3, 8*, 9*, 11, 12}; {1, 10} → {2}</p> <p>Returns the natural logarithm of x.</p> |
| $\text{LN}\beta$ | | <p>(2) {2, 3, 11, 12}; {1} → {2}</p> <p>Returns the natural logarithm of <i>Euler's Beta function</i> (see p. 88).</p> |
| $\text{LN}\Gamma$ | | <p>(1) {2, 3, 11, 12}; {1} → {2}</p> <p>Returns the natural logarithm of $\Gamma(x)$ (see p. 88). Allows also for calculating really great factorials (see an example in the OM).</p> |
| $\text{LN}(1+x)$ | | <p>(1) {2, 8*, 11}</p> <p>For $x \approx 0$, this returns a more accurate result for the fractional part than $\ln(x)$ does.</p> |
| LOAD | | Restores the entire backup from FM and returns Backup restored . Thus, LOAD = LOADP + LOADR + LOADSS + LOADΣ. ¹⁸ |

¹⁸ See SAVE on p. 73 and App. A on pp. 143f for more.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------------------|----------------------------------|--|
| LOADP | g I/O LOADP | (0) Loads the entire program memory from backup and appends it to the programs already in RAM (if there is sufficient space – else an error will be thrown). ¹⁸ |
| LOADR | g I/O LOADR | (0) Recovers the numbered general purpose <i>registers</i> from backup. Lettered <i>registers</i> will not be recalled. ¹⁸ |
| LOADSS | g I/O LOADSS | (0) Recovers the system state from backup. ¹⁸ |
| LOADΣ | g I/O LOADΣ | (0) Recovers the statistical summation <i>registers</i> from backup. Throws an error if there are none. ¹⁸ |
| LocR | g P.FN g LocR n | (0) Allocates <i>n local registers</i> (≤ 100) and 16 <i>local flags</i> for the <i>current routine</i> . See the OM, Sect. 3. |
| LocR? | g INFO f LocR? | (-1) {} → {1} Returns the number of <i>local registers</i> currently allocated. |
| LOG ₁₀ | g lg | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} ({1} → {2}) Returns the logarithm of <i>x</i> for base 10. |
| LOG ₂ | g EXP lb x | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} ({1} → {2}) Returns the logarithm of <i>x</i> for base 2. |
| LOG _{xy} | g EXP log_{xy} | (2) {1, 2, 3, 8*, 9*, 10, 11, 12}; ({1} → {2}) Returns the logarithm of <i>y</i> for the base <i>x</i> . |
| LogF | f STAT ▾ LogF | (0) Selects the logarithmic curve fit model. Relevant for CORR, COV, L.R., s _{XY} , \hat{x} , and \hat{y} . See pp. 212ff for more. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|------------------------------------|---|--|
| Logis | g PROB | |
| Logis _e | f Logis: Logis etc. | (1) {2, 11} <i>Logistic distribution with μ given in I and s in J.</i> See pp. 212ff for details. |
| Logis _p | | |
| Logis ⁻¹ | | |
| Logis: | g PROB f Logis: | <i>_submenu</i> . See p. 126. |
| LOOP | f LOOP | <i>menu</i> . See p. 125. |
| l _{PL} | g CNST l _{PL} | (-1) {} → {2} <i>Planck length in meter.</i> |
| ly→m | g U→ x: ly→m | (1) {2, 11}; {1} → {2} Converts distances. See pp. 140ff. |
| L.INTS | f CATALOG VARS L.INTS | <i>submenu</i> of <i>long integer</i> variables defined at execution time. See pp. 117ff. |
| L.R. | f STAT ▲ L.R. | (-2) or (-3) {} → {2} Pushes the parameters a_2 (in Z), a_1 (in Y), and a_0 (in X) of the fit curve through the data points accumulated in the statistical summation <i>registers</i> on the <i>stack</i> , according to the curve fit model selected (see LINF, ORTHOF, EXPF, POWERF, LOGF, HYPF, ROOTF, PARABF, CAUCHF, GAUSSF). For a straight line, a_0 is its y-intercept and a_1 is its slope. See pp. 212ff for more. |
| m ² →ac | g U→ f A: m ² → acre | (1) {2, 11}; {1} → {2} |
| m ² →acre _{US} | g U→ f A: m ² → acre _{US} | Convert areas. See pp. 140ff. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------------------------|---|--|
| $m^2 \rightarrow ha$ | g U→ f A: $m^2 \rightarrow ha$ | <p>(1) {2, 11}; {1} → {2}</p> <p>Convert volumes. See pp. 140ff.</p> |
| $m^3 \rightarrow bbl$ | g U→ f V: f $m^3 \rightarrow \text{barrel}$ | |
| $m^3 \rightarrow fz_{\text{UK}}$ | g U→ f V: f $m^3 \rightarrow fz_{\text{UK}}$ | |
| $m^3 \rightarrow fz_{\text{US}}$ | etc. | |
| $m^3 \rightarrow gl_{\text{UK}}$ | g U→ f V: $m^3 \rightarrow gl_{\text{UK}}$ | |
| $m^3 \rightarrow gl_{\text{US}}$ | etc. | |
| MANT | f PARTS MANT | (1) {2, 11}; {1} → {2} Returns the mantissa m of the number $x = m \cdot 10^h$ displayed. Cf. EXPT. |
| MASKL | f BITS MASKL n | (-1) {} → {10} Work like MASKL and MASKR on HP-16C, but with the mask length (or its address) following the command instead of taken from X. Thus, the mask is pushed on the stack. |
| MASKR | f BITS MASKR n | Example: For $W \text{ S17E } 8$, MASKL 3 returns a mask word $1110\ 0000_2$. Use it e.g. for extracting the three most significant bits of an arbitrary byte via AND. |
| MATRS | f CATALOG VARS MATRS | Submenu of matrix variables defined at execution time. See pp. 117f. |
| MATR? | g TEST ▲ MATR? | (0) Checks if x is a real or complex matrix. |
| MATX | f MATX | Menu. See p. 125. |
| Mat_X | f MATX SIM EQ Mat X | (-1) Returns the solution vector of a system of linear equations (see Section 2 of the OM). |
| max | g X-FN g max | (2) {1, 2, 4, 5, 6, 7, 10, 11} Returns the maximum of x and y . |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------------------|---|--|
| m_e | g [CNST] m_e | (-1) {} → {2} Electron mass in <i>kilogram</i> . |
| MEM? | g [INFO] MEM? | (-1) {} → {1} Returns the number of free <i>bytes</i> in program memory, also taking into account the local <i>registers</i> allocated. |
| MENU | g [P.FN] P.FN2 MENU | Displays the programmable <i>menu</i> . See the <i>HP-42S OM, Part 2, Section 10</i> , p. 146. |
| MENUS | f [CAT.] MENUS | <i>Submenu</i> of all <i>menus</i> defined at execution time. See pp. 117ff. |
| min | g [X.FN] g min | (2) {1, 2, 4, 5, 6, 7, 10, 11} Returns the minimum of <i>x</i> and <i>y</i> . |
| MIRROR | f [BITS] f MIRROR | (1) {10} Reflects the bit pattern in <i>x</i> (e.g. 0001 0111 ₂ would become 1110 1000 ₂ for word size 8). |
| mi.→m | g [U→] x: f mi.→m | (1) {2, 11}; {1} → {2} Converts distances. See pp. 140ff. |
| M_{Moon} | g [CNST] M_{Moon} | (-1) {} → {2} |
| m_n | etc. | Mass of the Moon in <i>kilogram</i> ; |
| m_n/m_p | | neutron mass in <i>kilogram</i> ; neutron to proton mass ratio. |
| MOD | g [INTS] f MOD | (2) {1, 2, 10, 11} Returns <i>y mod x</i> (modulo, see <i>Section 2</i> of the OM for examples). Cf. RMD. |
| MODE | g [MODE] | <i>Menu</i> . See p. 125. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------|---|---|
| MONTH | g CLK f MONTH | (1) {2, 6, 11} → {1} Assumes x containing a <i>date</i> in the format selected (or a real number in corresponding format) and extracts the month. |
| m_p | g CNST m_p etc. | (-1) {} → {2} |
| m_{PL} | | Proton mass and <i>Planck</i> mass in <i>kilogram</i> ; proton to electron mass ratio. |
| m_p/m_e | | |
| MSG | g P.FN P.FN2 f MSG | (0) {1, 2, 11} Throws the (<i>temporary</i>) error message specified by the integer part of x . Cf. ERR. See App. C on pp. 175ff for the respective error codes. |
| m_u | g CNST m_u | (-1) {} → {2} |
| $m_u c^2$ | g CNST $m_u c^2$ | Atomic mass constant in <i>kilogram</i> and its energy equivalent in <i>joule</i> . |
| MULπ | g MODE MULπ | (0) Sets the ADM to <i>multiples of π</i> . Indicated in the status bar. |
| MULπ→ | f L→ f MULπ→ | (1) {1, 2, 11} → {4} Converts angles as described on pp. 148f. |
| MVAR | g P.FN P.FN2 f MVAR name | (0) Defines a <i>menu variable</i> . Such variables are required for VARMNU. Works in <i>PEM</i> only. |
| MyMenu | f CAT. MENUS MyMenu | User menu. |
| Myα | f CAT. CHARS Myα | User menu in <i>AIM</i> . See the OM, Sect. 6. |
| m_μ | g CNST m_μ | (-1) {} → {2} Muon mass in <i>kilogram</i> . |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|---|--|
| M.DELR | f DELR with M.EDIT displayed | (0) {8, 9} Deletes the current row of elements (where the cursor is in). Will not work if the matrix has only one row. |
| M.DIM | f MATX f DIM name | (0) {1, 2} Creates a new named matrix or re-dimensions an existing matrix to IP(y) rows and IP(x) columns. See DIM in the HP-42S Owner's Manual, p. 217. |
| M.DIM? | g INFO g DIM? f MATX ▲ f DIM? | {8, 9} → {1} Returns the dimensions of the matrix x (rows to Y, columns to X). Note the matrix is saved in L. Previous y goes into Z, previous z into T, etc. |
| M.DY | g CLK ▲ M.DY | (0) Selects the format mm/dd/yyyy for dates. |
| M.EDI | f MATX EDIT | (2) {8, 9} Opens x using the <i>Matrix Editor</i> (like MATRIX EDIT in HP-42S). ¹⁹ See Section 2 of the OM. |
| M.EDIN | f MATX f EDITN name | (2) Opens a named matrix using the <i>Matrix Editor</i> (like MATRIX EDITN in HP-42S). See Section 2 of the OM. |
| M.EDIT | | Submenu for matrix editing, called by M.EDI or M.EDIN. See p. 125. |

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|------------------------------|--|
| M.GET | f [MATX] g GETM | (0) {1, 2} → {8, 9} Gets a sub-matrix with IP(y) rows and IP(x) columns out of the indexed matrix into X (like GETM in HP-42S). Cf. M.PUT. |
| M.GOTO | f GOTO | (0) Asks for target row and column and moves to this matrix element. |
| M.GROW | f GROW | (0) Allows the indexed matrix to grow automatically (see J+ above and Section 2 of the OM; see also GROW in the HP-42S Owner's Manual, p. 213.). Cf. M.WRAP. |
| M.INSR | f INSR | (0) Inserts a new row of elements containing zero, left of the current cursor position in the matrix. |
| M.LU | f [MATX] ▲ f M.LU | (1) WP 34S: Takes a <i>descriptor</i> of a square matrix in X. Transforms (X) into its LU decomposition in-situ. The value in X is replaced by a <i>descriptor</i> that defines the pivots that were required to calculate the decomposition. The most significant digit is the pivot for the first diagonal entry, the next most significant for the second and so forth. |
| M.NEW | f [MATX] NEW | (2) {1, 2} → {8} Creates a new matrix (like NEW in HP-42S). Its number of rows shall be supplied in Y and its number of columns in X. M.NEW returns a matrix x with all its elements set to zero. |
| M.OLD | OLD with M.EDIT displayed | (0) Recalls the old element content (like OLD in HP-42S). See the OM, Sect. 2. |
| M.PUT | f [MATX] g PUTM | (0) {8, 9} Puts the matrix x as is into the indexed matrix (like PUTM in HP-42S). Cf. M.GET. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------|---|--|
| M.R>R | f MATX ▲ f R>R | (0) {8, 9} Swaps row x and row y of the indexed matrix (like R>>R in HP-42S). |
| M.SIMQ | | _submenu of MATX, called by SIM_EQ. |
| M.SQR? | g TEST ▲ f M.SQR? | (0) Returns true if x is a square matrix. |
| M.WRAP | f WRAP with M.EDIT displayed | (0) Controls the index pointers (see Section 2 of the OM). Cf. M.GROW. |
| m: | g U→ m: | _submenu. See p. 140. |
| m→au | g U→ x: m→au | (1) {2, 11}; {1} → {2} Convert distances or heights. See pp. 140ff. |
| m→fm. | g U→ x: ▲ m → fathom | |
| m→ft. | g U→ x: f m→ft. | |
| m→ft _{us} | g U→ x: ▲ m → survey foot _{us} | |
| m→in. | g U→ x: g m→in. | |
| m→ly | g U→ x: m→ly | |
| m→mi. | g U→ x: f m→mi. | |
| m→nmi. | g U→ x: f m→nmi. | |
| m→pc | g U→ x: m→pc | |
| m→pt. | g U→ x: g m → point | |
| m→yd. | g U→ x: g m→yd. | |
| m _⊕ | g CNST m _⊕ | (-1) {} → {2} |
| m _⊙ | etc. | Masses of the Earth and Sun in kilogram. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------|------------------------------------|---|
| N_A | g [CNST] N_A | (-1) {} → {2} Avogadro's number in <i>particles per mol.</i> |
| NAND | f [BITS] f NAND | (2) Works in analogy to AND. See p. 18. |
| NaN | g [CNST] NaN | (-1) <i>Not a Number.</i> |
| NaN? | g [TEST] ▲ f NaN? | (0) Returns <i>true</i> if x is <i>Not a Number</i> . |
| NBin | g [PROB] | (1) {2, 11} |
| NBin _e | g [NBin:] NBin etc. | <i>Negative binomial distribution</i> with the total number of failures f in X, the probability of a success p_0 in I, and the number of draws n in J. See pp. 212ff for more information. |
| NBin _p | | |
| NBin ⁻¹ | | |
| NBin: | g [PROB] g [NBin:] | <i>Submenu</i> . See p. 126. |
| NEIGHB | g [INFO] f NEIGHB | <p>(2) {1}</p> <p>Returns ...</p> <ul style="list-style-type: none"> • $x + 1$ for $x < y$; • x for $x = y$; • $x - 1$ for $x > y$. <p>(2) {2, 11}</p> <p>Returns the nearest machine-representable number to x in the direction towards y in the mode set. For</p> <ul style="list-style-type: none"> • ... $x < y$, it is the machine successor of x ; • ... $x = y$, it is y ; • ... $x > y$, it is the machine predecessor of x. <p>NEIGHB may be useful investigating numeric stability (see NEIGHBOR in the <i>HP-71 Math Pac</i>).</p> |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------|-----------------------------|---|
| NEXTP | g X.FN g NEXTP | (1) {1, 2, 11} → {1} Returns the next prime number greater than x . |
| nmi.→m | g U→ x: f nmi.→m | (1) {2, 11}; {1} → {2} Converts distances. See pp. 140ff. |
| NOP | g P.FN P.FN2 f NOP | (0) 'Empty' program step (for historical reasons only). |
| NOR | f BITS f NOR | (2) Works in analogy to AND. See p. 18. |
| Norml | g PROB | (1) {2, 11} |
| Normle | Norml: Norml etc. | <i>Normal distribution</i> with an arbitrary mean μ given in I and a standard deviation σ in J. See Sect. 2 of the OM for an application example and pp. 212ff for more. |
| Normlp | | |
| Norml ⁻¹ | | Norml ⁻¹ returns x for a given probability p in X, with μ in I and σ in J. |
| Norml: | g PROB Norml: | Submenu. See p. 126. |
| NOT | f BITS NOT | (1) {10} Inverts x bit-wise as on HP-16C. |
| | | (1) {1, 2, 11} → {1} Returns 1 for $x = 0$, and 0 for $x \neq 0$. |
| nΣ | g SUMS n | (-1) {} → {1} Recalls the number of accumulated data points. |
| N→lbf | g U→ F&p: N→lbf | (1) {2, 11}; {1} → {2} Converts forces. See pp. 140ff. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|-----------------------------------|---|
| ODD? | g TEST f ODD? | (0) Checks if x is integer and odd. |
| OFF | g OFF | (0) In PEM, inserts a step to turn your WP 43S off under program control. Else turns your WP 43S off. |
| OR | f BITS OR | (2) Works in analogy to AND. See p. 18. |
| OrthoF | f STAT ▼ f OrthoF | (0) Selects the linear orthogonal fit model. Relevant for CORR, COV, L.R., s_{XY} , \hat{x} , and \hat{y} . See pp. 221ff for more. |
| ORTHOG | g X.FN Orthog | Submenu. See p. 129. |
| oz→kg | g U→ m: oz→kg | (1) {2, 11}; {1} → {2} Converts masses. See pp. 140ff. |
| P ₀ | g CNST P₀ | (-1) {} → {2} Standard atmospheric pressure in pascal. |
| ParabF | f STAT ▼ f ParabF | (0) Selects the parabolic fit model. Relevant for COV, CORR, L.R., s_{XY} , \hat{x} , and \hat{y} . See pp. 221ff for more. |
| PARTS | f PARTS | Menu. See p. 126. |
| PAUSE | g P.FN PAUSE n | (0) With 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 | g U→ F&p: f Pa→atm | (1) {2, 11}; {1} → {2} Convert pressures. See pp. 140ff. |
| Pa→bar | g U→ F&p: Pa→bar | |
| Pa→iHg | g U→ F&p: f Pa → in.Hg | |
| Pa→psi | g U→ F&p: Pa→psi | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------------|---|--|
| Pa \rightarrow tor | [g] [U \rightarrow] F&p: [f] Pa \rightarrow torr | |
| pc \rightarrow m | [g] [U \rightarrow] x: pc \rightarrow m | (1) {2, 11}; {1} \rightarrow {2} Converts distances. See pp. 140ff. |
| PERM | [g] PROB P _{yx} | (2) {1} Returns the number of possible <u>arrangements</u> (a.k.a. <u>permutations</u>) 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 <u>counted</u> separately. Cf. COMB. (2) {2, 3, 11, 12} See pp. 210ff for the formula. |
| PGMINT | [f] ADV [f] PGMINT labl | Specifies the address of the expression to be integrated or solved, respectively. |
| PGMSLV | [f] ADV [f] PGMSLV labl | See Section 4 of the OM. |
| PIXEL | [g] P.FN P.FN2 [g] PIXEL | (0) Turns on a single pixel (dot) on the screen. The location of the pixel is given by the numbers in the X- and Y-registers. See AGRAPH on p. 17 for more. |
| PLOT | [f] STAT [g] PLOT | (0) Plots the n data points given by the $n \times 2$ matrix x . See p. xxviii for more. |
| P _n | [g] X.FN Orthog P _n | (1) {2, 11}; {1} \rightarrow {2} <i>Legendre polynomials</i> . See pp. 227f for more. |
| POINT | [g] P.FN P.FN2 [g] POINT | (1) {1, 2, 11} Turns on a square point (3x3 px) on the screen. The location of its center is given by the integer parts of the numbers in X and Y. See AGRAPH on p. 17 for more. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------|--|--|
| Poiss | g PROB | (1) {2, 11}; {1} → {2} |
| Poiss _e | g Poiss: Poiss etc. | Poisson distribution with the number of successes g in X and the Poisson parameter λ in I . See pp. 212ff for details. |
| Poiss ⁻¹ | g PROB g Poiss: Poiss ⁻¹ | (1) {2, 11} Returns the maximum number of successes m for a given probability p in X and λ in I . |
| Poiss: | g PROB g Poiss: | Submenu. See p. 126. |
| PopLR | g P.FN g PopLR | (0) Pops the local registers allocated to the <i>current routine</i> (see <i>Section 3</i> of the OM) without returning to the calling routine. See LOC.R and RTN. |
| PowerF | f STAT ▾ PowerF | (0) Selects the power curve fit model. Relevant for CORR, COV, L.R., s_{XY} , \hat{x} , and \hat{y} (see pp. 212ff for more). |
| PRCL | g P.FN f PRCL | (0) Copies the <i>current program</i> (from FM or RAM) and appends it to RAM, where it can then be edited (see the OM). PRCL allows for duplicating programs in RAM. Will only work with enough space at destination. Recall a library routine from FM, edit it, and PSTO – this way you can modify this part of the FM library (see PSTO). |
| PRIME? | g TEST f PRIME? | (0) {1, 2, 11} Checks if the absolute value of IP(x) is a prime. The method is believed to work for integers up to 9×10^{18} . |
| PROB | g PROB | Menu. See p. 126. |
| PROGS | f CAT. PROGS | Submenu of global labels defined at execution time. See pp. 117f. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|----------------------------------|---|
| pr→dB | g U ▲ power ratio → dB | (1) {2, 11}; {1} → {2} Converts ratios. See pp. 140ff. |
| psi→Pa | g U F&p: psi→Pa | (1) {2, 11}; {1} → {2} Converts pressures. See pp. 140ff. |
| PST0 | g P.FN f PST0 | (0) Copies the <i>current program</i> (see the OM) from RAM and appends it to the FM 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 CATALOG PROGS and called by XEQ. |
| pt.→m | g U x: g point → m | (1) {2, 11}; {1} → {2} Converts print heights. See pp. 140ff. |
| PUTK | g P.FN f PUTK r | (0) Assumes a key code in the address specified. Stops program execution, takes said code and puts it in the keyboard buffer resulting in immediate execution of the corresponding call. R/S is required to resume program execution then. May help in user interaction with routines (see the OM, Section 3). |
| P.FN | g P.FN | Menu . See p. 127. |
| P.FN2 | g P.FN P.FN2 | Submenu . See p. 127. |
| P: | g U P: | Submenu . See p. 140. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|------------------------------|---|
| R | g [CNST] R | (-1) {} → {2} Molar gas constant in <i>joule per mol and kelvin</i> . |
| RAD | g [MODE] RAD | (0) Sets the <i>ADM</i> to <i>radians</i> . Indicated in the status bar. |
| RAD→ | f [L→] f RAD→ | (1) {1, 2, 11} → {4} Converts angles as described on pp. 148f. |
| RAM | f [CATALOG] PROGS RAM | <i>Submenu</i> of global labels defined at execution time. See pp. 117f. |
| RAN# | g [PROB] ▲ RAN# | (-1) {} → {2} Returns a random number between 0 and 1 like RAN does in HP-42S. See also SEED. |
| RBR | f [RBR] | Calls the <i>register browser</i> . See the OM, Sect. 5. You may call RBR also in <i>PEM</i> but it is not programmable. ATTENTION: Within RBR, real and complex numbers are generally displayed in the format chosen within the screen space available. Since RBR uses the small font, however, more digits are displayable here than in a numeric row using large font. For real <i>DP</i> numbers and ALL 00 set, for example, RBR display will turn to SCI or ENG at 33 instead of 16 digits in worst case. Extended display precision may be observed for complex numbers as well. |
| RCL | RCL r | (-1) Recalls the content of a <i>register</i> or variable. |
| RCLCFG | RCL f Config r | (0) Recalls a <i>configuration</i> stored by STOCFG (see Sections 2 and 6 of the OM). |
| RCLEL | f [MATX] g RCLEL | (-1) {} → {2, 3} |
| | RCL g ...EL | Recalls a copy of the current element a_{ij} of the indexed matrix. Cf. STOEL. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|----------------------------|--|
| RCLIJ | f [MATX] ▲ RCLIJ | (-2) {} → {1} Recalls the current values of the matrix index pointers into X (= column number) and Y (= row number). If the pointers both equal zero, then there is currently no indexed matrix. Cf. STOIJ. |
| | [RCL] g ...IJ | |
| RCLS | [RCL] f Stack r | Recalls 4 or 8 values from a set of <i>registers</i> starting at address <i>r</i> , and pushes them on the <i>stack</i> . This is the converse command of STOS. |
| RCL+ | [RCL] + r | (1) Recalls a content of a <i>register</i> or variable, executes the operation specified, and puts the result on the <i>stack</i> like a <i>monadic</i> function. ²⁰ |
| RCL- | [RCL] - r | |
| RCL× | [RCL] × r | |
| RCL / | [RCL] / r | |
| RCL↑ | [RCL] f Max r | (1) {1, 2, 4, 5, 6, 10, 11} |
| | [RCL] ▲ r | Replaces <i>x</i> with the maximum of <i>r</i> and <i>x</i> . ²⁰ |
| RCL↓ | [RCL] f Min r | (1) {1, 2, 4, 5, 6, 10, 11} |
| | [RCL] ▼ r | Replaces <i>x</i> with the minimum of <i>r</i> and <i>x</i> . ²⁰ |
| RDP | g DISP f RDP n | (1) {2, 3, 5, 8*, 9*, 11, 12} Rounds <i>x</i> to <i>n</i> decimal places ($0 \leq n \leq 99$, think of FIX format), taking the RM setting into account. See RM and compare RSD. |
| Re | g CPX Re | (1) {3} → {2}; {9} → {8}; {12} → {11} |
| | f PARTS g Re | Returns the real part of <i>x</i> . Cf. IM. |
| r _e | g CNST r _e | (-1) {} → {2} Classical electron radius in <i>meter</i> . |

²⁰ Only legal operations according to the matrices in Section 2 of the OM will work. See also the examples given there.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|---|--|
| REALS | f [CAT.] VARS REALS | Submenu of real variables defined at execution time. See pp. 117f. |
| REAL? | g [TEST] ▲ REAL? | (0) Checks if x is a real number or matrix. |
| RECV | g [I/O] f RECV | (0) Prepares your WP 43S for receiving data via serial I/O. See SEND and Sect. 3 in the OM for more. |
| RESET | g [CLR] g RESET | <p>Executes CLALL and resets all modes to <i>startup default</i>, i.e. 2COMPL, ALL 0, CPXi, DEG, DENMAX 0, DSTACK 4, GAP 3, J/G 1752-01-01, LinF, LocR 0, REALRE, RM 0, TDISP -1, WSIZE 64, and Y.MD.</p> <p>The system flags ALLSCI, DECIM., DENANY, MULTx, PROFRC, RECTN, and TDM are set, DENFIX, LEAD.0s, and SSIZE are clear.</p> <p>See these individual commands and flags for more.</p> |
| RE→CX | <p>[CC] (works in run mode only)</p> <p>g [CPX] f RE→CX</p> | <p>(2) {2} → {3}; {11} → {12}</p> <p>Composes a complex number out of two reals or integers x and y, setting \mathbb{C} and taking either</p> <ul style="list-style-type: none"> • (for \mathbb{L}) the real part from \mathbf{Y} and imaginary part from \mathbf{X}, or • (for \odot) the magnitude from \mathbf{Y} and phase from \mathbf{X}. <p>(2) {8} → {9}</p> <p>Works in analogy for two real matrices x and y.</p> |
| Re↔Im | g [CPX] Re↔Im | (1) {3, 9*, 12} |
| | | Swaps real and imaginary parts of complex objects. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|------------|---|
| RJ | | <p>{10}</p> <p>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 right justify the word in X.</p> <p>Example: 10 1100₂ RJ results in $y = 1011_2$ and $x = 2$.</p> |
| R _K | | <p>(-1) {} → {2}</p> <p>Von Klitzing constant in ohm.</p> |
| RL | etc. | <p>(1) {10}</p> <p>Work like n consecutive RLs / RLCs on HP-16C, similar to RL_n / RLC_n there. For RL, $0 \leq n \leq 63$. For RLC, $0 \leq n \leq 64$. RL 0 / RLC 0 execute as NOP, but load L. See the OM, Sect. 2, for more.</p> |
| RM | | <p>(0) Sets floating point rounding mode. This rounding mode is used only for RSD or when converting from the extended precision internal format (39 digits) to packed reals. It will not alter the display nor change the behavior of ROUND. The following seven modes are supported:</p> <p>0: round half even: $\frac{1}{2}\mathbb{E}$ 0.5 rounds to next even number (default).²¹</p> <p>1: round half up: $\frac{1}{2}\uparrow$ 0.5 rounds up ('businessman's rounding'²²).</p> <p>2: round half down: $\frac{1}{2}\downarrow$ 0.5 rounds down.</p> <p>3: round up: $\leftarrow\mathbb{0}\rightarrow$ rounds away from 0.</p> <p>4: round down: $\rightarrow\mathbb{0}\leftarrow$ rounds towards 0.</p> <p>5: ceiling: $\lceil x \rceil$ rounds towards $+\infty$.</p> <p>6: floor: $\lfloor x \rfloor$ rounds towards $-\infty$.</p> |

²¹ This is the way of rounding used in science.

²² 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) |
|-------------------|--------------------------------|--|
| | | The abbreviations printed on grey are used in STATUS for indicating the respective rounding modes (see Section 5 of the OM). |
| RMD | g INTS f RMD | (2) {1, 2, 10, 11} Returns the remainder of a division. Equals RMD on HP-16C but works for reals as well. See Sect. 2 of the OM for examples. Cf. MOD. |
| R _{Moon} | g CNST R_{Moon} | (-1) {} → {2} Mean radius of the Moon in <i>meter</i> . |
| RM? | g INFO RM? | (-1) {} → {1} Returns the floating point rounding mode set. See RM for more. |
| RNORM | f MATX ▲ f 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 | f STAT ▼ f RootF | (0) Selects the root fit model. Relevant for CORR, COV, L.R., s_{XY} , \hat{x} , and \hat{y} . See pp. 221ff for more. |
| ROUND | g DISP ROUND | (1) {2, 3, 4, 5, 6, 8*, 9*, 11, 12} Rounds x using the current display format like RND on HP-42S. |
| ROUNDI | g DISP ROUNDI | (1) {8*}; {2, 11} → {1}; Rounds x to next integer. $\frac{1}{2}$ rounds to 1. |
| | f PARTS f ... | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|-------------------------|--|
| RR | RR <i>n</i> etc. | (1) {10} Work like <i>n</i> consecutive RRs / RRCs on HP-16C, similar to RRn / RRCn there. For RR, $0 \leq n \leq 63$. For RRC, $0 \leq n \leq 64$. RR 0 / RRC 0 execute as NOP, but load L. See the OM, Sect. 2, for more. |
| RSD | RSD <i>n</i> | (1) {2, 3, 4, 8*, 9*, 11, 12} Rounds <i>x</i> to <i>n</i> significant digits ($1 \leq n \leq 34$), taking the RM setting into account. See RM, cf. RDP. |
| RSUM | RSUM | (1) {8, 9} Calculates the row sum of the matrix <i>x</i> , returning an $m \times 1$ matrix filled with the row sums of the $m \times n$ input matrix. |
| RTN | | (0) In PEM, RTN is the logically last command in a routine (see Section 3 of the OM). In a routine executing, RTN pops local data (cf. POPLR) and returns to the caller, i.e. moves the program pointer one step behind the XEQ instruction that called said routine. If there is none (i.e. this routine is top level), program execution halts, the program pointer is set to step 0000, and is lit. If pressed in run mode with no routine executing, RTN resets the program pointer to the start of current program (see the OM, Sec. 3). If the program is in FM, the pointer is set to step 0000 in RAM, and is lit. |
| RTN+1 | RTN+1 | (0) Works like RTN, but moves the program pointer <u>two</u> steps behind the XEQ instruction that called said routine. |
| R-CLR | | (0) {2, 11} Interprets <i>x</i> in the form sss.nn. Clears nn registers starting with address sss. Example: For <i>x</i> = 34.567, R-CLR will clear R34 through R89. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|------------|--|
| | | <p>ATTENTION: For $nn = 0$, clearing will cover the maximum available:</p> <ul style="list-style-type: none"> • For $sss \in [0; 99]$, it will stop at R99. • For $sss \in [100; 111]$, it will stop at K. • For $sss \geq 112$, it will stop at the highest currently allocated local register. |
| R-COPY | | <p>(0) {2, 11}</p> <p>Interprets x in the form $sss.nnnnn$. Takes nn registers starting with address sss and copies their contents to ddd etc.</p> <p>Example: For $x = 7.0304567$, $r07$, $r08$, $r09$ will be copied into R45, R46, R47, respectively.</p> <p>For $x < 0$, R-COPY will take nn registers from FM instead, starting with register number sss. Destination will be in RAM always.</p> <p>ATTENTION: For $nn = 0$, copying will cover the maximum available as explained with R-CLR. Then x must be negative.</p> |
| R-SORT | | <p>(0) {2, 11}</p> <p>Interprets x in the form $sss.nn$. Sorts the contents of nn registers starting with address sss.</p> <p>Example: Assume $x = 49.036\ 9$, $r49 = 1.2$, $r50 = -3.4$, and $r51 = 0$; then R-SORT will return $r49 = -3.4$, $r50 = 0$, and $r51 = 1.2$.</p> <p>ATTENTION: For $nn = 0$, sorting will cover the maximum available as explained with R-CLR.</p> |
| R-SWAP | | <p>(0) {2, 11}</p> <p>Works like R-COPY but <u>swaps</u> the contents of source and destination registers.</p> |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|-------------------------------|--|
| R→D | f L→ g R→D | (1) {1, 2, 11} → {4} Converts angles as described on pp. 148f. |
| R↑ | f R↑ | Rotates the stack contents one level up or down, respectively. See Section 1 of the OM for details. |
| R↓ | R↓ | |
| R _∞ | g CNST R _∞ etc. | (-1) {} → {2} |
| R _⊕ | | Rydberg constant (see p. 136); |
| R _⊖ | | mean radii of the Earth and Sun in <i>meter</i> . |
| s | f STAT 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. 212ff for the formula. |
| Sa | g CNST Sa | (-1) {} → {2} Semi-major axis in <i>meter</i> of the Earth model WGS84. ²³ |
| SAVE | f SAVE | (0) Saves user program space, registers and system state to FM, and returns Saved. Recall your backup using the different flavors of LOAD. |
| SB | f BITS g SB n | (1) {10} Sets the specified bit in x . |
| Sb | g CNST Sb | (-1) {} → {2} Semi-minor axis in <i>meter</i> of WGS84. ²³ |
| SCI | g DISP SCI n | (0) Sets scientific display format (see Section 2 of the OM). |

²³ This model is used to define the Earth's surface for surveying and GPS. See http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------------|---|---|
| scw→kg | g U→ m: f short cwt → kg | (1) {2, 11}; {1} → {2} Converts masses. See pp. 140ff. |
| SDIGS? | g INFO f SDIGS? | (-1) {} → {1} Returns the number of significant digits set by SETSIG. Also returned by STATUS. |
| SDL | g P.FN P.FN2 f SDL n etc. | (1) {2, 11} Shifts digits left (right) by <i>n</i> decimal positions, equivalent to multiplying (dividing) <i>x</i> by 10^n . Cf. SL and SR for binary integers. |
| Se² | | (-1) {} → {2} First eccentricity squared of the Earth model WGS84 (see footnote 23 on p. 69). |
| SEED | g PROB ▲ SEED | (0) {2, 11} Stores a seed for random number generation. If <i>x</i> = 0, the seed is taken from the real-time clock. |
| SEND | g I/O f SEND | (0) Sends all RAM data to the device connected via serial I/O. See RECV and Section 3 in the OM for more. |
| SETCHN | g DISP ▲ CHINA | (0) Sets regional format preferences (see Section 2 of the OM). |
| SETDAT | g CLK ▲ SETDAT | (0) Sets the date for the real-time clock (the emulator takes this information from the PC clock). |
| SETEUR | g DISP ▲ EUROPE | (0) Set regional format preferences (see Section 2 of the OM). |
| SETIND | g DISP ▲ INDIA | |
| SETJPN | g DISP ▲ JAPAN | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|-----------------------|--|
| SETSIG | g MODE SETSIG | (0) {1} Sets the number of significant digits (0 ... 34) for rounding after each operation. SETSIG 0 sets maximum precision. |
| SETTIM | g CLK ▲ SETTIM | (0) Sets the time for the real-time clock (the emulator takes this information from the PC clock). |
| SETUK | g DISP ▲ UK | (0) Set regional format preferences (see Section 2 of the OM). etc. |
| SETUSA | | |
| Se'² | g CNST Se'² | (-1) {} → {2} Second eccentricity squared of the Earth model WGS84 (see footnote 23 on p. 69). |
| SF | g FLAGS SF n | (0) Sets the flag specified. |
| Sf⁻¹ | g CNST Sf⁻¹ | (-1) {} → {2} Flattening parameter of the Earth model WGS84 (see footnote 23 on p. 69). |
| SHOW | f SHOW | (0) {1, 2, 3, 4, 11, 12} Shows all digits stored in X until next keystroke. Wherever one display row is not sufficient, small font will be employed. For DP reals, 34 digits will be shown using two display rows. SP and DP complex numbers will be displayed with all their digits using as many display rows as necessary. Up to 294 digits of long integers will be shown using up to 7 display rows; for long integers exceeding 294 digits, the most significant 288 will be shown with a trailing power of 10. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|----------------------------|---|
| SIGN | f [PARTS] sign | (1) {8}; {1, 2, 10, 11} → {1} Returns 1 for $x > 0$, -1 for $x < 0$, and 0 for $x = 0$ or non-numeric data. Corresponds to the mathematical function $\text{signum}(x)$. |
| | g [CPX] f sign | (1) {3, 12} Returns the unit vector of the complex number x (cf. UNITV). Maintained for backward compatibility only. |
| SIGNMT | f [BITS] ▼ SIGNMT | (0) Sets sign-and-mantissa mode for operations on <i>short integers</i> . See the OM, Section 2. Indicated in the status bar. |
| | g [INTS] ▲ ... | |
| SIM_EQ | f [MATX] SIM EQ n | (0) Solves a system of n linear equations $(\text{MATA}) \cdot \overrightarrow{\text{MATX}} = \overrightarrow{\text{MATB}}$. If these matrices are not defined before, they will be created automatically at execution time. See Sect. 2 of the OM for more. |
| sin | TRI sin | (1) {2, 3, 8*, 9*, 11, 12}; {1, 4} → {2} Returns the sine of the angle in X. |
| sinc | g [X.FN] ▲ sinc | (1) {2, 3, 8*, 9*, 11, 12} Returns $\frac{\sin(x)}{x}$ for $x \neq 0$ and 1 for $x = 0$. Note input has to be supplied in radians. |
| sinh | g [EXP] g sinh | (1) {2, 3, 8*, 9*, 11, 12} |
| | TRI g sinh | Returns the hyperbolic sine of x. |
| SKIP | g [P.FN] P.FN2 g SKIP n | (0) Skips n program steps forwards ($0 \leq n \leq 255$). So e.g. SKIP 2 skips over the next two steps, going e.g. from step 123 to step 126. If SKIP attempts to cross an END, an error is thrown. ATTENTION: 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 . |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|--------------------------------------|--|
| SL | f [BITS] ▲ SL <i>n</i> | (1) {10} Works like <i>n</i> (≤ 63) consecutive SLs on HP-16C. SL 0 executes as NOP, but loads L. See Sect. 2 of the OM for more. |
| SLVQ | f [ADV] SLVQ | $[1, 2, 3] \rightarrow \{1 \text{ or } 2 \text{ or } 3\}; \{11, 12\} \rightarrow \{11 \text{ or } 12\}$ Solves the quadratic equation $ax^2 + bx + c = 0$ with its parameters on the input stack [<i>c, b, a, ...</i>], and tests the result. The following holds for real parameters: <ul style="list-style-type: none">• If $r := b^2 - 4ac \geq 0$, SLVQ returns $-\frac{b \pm \sqrt{r}}{2a}$ in Y and X. In a routine, the step after SLVQ will be executed.• Else, SLVQ returns the first complex root in X and the second in Y (the complex conjugate of the first). In a routine, the step after SLVQ will be skipped. In either case and also for complex parameters, SLVQ returns r in Z. Higher stack registers are kept unchanged. L will contain equation parameter c. |
| s_m | f [STAT] <i>s_m</i> | (-2) {} $\rightarrow \{2\}$ Takes the statistical data accumulated and pushes the standard errors (i.e. std. deviations of the means \bar{y} and \bar{x}) on the stack. Output format will be like the one of s (see the OM, Sect. 2). |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------|--------------------------------|---|
| S MODE? | g INFO S MODE? | (-1) {} → {1} Returns the <i>integer sign mode</i> set for <i>short integers</i> , i.e. true 2 for 2's complement, true 1 for 1's complement, false 0 for unsigned, or true -1 for sign & mantissa mode. |
| S _{MW} | f STAT f S_{MW} | (-1) {} → {2} Returns the <i>standard error</i> for weighted data, i.e. the <i>standard deviation</i> of the mean \bar{x}_w . |
| SOLVE | f ADV SOLVE var | {2, 3} Solves the equation $f(var) = 0$, with f calculated by the equation specified (in PEM by PGMSLV). Two initial estimates of the root must be supplied in X and Y when calling SOLVE. It returns var_{root} in X, the second last var -value tested in Y, then $f(var_{root})$ in Z, and 0 in T. Additionally, SOLVE acts as 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. ATTENTION: SOLVE fills all <i>stack registers</i> with x before calling the routine specified. |
| Solver | g EQN Solver | Submenu for solving a given equation. See the OM, Sect. 4, for more. |
| SPEC? | g TEST ▲ f SPEC? | (0) True if x is 'special' (i.e. $\pm\infty$ or NaN). |
| SR | f BITS ▲ SR n | (1) {10} Works like n (≤ 63) consecutive SRs on HP-16C. SR 0 executes as NOP, but loads L. See Section 2 of the OM for more. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|---|---|
| SSIZE? | [g] [INFO] SSIZE? | (-1) {} → {1} Returns the number of <i>stack registers</i> currently allocated, 4 or 8. |
| STAT | [f] [STAT] | Menu. See p. 127. |
| STATUS | [g] [FLAGS] STATUS | Flag browser. See Section 5 of the OM. |
| STK | [g] [STK] | Menu. See p. 127. |
| STO | [STO] <i>r</i> | (0) Stores <i>x</i> into destination. |
| STOCFG | [STO] [f] Config <i>r</i> | (0) Stores the current <i>configuration</i> for later use as described in Section 2 of the OM. RCLCFG recalls such data. |
| STOEL | [f] [MATX] [g] STOEL [STO] [g] ...EL | (1) {1, 2, 3} Stores a copy of <i>x</i> into the indexed matrix at the current element, a_{ij} . Cf. RCLEL. |
| STOIJ | [f] [MATX] [▲] STOIJ [STO] [g] ...IJ | (1) {1} Sets the index pointers to IP(<i>x</i>) (= column number) and IP(<i>y</i>) (= row number). Cf. RCLIJ. |
| STOP | [R/S] | (0) Stops program execution. May be inserted in programs to wait for input, for example. |
| STOS | [STO] [f] Stack <i>r</i> | (0) Stores the entire <i>stack</i> in a set of 4 or 8 <i>registers</i> , starting at the destination address specified. See RCLS. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|-------------------------|--|
| STO+ | STO + <i>r</i> | (0) Executes the specified operation on <i>r</i> and stores the result (e.g. $r - x$) at the address specified. ²⁴ |
| STO- | STO - <i>r</i> | |
| STOx | STO × <i>r</i> | |
| STO/ | STO ÷ <i>r</i> | |
| sto→kg | g [U+] m: f stone → kg | (1) {2, 11}; {1} → {2} Converts masses. See pp. 140ff. |
| STO↑ | STO f Max <i>r</i> | (0) {1, 2, 4, 5, 6, 10, 11} |
| | STO ▲ <i>r</i> | Stores the maximum of <i>r</i> and <i>x</i> in the address specified. ²⁴ |
| STO↓ | STO f Min <i>r</i> | (0) {1, 2, 4, 5, 6, 10, 11} |
| | STO ▼ <i>r</i> | Stores the minimum of <i>r</i> and <i>x</i> in the address specified. ²⁴ |
| STRI? | g TEST g STRI? | (0) True if <i>x</i> is an alphanumeric string (like STR? in HP-42S). |
| STRING | f CAT. VARS STRING | Submenu of alpha string variables defined at execution time. See pp. 117f. |
| SUM | f STAT f SUM | (-2) {} → {2} Recalls the linear sums Σy and Σx . Useful in basic 2D vector algebra. Output is labeled in analogy to s. |
| s _w | f STAT f s _w | (-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 $\Sigma+$). See pp. 212ff for the formula. |

²⁴ Only legal operations according to the matrices in Section 2 of the OM will work. See also the examples given there.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|---|---|
| s_{xy} | f STAT ▲ s_{xy} | (-1) {} → {2} Calculates the <i>sample covariance</i> for the two data sets entered via (Σ+) , depending on the curve fit model selected. See pp. 212ff for the formula and COV for the <i>population covariance</i> . |
| SYSTEM | g MODE g SYSTEM | (0) Returns to DMCP. See App F. |
| S.INTS | f CATALOG VARS S.INTS | Submenu of <i>short integer variables</i> defined at execution time. See pp. 117f. |
| s.t→kg | g U↔ m: ▲ short ton → t | (1) {2, 11}; {1} → {2} |
| s→year | g U↔ f s→year | Convert masses and times. See pp. 140ff. |
| T ₀ | g CNST T₀ | (-1) {} → {2} Standard temperature (0°C) in <i>kelvin</i> . |
| tan | TRI tan | (1) {2, 3, 8*, 9*, 11, 12}; {1, 4} → {2} Returns the tangent of the angle in X. Returns “ <i>Not a Number</i> ” for $x = \pm 90^\circ$ or equivalents if SPCRES is set. |
| tanh | g EXP g tanh TRI g tanh | (1) {2, 3, 8*, 9*, 11, 12} Returns the hyperbolic tangent of x. |
| TDISP | g CLK ▲ TDISP n | (0) Sets time display format. TDISP 0 and 1 allow for displaying just <i>hours</i> and <i>minutes</i> , TDISP 2 for <i>seconds</i> , too, and $n \geq 3$ also for $n - 2$ digits showing decimal fractions of <i>seconds</i> . TDISP -1 allows for displaying all digits. |
| TEST | g TEST | Menu . See p. 127. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|------------------------------------|--|---|
| $t_e(x)$ | g PROB t: $t_e(x)$ etc. | (1) {2, 11} <i>Student's t distribution.</i> The degrees of freedom are stored in J . $t_e(x)$ equals $Q(t)$ on HP-21S. See Section 2 of the OM for an application example and pp. 212ff for more mathematical details. |
| $t_p(x)$ | | |
| $t(x)$ | | |
| $t^{-1}(p)$ | | |
| TICKS | g P.FN TICKS | (-1) {} → {1} Returns the number of ticks from the real-time clock at execution time. 1 tick = 0.1 s. Counting starts when the calculator is turned on. |
| TIME | g CLK TIME | (-1) {} → {5} Recalls the time from the real-time clock at execution (see Sect. 2 of the OM for the output format). |
| TIMER | f TIMER | Starts the timer application based on the real-time clock and following the timer of HP-55. See Sect. 5 of the OM for a detailed description. |
| TIMES | f CATALOG VARS f TIMES | Submenu of time variables defined at execution time. See pp. 117f. |
| T_n | g X.FN Orthog T_n | (2) {2, 11}; {1} → {2} <i>Chebyshev polynomials of first kind.</i> See pp. 227f for details. |
| TONE | g I/O f TONE n | (0) Sounds a tone according to n (= 1 ... 9). |
| $\text{ton} \rightarrow \text{kg}$ | g U→ m: ▲ ton→kg | (1) {2, 11}; {1} → {2} Converts masses. See pp. 140ff. |
| TOP? | g TEST g TOP? | (0) Returns ... <ul style="list-style-type: none"> • false if called with the program pointer being in a subroutine; • true if called in the top routine (i.e. if the program-running <i>flag</i> is set and the <i>SRS</i> pointer is clear). |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------------|---|---|
| tor→Pa | [g] [U] F&p: [f] torr → Pa | (1) {2, 11}; {1} → {2} Converts pressures. See pp. 140ff. |
| T_p | [g] [CNST] T_p | (-1) {} → {2} |
| t_{PL} | [g] [CNST] t_{PL} | Planck temperature in Kelvin; Planck time in seconds. |
| TRANS | [f] [CATALOG] FCNS TRANS | Works like [M] ^T on p. 98. Maintained for backward compatibility only. |
| TRI | [TRI] | Menu. See p. 127. |
| trz→kg | [g] [U] m: [f] tr.oz → kg | (1) {2, 11}; {1} → {2} Converts masses. See pp. 140ff. |
| TVM | [g] [FIN] TVM | Application. See Section 5 of the OM. |
| t: | [g] [PROB] t: | Submenu. See p. 126. |
| t↔ | [g] [STK] t↔ r | Swaps <i>t</i> and <i>r</i> , in analogy to <i>x↔</i> |
| ULP? | [g] [INFO] [f] ULP? | (1) {1, 2, 11} Returns 1 times the smallest power of ten which can be added to <i>x</i> or subtracted from <i>x</i> to actually change the value of <i>x</i> in your WP 43S in the mode set. Thus 1 is returned for integers. Indicated in STATUS. |
| U_n | [g] [X.FN] Orthog U_n | (2) {2, 11}; {1} → {2} <i>Chebyshev polynomials of second kind.</i> See pp. 227f for details. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------|---|---|
| UNITV | f [MATX] f UNITV | (1) {8, 9} Returns the unit vector for the matrix x (like UVEC in HP-42S). Each element of the matrix is adjusted so its overall Euclidean norm becomes 1 (see ENORM); for a vector, its magnitude will become 1. |
| | g [CPX] UNITV | (1) {3, 12} Returns a complex number with magnitude $ r = 1$ in direction of x . |
| UNSIGN | f [BITS] ▼ UNSIGN | (0) Sets unsigned mode for mode for operations on <i>short integers</i> . Indicated in the status bar. Cf. UNSGN on HP-16C. See Section 2 of the OM. |
| | g [INTS] ▲ ... | |
| U→ | g U→ | Menu. See p. 127. |
| VARMNU | g [P.FN] P.FN2 f VARMNU <i>label</i> | Creates a variable menu using the MVAR instructions following the global label specified. Cf. the HP-42S Owner's Manual. |
| VARS | f [CAT.] VARS | Submenu of variables defined at execution time. See pp. 117f. |
| VERS? | g [INFO] g VERS? | (0) Shows your firmware version and build number (see Section 2 of the OM). |
| VIEW | f [VIEW] <i>r</i> | (0) Shows <i>r</i> until the next key is pressed. Example: If <i>r</i> is a variable called Test12 containing -123.45, VIEW Test12 ENTER↑ will display Test12 = -123.45 |
| v_m | g [CNST] v_m | (-1) {} → {2} Molar volume of an ideal gas at standard conditions in <i>cubic meter per mol</i> . |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|---------------------|---------------------------------------|---|
| V: | [g] [U] [f] V: | _submenu. See p. 140. |
| V ₄ | [g] [A] | (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 | [g] [CLK] WDAY | (0) {2, 6, 11} → {1} Assumes <i>x</i> containing a <i>date</i> in the format selected (or a real number in corresponding format) and returns the name of the respective day and a corresponding integer (Monday = 1). ²⁵ |
| Weibl | [g] [PROB] | (1) {2, 11} |
| Weibl _e | [f] Weibl: Weibl etc. | Weibull distribution with its shape parameter b in I and its characteristic lifetime T in J. See pp. 212ff for details. |
| Weibl _p | | |
| Weibl ⁻¹ | | Weibl ⁻¹ returns the survival time <i>t_s</i> for a given probability <i>p</i> in X, with b in I and T in J. |
| Weibl: | [g] [PROB] [f] Weibl: | _submenu. See p. 126. |
| WHO? | [g] [INFO] [g] WHO? | (0) Displays credits to the brave men who made this project work. |
| Wh→J | [g] [U] [E] Wh→J | (1) {2, 11}; {1} → {2} Converts energies. See pp. 140ff. |
| W _m | [g] [X.FN] [▲] W _m etc. | (1) {2, 3, 11, 12}; {1} → {2} |
| W _p | | W _p returns the principal branch of Lambert's W for given <i>x</i> ≥ -1/e. W _m returns its negative branch (works for <i>x</i> ∈ ℝ only). W ⁻¹ returns <i>x</i> for a given W _p (≥ -1). See pp. 242ff for more. |
| W ⁻¹ | | |

²⁵ Translator's note: These day numbers correspond to Chinese weekdays 1 to 6 directly. For Portuguese weekdays ('segunda-feira' etc.), add 1 to days 1 to 5.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------|-----------------------------|---|
| WSIZE | f [BITS] ▼ WSIZE n | (0) Works almost like on HP-16C, but with the parameter $1 \leq n \leq 64$ trailing the command instead of taken from X. Reducing word size truncates the values in the stack as allocated and in L. All other memory content stays as is (see App. B on pp. 161ff). |
| | g [INTS] ▲ ... | Increasing the word size will add empty bits to each stack register. WSIZE 0 sets the word size to maximum, i.e. 64 bits. WSIZE is indicated in the status bar. |
| WSIZE? | g [INFO] g WSIZE? | (-1) {} → {1} Recalls the word size set. |
| W→hp _E | g [U→] P: W→hp _E | (1) {2, 11}; {1} → {2} |
| W→hp _M | etc. | Convert powers. See pp. 140ff. |
| W→hp _{UK} | | |
| Ȑx | f [STAT] Ȑx | (-2) {} → {2} Calculates the arithmetic means of the y- and x-data accumulated and pushes them on the stack. See also s, s _m , and σ. |
| Ȑx | f [STAT] ▲ Ȑx | (1) {2, 11}; {1} → {2} Returns a forecast x for a given y (in X) according to the curve fit model chosen. See L.R. for more. |
| x ² | g [EXP] x ² | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} Return the square of x. |
| | f [STAT] x ² | |
| | f [STAT] ▲ x ² | |
| x ³ | g [EXP] x ³ | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} Returns the cube of x. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------|---------------------------------|--|
| XEQ | [XEQ] <i>label</i> | (0) Executes the function or routine with the label specified. – In PEM, inserts a call to the subroutine with the label specified. |
| \bar{x}_G | f [STAT] g \bar{x}_G | (-2) {} → {2} Calculates the <i>geometric means</i> of the y- and x-data accumulated and pushes them on the <i>stack</i> . See pp. 221ff for the formula. Output format will be similar to the one of \bar{x} . See also ε , ε_m , and ε_p . |
| \bar{x}_H | f [STAT] ▲ f \bar{x}_H | (-2) {} → {2} Calculates the <i>harmonic means</i> of the y- and x-data accumulated and pushes them on the <i>stack</i> . |
| xIN | [XEQ] <i>type</i> | with <i>type</i> = NILADIC, MONADIC, DYADIC, TRIADIC, or ..._COMPLEX defines how many <i>stack</i> levels are used for parameter input to the function under consideration. Furthermore it does some initialization work (e.g. SSIZE8). xIN is the recommended way to start an XROM routine. Thereafter, SSIZE4 is legal. Note xIN cannot nest and XROM routines using xIN cannot call user code. |
| XNOR | f BITS f XNOR | (2) Work in analogy to AND. See p. 18. |
| XOR | f BITS XOR | |
| xOUT | [XEQ] <i>way</i> | Cleans and reverts the settings of xIN, taking care of a proper return including the correct setting of I and the <i>stack</i> . Typically, <i>way</i> = xOUT_NORMAL . Generally, xOUT shall be the last command of an XROM routine. |
| \bar{x}_{RMS} | f [STAT] ▲ g \bar{x}_{RMS} | (-2) {} → {2} Calculates the <i>quadratic means</i> of the y- and x-data accumulated and pushes them on the <i>stack</i> . |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------------------|-------------------------------------|---|
| \bar{x}_w | f [STAT] f \bar{x}_w | (-1) {} → {2} Returns the <i>arithmetic mean</i> for weighted data (where the weight y of each data point x was entered via $\Sigma+$). See pp. 221ff for the formula. See also s_w and s_{mw} . |
| $\sqrt[x]{y}$ | g [EXP] $\sqrt[x]{y}$ | (2) Returns the x^{th} root of y . Roots of negative integers or reals will return complex numbers if CPXRES is set. |
| X.FN | g [X.FN] | Menu. See p. 129. |
| $x!$ | f $x!$ | (1) {1, 10} Returns the <i>factorial</i> $n!$. Note this is only defined for positive integers. $20!$ is the biggest factorial $< 2^{64}$. $450!$ is the biggest factorial allowed for <i>long integers</i> . (1) {2, 3, 11, 12} Returns $\Gamma(x + 1)$. 204.3796629328708 is the max. x for SP reals. 2123.5499566246323631 is the max. x for DP reals. |
| $x:$ | g [U→] $x:$ | Submenu. See p. 140. |
| $x \rightarrow \text{DATE}$ | g [CLK] $x \rightarrow \text{DATE}$ | (1) {2} → {6} Interprets the real number x as a date coded in the date format selected (Y.MD, D.MY, or M.DY) and converts it to a proper <i>date</i> . |
| $x \rightarrow \alpha$ | g [α.FN] $x \rightarrow \alpha$ | (1) {1, 2, 10, 11} → {7} Interprets x as a character code and converts the integer part of x to the respective character x , similar to XTOA in the HP-42S. |
| $x \leftrightarrow r$ | g [STK] $x \leftrightarrow r$ | Swaps x and r , analogous to $x \leftarrow y$. Will be listed like $x \leftrightarrow J$, $x \leftrightarrow .12$, $x \leftrightarrow 12$, etc. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------------|---------------------------------------|--|
| $x \leftrightarrow y$ | <code>x↔y</code> | Swaps the <i>stack</i> contents x and y . |
| $x = ?$ | <code>g TEST x= ? r</code> | (0) Compare x with r . See $x < ?$ for more. |
| $x \neq ?$ | <code>g TEST x≠ ? r</code> | (0) Compare x with r . See $x < ?$ for more. |
| $x = +0?$ | <code>g TEST ▲ x=+0?</code> etc. | (0) {1, 2, 3, 10, 11, 12} These tests are for comparing <i>short integers</i> in modes 1COMPL and SIGNMT, and for <i>long integers</i> , real or complex numbers if SPCRES is set. Then e.g. $0 / (-7)$ will display -0 . |
| $x = -0?$ | <code>g TEST ▲ x=-0?</code> | (0) {1, 2, 3, 10, 11, 12} Will be true if the <u>rounded</u> values of x and r are equal (see ROUND). See $x < ?$ for more. |
| $x \approx ?$ | <code>g TEST ▲ x≈ ? r</code> | (0) {2, 3, 4, 5, 8*, 9*, 11, 12} |
| $x < ?$ | <code>g TEST x< ? r</code> etc. | (0) {1, 2, 4, 5, 6, 7, 10, 11} Compare x with r . Example: <code>TEST x< ? K</code> compares x with k , and will be listed as <code>x< ? K</code> in a routine. It will return true if $x < k$ at execution time. See examples in Sect. 1 of the OM for more. |
| \hat{y} | <code>f STAT ▲ ŷ</code> | (1) {2, 11}; {1} → {2} Returns a forecast \hat{y} (in X) for a given x according to the curve fit model chosen. See L.R. for more. |
| $yd.\rightarrow m$ | <code>g U→ x: g yd.→m</code> | (1) {2, 11}; {1} → {2} Converts distances. See pp. 140ff. |
| YEAR | <code>g CLK f YEAR</code> | (1) {2, 6, 11} → {1} Assumes x containing a <i>date</i> in the format selected (or a real number in corresponding format) and extracts the year. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------------------------|--|--|
| year→s | g U→ f year→s | (1) {2, 11}; {1} → {2} Converts times. See pp. 140ff. |
| y^x | y^x | (2) {1, 2, 3, 10, 11, 12} Returns the x^{th} power of y . It allows for raising any positive real number to an arbitrary real power, as well as any negative real number to an arbitrary integer power, all returning real results. Exceeding these boundaries may produce complex results (or errors if CPXRES is clear). |
| Y.MD | g CLK ▲ Y.MD | (0) Sets the format yyyy-mm-dd for dates. |
| y\leftrightarrow | g STK y\leftrightarrow r | Swaps y and r , in analogy to $x\leftarrow$. |
| z₀ | g CNST z₀ | (-1) {} → {2} Characteristic impedance of vacuum in ohm. |
| z\leftrightarrow | g STK z\leftrightarrow r | Swaps z and r , in analogy to $x\leftarrow$. |
| α | g CNST α | (-1) {} → {2} Fine-structure constant. |
| αINTL | f CAT. CHARS αINTL | Submenu. See pp. 117ff. |
| | g + | Menu in AIM (see p. 129). |
| αLENG? | g INFO g αLENG? r | (-1) {} → {1} |
| | g α.FN f αLENG? r | Returns the number of characters found in r , similar to ALENG in HP-42S. ²⁶ |
| αMATH | f CAT. CHARS αMATH | Submenu. See pp. 117ff. |
| | g - | Menu in AIM. See p. 130. |

²⁶ This command will throw an error if there is no string in r at execution time.

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------------|---|---|
| $\alpha\text{POS?}$ | [g] [INFO] [g] $\alpha\text{POS? } r$ | (-1) {} → {1} Looks in r for the target given in X . If a match is found, αPOS returns the position number where the target was found (counting the left-most character as position 0). If a match is not found, αPOS returns -1. ²⁶ |
| | [g] [a.FN] $\alpha\text{POS? } r$ | The target may be an individual character code or an <i>alpha string</i> . αPOS saves a copy of the target in L . It works similar to POSA in HP-42S. |
| αRL | [g] [a.FN] $\alpha\text{RL } r$ | (0) Rotates r by x characters like AROT in HP-42S, but with $x \geq 0$. $\alpha\text{RL } 0$ executes as NOP, but loads L . ²⁶ |
| αRR | [g] [a.FN] $\alpha\text{RR } r$ | (0) Works like αRL but rotates to the right. |
| αSL | [g] [a.FN] $\alpha\text{SL } r$ | (0) Shifts the x leftmost characters out of r , like ASHF in HP-42S. This allows for deleting the first x characters in the string. $\alpha\text{SL } 0$ executes as NOP, but loads L . ²⁶ |
| αSR | [g] [a.FN] $\alpha\text{SR } r$ | (0) Works like αSL but for the x rightmost characters out of r , deleting the last x characters in the string. ²⁶ |
| αFN | [g] [a.FN] | ► Menu . See p. 130. |
| $A\ldots\Omega$ | [f] [CAT.] [CHARS] $A\ldots\Omega$ | Submenu of Greek letters, see pp. 117ff. |
| $\alpha\cdot$ | [f] [CAT.] [CHARS] $\alpha\cdot$ | Submenu . See pp. 117ff. |
| | [g] [] | Menu in A/M. See p. 130. |
| $\alpha\rightarrow x$ | [g] [a.FN] $\alpha\rightarrow x r$ | (-1) {} → {1} Pushes the character code of the leftmost character in r on the <i>stack</i> and removes this character from the string, similar to ATOX in HP-42S. ²⁶ |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|------------------|--|---|
| $\beta(x,y)$ | g X.FN ▲ $\beta(x,y)$ | (2) {2, 3, 11, 12}; {1} → {2} Returns Euler's Beta $B(x, y) = \frac{\Gamma(x) \Gamma(y)}{\Gamma(x+y)}$ with $Re(x) > 0$ and $Re(y) > 0$. Called β here to avoid ambiguity. See $\Gamma(x)$ below. |
| γ | g CNST γ | (-1) {} → {2} Newtonian constant of gravitation (also called G by other authors) in $m^3 / kg\ s^2$; |
| γ_{EM} | g CNST γ_{EM} | Euler-Mascheroni constant (for mathematics); |
| γ_p | g CNST γ_p | proton gyromagnetic ratio (see p. 137). |
| Γ_{xy} | g X.FN ▲ Γ_{xy} | (2) {2, 11}; {1} → {2} Returns the lower incomplete Gamma function. See pp. 242ff for more. |
| γ_{xy} | g X.FN ▲ f γ_{xy} | (2) {2, 11}; {1} → {2} Returns the upper incomplete Gamma function. See pp. 242ff for more. |
| $\Gamma(x)$ | g PROB ▲ $\Gamma(x)$ | (1) {2, 3, 11, 12}; {1} → {2} Returns $\Gamma(x)$. Note x! calls $\Gamma(x + 1)$. See also LNF. |
| δx | f CAT. PROGS δx | Predefined global label for $f'(x)$ and $f''(x)$ – see Section 4 of the OM. |
| $\Delta\nu_{Cs}$ | g CNST $\Delta\nu_{Cs}$ | (-1) {} → {2} Hyperfine transition frequency of ^{133}Cs in hertz. |
| $\Delta\%$ | f Δ% | (1) {2, 11}; {1} → {2} Returns $100 \frac{x-y}{y}$ leaving y unchanged, like %CH in HP-42S. Use it also for calculating markups or margins as explained in the OM, Sect. 2. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------|--------------------------|--|
| ε | f STAT g ε | (-2) {} → {2} Calculates the <i>scattering factors</i> ε_y and ε_x for <i>log-normally</i> distributed sample data and pushes them on the stack. This ε_x works for the <i>geometric mean</i> \bar{x}_g in analogy to the <i>standard deviation</i> s for the <i>arithmetic mean</i> \bar{x} but <u>multiplicative</u> instead of additive. See pp. 212ff for more information. |
| ε_0 | g CNST ε_0 | (-1) {} → {2} Electric constant or vacuum permittivity in <i>ampere-second per volt-meter</i> . |
| ε_m | f STAT g ε_m | (-2) {} → {2} Works like ε 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>). |
| ε_p | f STAT g ε_p | (-2) {} → {2} Works like ε 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. 245 for more. |
| λ_c | g CNST λ_c | (-1) {} → {2} |
| λ_{cn} | etc. | <i>Compton wavelength of the electron, neutron, and proton in meter.</i> |
| λ_{cp} | | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|----------------|---|---|
| μ_0 | g [CNST] μ_0 etc. | (-1) {} → {2} Magnetic constant or vacuum permeability in <i>volt-second per ampere-meter</i> ; |
| μ_B | | Bohr magneton in <i>joule per tesla</i> ; |
| μ_e | | electron magnetic moment in <i>joule per tesla</i> ; |
| μ_e/μ_B | | ratio of electron magnetic moment to <i>Bohr magneton</i> ; |
| μ_n | | neutron and proton magnetic moments, nuclear magneton, and |
| μ_p | | |
| μ_u | | Muon magnetic moment in <i>joule per tesla</i> . |
| μ_μ | | |
| π | g [Π] | (-1) {} → {2} Recalls π . |
| Π_n | f [ADV] Π_n <u>label</u> | Computes a product using the routine specified. See Section 4 of the OM for more. ATTENTION: Π_n fills all <i>stack registers</i> with x before calling the routine specified. |
| σ | f [STAT] σ | (-2) {} → {2} Works like s but returns the <i>standard deviations</i> of the two <i>populations</i> instead. See pp. 212ff. |
| σ_B | g [CNST] σ_B | (-1) {} → {2} <i>Stefan-Boltzmann constant</i> (see p. 138). |
| Σ^1/x | g [SUMS] ▲ Σ^1/x etc. | (-1) {} → {2} Recall the corresponding statistical sums, necessary for means and regressions beyond the linear model. Calling these sums by name significantly improves program readability. Note they are stored in dedicated <i>registers</i> of your WP 43S (see App. B on pp. 161ff.). |
| Σ^1/x^2 | | |
| Σ^1/y | | |
| Σ^1/y^2 | | |

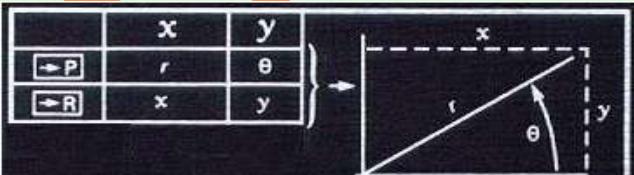
| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|------------------|---|--|
| $\Sigma \ln^2 x$ | g SUMS f $\Sigma \ln^2 x$ etc. | <p>ATTENTION: Depending on input data, some of the logarithmic sums may become non-numeric or some of the inverted may become infinite. If this happens no error will be thrown, however, regardless of the status of SPCRES.</p> <p>For space reasons, two sums are abbreviated:</p> <p>$\Sigma \ln xy$ denotes $\sum \ln(x) \ln(y)$.</p> <p>$\Sigma \ln y/x$ denotes $\sum \frac{\ln(y)}{x}$.</p> |
| $\Sigma \ln^2 y$ | | |
| $\Sigma \ln x$ | | |
| $\Sigma \ln xy$ | | |
| $\Sigma \ln y$ | | |
| $\Sigma \ln y/x$ | g SUMS g $\Sigma \ln y/x$ | <p>Computes a sum using the routine specified. See Section 4 of the OM for more.</p> <p>ATTENTION: Σ fills all stack registers with x before calling the routine specified.</p> |
| Σ_n | f ADV Σ_n labl | |
| s_w | f STAT f s_w | <p>(-1) {} → {2}</p> <p>Works like s_w but returns the <i>standard deviation</i> of the <i>population</i> instead. See pp. 212ff.</p> <p>Σx g SUMS Σx etc.</p> <p>Σx²</p> <p>Σx²y g SUMS g Σx^2y</p> <p>Σx²/y g SUMS ▲ $\Sigma x^2/y$</p> <p>Σx³ g SUMS ▲ f Σx^3 etc.</p> <p>Σx⁴</p> <p>Σxlny g SUMS g $\Sigma xlny$</p> <p>Σxy g SUMS Σxy</p> <p>Σx/y g SUMS ▲ $\Sigma x/y$</p> <p>Σy g SUMS Σy etc.</p> <p>Σy²</p> |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-----------------|---|--|
| Sylnx | g SUMS g Sylnx | See Σ^1/x above for more |
| $\Sigma+^{27}$ | f STAT $\Sigma+$ | <p>{8} → {2}</p> <p>If X 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 and the matrix will be in L.</p> |
| | | {1, 2, 11} Adds one 2D data point to the statistical sums. |
| $\Sigma-^{27}$ | f STAT f $\Sigma-$ | {1, 2, 11} Subtracts one 2D data point from the statistical sums. |
| Φ | g CNST Φ | (-1) {} → {2} |
| Φ_0 | g CNST Φ_0 | Golden ratio and magnetic flux quantum, the latter in <i>volt-second</i> . |
| $\chi^2_e(x)$ | g PROB $\chi^2:$ $\chi^2(x)$ | (1) {2, 11} |
| $\chi^2_p(x)$ | etc. | <i>Chi-square distribution</i> (with its degrees of freedom given in I). $\chi^2_e(x)$ equals $Q(\chi^2)$ on HP-21S. See <i>Section 2</i> of the <i>OM</i> for an application example and pp. 212ff for more. |
| $(\chi^2)^{-1}$ | | |
| $\chi^2:$ | g PROB $\chi^2:$ | Submenu. See p. 126. |
| ω | g CNST ω | (-1) {} → {2} Angular velocity of the Earth in <i>radians per second</i> according to <i>WGS84</i> (see footnote 23 on p. 69). |

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

| Item | Keystrokes | Remarks (see pp. 12ff for general information) | | | | | | | | | |
|--------------|--------------------|--|------|---|---------------------|------|----|-------------------------|-------|---|-------|
| $(-1)^x$ | | (1) {1, 2, 3, 8*, 9*, 10, 11, 12} If x is non-integer, returns $\cos(\pi x)$. | | | | | | | | | |
| $[M]^T$ | | (1) {8, 9} Returns the transpose of the matrix x (like TRANS in HP-42S). The transpose is another matrix with rows changed by columns. If A is an $n \times m$ matrix and a_{ij} is an element of it then A^T will be an $m \times n$ matrix B with $b_{ij} = a_{ji}$. The transpose is done in-situ and does not require any additional memory. | | | | | | | | | |
| $[M]^{-1}$ | | (0) {8, 9} Takes the square matrix in X and inverts it in-situ (like INVRT on HP-42S). | | | | | | | | | |
| $+$ | | (2) Returns $y + x$ for compatible objects. | | | | | | | | | |
| $+/-$ | (for closed input) | (1) 'Unary minus', returns $x \times (-1)$. | | | | | | | | | |
| $\pm\infty?$ | | (0) {2, 11} → {1} Tests x for infinity. Returns <table style="margin-left: 20px; border-collapse: collapse;"> <tr> <td>true</td> <td style="text-align: right;">1</td> <td>for $x = +\infty$,</td> </tr> <tr> <td>true</td> <td style="text-align: right;">-1</td> <td>for $x = -\infty$, and</td> </tr> <tr> <td>false</td> <td style="text-align: right;">0</td> <td>else.</td> </tr> </table> | true | 1 | for $x = +\infty$, | true | -1 | for $x = -\infty$, and | false | 0 | else. |
| true | 1 | for $x = +\infty$, | | | | | | | | | |
| true | -1 | for $x = -\infty$, and | | | | | | | | | |
| false | 0 | else. | | | | | | | | | |
| $-$ | | (2) Returns $y - x$ for compatible numeric objects. See the tables in the OM, Sect. 2, for details. | | | | | | | | | |
| $-\infty$ | | (-1) {} → {2} Minus infinity. See p. 139. | | | | | | | | | |
| \times | | (2) Like $-$, but returns $y \times x$. | | | | | | | | | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|--------------------------|------------------------|--|
| $\times\text{MOD}$ | | (3) {1, 2, 10, 11} Returns $(z \times y) \bmod x$ for $x > 1, y > 0, z > 0$. See MOD. |
| / | | (2) Like $-$, but returns $y \times x^{-1}$. Returns $y \bmod x$ if both y and x are of data type 1 or 10; cf. IDIV. |
| $^{\wedge}\text{MOD}$ | | (3) {1, 2, 10, 11} Returns $(z^y) \bmod x$ for $x > 1, y > 0, z > 0$. See MOD. |
| \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 date in x . Thus inverts DATE \rightarrow . |
| $\rightarrow\text{DEG}$ | | (1) {1, 2, 4, 11} \rightarrow {4} Converts angles as described on pp. 148f. |
| $\rightarrow\text{DP}$ | | (1) {1, 2, 11} \rightarrow {11}; {3, 12} \rightarrow {12} Converts x into a DP number. Numbers shown as fractions will be displayed as decimal numbers (cf. IMPFRC and PROFRC). Compare $\rightarrow\text{SP}$. |
| $\rightarrow\text{D.MS}$ | | (1) {1, 2, 4, 11} \rightarrow {4} |
| $\rightarrow\text{GRAD}$ | | Convert angles as described on pp. 148f. |
| $\rightarrow\text{HR}$ | | (1) {5} \rightarrow {2} Operates on times like $\rightarrow\text{REAL}$ below. Maintained for backward compatibility only. |
| $\rightarrow\text{H.MS}$ | (for closed input) | (1) {1, 2, 5, 11} \rightarrow {5} Converts x to a sexagesimal time – cf. p. 113. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|--------------------------------|---|
| →INT | f # base (for closed input) | (1) {1, 2, 10, 11} → {10} Converts the integer part of x to a <i>short integer</i> of the base specified. Conversion to decimal may be abbreviated by #D, to hexadecimal by #H. Cf. p. 113. |
| →MULπ | f L → →MULπ | (1) {1, 2, 4, 11} → {4} Converts angles as described on pp. 148f. |
| →POL | g P | [2, 11]; {1} → {2} Assumes X and Y containing 2D <i>Cartesian</i> coordinates of a point or components of a vector (x, y). Converts them to the respective polar coordinates or components (r, θ). See the picture and cf. →REC.  For switching the display format of complex numbers, CF RECTN . |
| →RAD | f L → →RAD | (1) {1, 2, 4, 11} → {4} Converts angles as described on pp. 148f |
| →REAL | f .d (for closed input) | (1) {1, 2, 4, 5, 6, 10, 11} → {2} Converts x to an SP real number. Any object (e.g. a <i>time</i>) tagged sexagesimal will be converted in a decimal number. For {6}, the date format chosen is taken into account. Numbers shown as fractions will be displayed as decimal numbers (cf. FRACT and PROPFR). For returning the real part of a complex number, choose RE. For cutting a complex number into its parts, use CC. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|------|----------------|---|
| →REC | f R↔ | [2, 11]; {1, 4} → {2} Assumes X and Y containing 2D polar coordinates of a point or components of a vector (r, θ). Converts them to the respective Cartesian coordinates or components (x, y). See the picture and cf. →POL above. For switching the display format of complex numbers, SF RECTN. |
| →SP | f SP↔ | (1) {1, 2, 11} → {2}; {3, 12} → {3} |
| | g X.FN ▲ f →SP | Converts x to an SP real number. Numbers shown as fractions will be displayed as decimal numbers (cf. FRACT and PROPFR). Cf. →DP. |
| ⤒ | g STK ⤒ ---- | Shuffles the contents of the <i>stack registers</i> X, Y, Z, and T at execution time. Examples: ⤒xyz works like ENTER↑ (but does <u>not</u> disable <i>automatic stack lift!</i>), ⤒yxzt works like x↔y, ⤒zytx works like R↓ in a 4-level stack, ⤒txyz works like R↑ in a 4-level stack, but also ⤒yytt or ⤒zzzx is possible. ATTENTION: 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 ⤒, you may lose some stack contents and make a mess of the stack easily. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|------------|----------------|--|
| % | [g] [FIN] % | (1) {2, 11}; {1} → {2} Returns $\frac{xy}{100}$, leaving y unchanged. |
| %MRR | [g] [FIN] %MRR | (3) {2, 11}; {1} → {2} Returns the mean rate of return in % per period, i.e. $100 \cdot \left(\sqrt[z]{x/y} - 1 \right)$ with $x = FV$ = future value after z periods, $y = PV$ = present value. For $z = 1$, Δ% returns the same result easier. |
| %T | [g] [FIN] %T | (1) {2, 11}; {1} → {2} Returns $\frac{100 x}{y}$, interpreted as % of total. Leaves y unchanged. |
| %Σ | [g] [FIN] %Σ | (1) {2, 11}; {1} → {2} Returns $\frac{100 x}{\sum x}$. |
| %+MG | [g] [FIN] %+MG | (2) {2, 11}; {1} → {2} Calculates a sales price by adding a margin of x % to the cost y , as %MU-Price in HP-17B. Formula: $p_{sale} = \frac{y}{1 - \frac{x}{100}}$ You may use %+MG for calculating net amounts as well; just enter a negative percentage in x . |
| \sqrt{x} | [\sqrt{x}] | (1) {1, 2, 3, 8*, 9*, 10, 11, 12}; ({1} → {2}, {2} → {3}) Returns the square root of x . Square roots of non-square long integers will return reals. Roots of negative long integers or reals will return complex numbers if CPXRES is set. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------------------|--|--|
| ∞ | | (-1) {} → {2} Infinity. See p. 139. |
| \int | (listed in programs as $\int \text{fd}$ trailed by the integration variable) | [2] Integrates the function given in the routine specified by PGMINT over the variable specified. Lower and upper integration limits must be supplied by the corresponding variables $\downarrow\text{Lim}$ and $\uparrow\text{Lim}$, accuracy by ACC. \int returns the (approximated) integral in X and an upper limit of its uncertainty in Y. ATTENTION: \int fills all stack registers with x before calling the routine specified in PGMINT. |
| | | Integrates the current equation. |
| $\int f$ | | Submenus. See pp. 123f. |
| $\int \text{fdx}$ | | |
| $ M $ | | (1) {8} → {2}; {9} → {3} Requires a square matrix in X and returns its determinant. The original matrix is stored in L. |
| $ x $ | or | (1) {1, 2, 4, 10, 11} Returns the absolute (unsigned) value of x. |
| | | (1) {8*} Returns a real matrix with the absolute values of all input matrix elements. Cf. ENORM. |
| | or | (1) {3} → {2}; {12} → {11} Returns the magnitude $\sqrt{\text{Re}(x)^2 + \text{Im}(x)^2}$ in X. |
| | | (1) {9*} → {8} Returns a real matrix with the magnitudes of all input matrix elements. Cf. ENORM. |
| | | |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|--|--|
| | g X.FN ▲ f | (2) {2, 3, 11, 12}; {1} → {2} Returns $\left(\frac{1}{x} + \frac{1}{y}\right)^{-1}$, being useful in electrical engineering especially. Returns 0. for x or y being zero. |
| ¶ | g ↗ or g CPX f ¶ or f PARTS f ¶ | (1) {3} → {2}; {12} → {11} Returns the phase or argument $\arg(x) = \arctan\left(\frac{\text{Im}(x)}{\text{Re}(x)}\right)$. Cf. x . (1) {9*} → {8} Returns a matrix with the phases of all input matrix elements. Cf. x . |
| ¶→ | f ↴ | Menu of angular conversions. See p. 131. |
| ¶ADV | g I/O ▲ ¶ADV | (0) Prints the current contents of the print buffer and a linefeed. ATTENTION: The printer will actually print only when a linefeed is sent to it. |
| ¶CHAR | g I/O ▲ ¶CHAR n | (0) Sends a single character (with the code specified) to the printer. Character codes $n > 127$ can only be specified indirectly. ¶MODE setting will be honored. See ¶ADV . |
| ¶DLAY | g I/O ▲ ¶DLAY n | (0) Sets a delay of n ticks (see TICKS) to be used with each linefeed on the printer. |
| ¶LCD | g I/O ▲ ¶LCD | (0) Sends the contents of the entire LCD to the printer. |
| ¶MODE | g I/O ▲ ¶MODE n | (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. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|------------|---|
| | | <p>2: Use the small display font, which allows for packing even more info in a row.</p> <p>3: Send the output to the serial channel. Works for plain ASCII only – no characters will be translated. Line setup is the same as for serial communication: 9600 baud, 8 bits, no parity.</p> |
| ■PROG | | (0) Prints the listing of the <i>current program</i> (see Sect. 3 of the OM), 1 row per step. See ■ADV. |
| ■REGS | | <p>(1) Interprets <i>x</i> in the form <i>sss.nn</i>. Prints the contents of <i>nn</i> registers starting with number <i>sss</i>. Each register takes one row starting with a label. See also ■ADV.</p> <p>ATTENTION for <i>nn</i> = 0 :</p> <ul style="list-style-type: none"> • For <i>sss</i> ∈ [0; 99], printing will stop at R99. • For <i>sss</i> ∈ [100; 111], printing will stop at K. • For <i>ss</i> ≥ 112, printing will stop at the highest allocated local register. |
| ■r | | (0) Prints the <i>register</i> specified, right adjusted, <u>without</u> labeling the output. Note ■r X is on the keyboard. If you want a heading label, compose the string in X first or use ■REGS. See ■ADV. |
| ■STK | | (0) Prints the <i>stack</i> contents. Each <i>register</i> prints in a separate row starting with a label indicating said <i>register</i> . See ■ADV. |
| ■TAB | | (0) Positions the print head to print column <i>n</i> (0 to 165, where <i>n</i> > 127 can only be specified indirectly). Useful in formatting (in ■MODE 1 or 2 in particular). Allows also for printer plots. If <i>n</i> is less than current print head position, a linefeed will be entered to reach the new position. See ■ADV. |

| Item | Keystrokes | Remarks (see pp. 12ff for general information) |
|-------|-------------------------|---|
| USER | [g] I/O [▲] [f] 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 [R/S] to stop the listing. |
| WIDTH | [g] I/O [▲] [f] WIDTH | (-1) Returns the number of print columns that <i>x</i> would take in the print mode set. See MODE and ADV. Second use: in MODE 1 or 2, WIDTH returns the width of <i>x</i> in px (including the last column being always blank) in the specified font. |
| Σ | [g] I/O [▲] [g] Σ | (0) Prints the summation registers. Each register prints in one row starting with its label. See ADV. |
| # | [g] I/O [▲] [g] # n | (0) Sends a single byte, 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. |
| # | [f] CATALOG FCNS # n | For inserting an integer $0 \leq n \leq 255$ in a single program step. Maintained for backward compatibility to WP 34S only. |
| #B | [f] BITS [g] #B | (1) {10} Counts the bits set in <i>x</i> (like on HP-16C). |

Names of Predefined Variables and System Flags Provided

There is a *name* overlap between some constants and commands on one side and predefined variables and system flags on the other. Thus, the latter set is kept separate from the other *items*. As required for the *items* above, these *names* must be unique.

| Name | Keystrokes if applicable | Remarks (see pp. 12ff for general information) |
|---------|--------------------------|---|
| A | | Reserved variable for <i>register A</i> |
| ACC | f ADV ∫fdx ACC | Reserved real variable for the accuracy of integration (see Sect. 4 of the OM). |
| ADM | | Reserved integer variable for the ADM: 0: DEG, 1: D.MS, 2: RAD, 3: MULπ, 4: GRAD. |
| ALLSCI | | System flags – see next chapter. |
| ALPHA | | |
| ALP.IN | | |
| ASL.BLK | | |
| AUTOFF | | |
| AUTXEQ | | |
| B | | Reserved variables for <i>registers B</i> and C . |
| C | | |
| CARRY | | System flags – see next chapter. |
| CPXj | | |
| CPXRES | | |
| D | | Reserved variable for <i>register D</i> . |

| Name | Keystrokes if applicable | Remarks (see pp. 12ff for general information) |
|--------|--------------------------|---|
| DECIM. | | System flags – see next chapter. |
| DENANY | | |
| DENFIX | | |
| DENMAX | | Reserved integer variable for the maximum denominator, filled by the command DENMAX. |
| DMY | | System flags – see next chapter. |
| FRACT | | |
| FV | g [FIN] TVM FV | Reserved variable for the future value of your investment or loan in TVM. ²⁸ |
| GROW | | System flag – see next chapter. |
| I | | Reserved variable for register I. |
| IGN1ER | | System flag – see next chapter. |
| INTING | | |
| i%/a | g [FIN] TVM i%/a | Reserved variable for the annual interest rate of your investment or loan in TVM. ²⁸ |
| J | | Reserved variables for registers J, K, and L. |
| K | | |
| L | | |
| LEAD.0 | | System flags – see next chapter. |
| LOWBAT | | |

²⁸ See Section 5 of the OM.

| Name | Keystrokes if applicable | Remarks (see pp. 12ff for general information) |
|--------|------------------------------|---|
| Mat_A | f [MATX] SIM EQ Mat A | |
| Mat_B | f [MATX] SIM EQ Mat B | Reserved variables for solving systems of linear equations (<i>SLE</i> , see <i>Section 2</i> of the <i>OM</i>). |
| Mat_X | f [MATX] SIM EQ Mat X | |
| MDY | | System flags – see next chapter. |
| MULTx | | |
| NPER | g [FIN] TVM n _{PER} | Reserved variable for the <u>total</u> number of <ul style="list-style-type: none"> • payment periods for your loan or • compounding periods for your investment. |
| NUM.IN | | |
| OVERFL | | |
| PER/a | g [FIN] TVM f per/a | Reserved variable for the <u>annual</u> number of <ul style="list-style-type: none"> • payments for your loan or • compounding periods of your investment. |
| PMT | g [FIN] TVM PMT | Reserved variable for the payment per period for your investment or loan in <i>TVM</i> . ²⁸ |
| PRINT | | |
| PROPFR | | |
| PRTACT | | |
| PV | g [FIN] TVM PV | Reserved variable for the present value of your investment or loan in <i>TVM</i> . ²⁸ |
| QUIET | | System flag – see next chapter. |
| REALDF | | Reserved integer variable for display format of reals: 0: ALL, 1: FIX, 2: SCI, 3: ENG. |

| Name | Keystrokes if applicable | Remarks (see pp. 12ff for general information) |
|--------|--------------------------|---|
| RECTN | | <i>System flag</i> – see next chapter. |
| REGS | | Reserved variable for the 100×1 matrix of registers – if required. |
| RUNIO | | <i>System flags</i> – see next chapter. |
| RUNTIM | | |
| SOLVIN | | |
| SPCRES | | |
| SPEED | | |
| SSIZE | | |
| ST.A | | Reserved variables for <i>stack registers A ... Z</i> |
| ST.B | | |
| ST.C | | |
| ST.D | | |
| ST.T | | |
| ST.X | | |
| ST.Y | | |
| ST.Z | | |
| TDM | | <i>System flags</i> – see next chapter. |
| TRACE | | |
| USER | | |
| VMDISP | | |
| YMD | | |
| αCAP | | |

| Name | Keystrokes if applicable | Remarks (see pp. 12ff for general information) |
|--------------------------------|--|--|
| $\text{\texttt{\$}}\text{Lim}$ | f ADV f fdx \text{\texttt{\\$}}\text{Lim} etc. | Reserved real variables for the upper and lower limit of integration (see 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). |

System Flags

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

| Purpose | SBI | Flag ²⁹ | Remarks |
|--------------|-------------|---------------------|---|
| Time display | Time string | TDM | 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 | Set for the respective date format chosen. The commands Y.MD, D.MY, and M.DY set the respective <i>flag</i> and clear the others. |

²⁹ The flags printed on green may be written and read by the user, those printed on yellow are read-only and are written by the system exclusively.

| Purpose | SBI | Flag ²⁹ | Remarks |
|----------------------|--------|--|--|
| Complex results | C / R | CPXRES | Set for allowing complex results also for real input (e.g. $\sqrt{-1}$). |
| Complex letter | — | CPXj | Set for the letter <i>j</i> representing the imaginary number <i>i</i> , clear for <i>i</i> . |
| Rectangular notation | L / ⊙ | RECTN | Set for rectangular display of complex numbers, clear for polar |
| Fraction display | /nnnn | FRACT | Set if fraction display is chosen, clear for decimal display (<i>a b/c</i> and <i>d/c</i> set FRACT, <i>.d</i> clears it). See next entries. |
| Fraction kind 1 | — | PROPFR | Set for <i>proper fractions</i> , clear for <i>improper fractions</i> (<i>a b/c</i> sets PROPFR, <i>d/c</i> clears it). PROPFR set allows only <i>proper fractions</i> in display (e.g. $1 \frac{2}{3}$ instead of $\frac{5}{3}$); any reals (with $ x < 10^6$) will be displayed according to the settings by DEN... below as <i>proper fractions</i> . |
| Fraction kind 2 | see OM | DENANY | Set if any denominator up to DENMAX may appear (DENMAX is indicated in the status bar). This is – for given DENMAX – the most precise way of displaying a decimal number as a fraction. Example: If DENMAX = 5 then DENANY set allows denominators 1, 2, 3, 4, and 5. |
| Fraction kind 3 | see OM | DENFIX (only relevant if DENANY is clear) | Set if the one and only denominator allowed is the value set by DENMAX. Clear if the denominator may be an integer factor of DENMAX. |

| Purpose | SBI | Flag ²⁹ | Remarks |
|-------------------|--------|--------------------|---|
| | | | Example: 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. Now you know why 60 was a holy number in ancient Babylon. |
| Overflow | • or ¢ | OVERFL | Reflects the status of the overflow bit |
| Carry | ¢ or • | CARRY | Reflects the status of the carry bit |
| Leading zeros | — | LEAD.0 | Set for leading zeros in <i>short integers</i> of bases 2, 4, 8, and 16 turned on (like flag 3 in HP-16C). |
| Alpha | A or α | ALPHA | Set for A/M, else clear |
| Upper case | A / α | αCAP | Set for capitals, clear for lower case |
| Running timer | ⌚ | RUNTIM | Set if the timer is running |
| Running I/O | ⇅ | RUNIO | Set if I/O is in progress |
| Printing | 🖨️ | PRINT | Set if your WP 43S is sending data to the printer |
| Tracing | — | TRACE | Set if the print line is in tracing mode, else prints must be triggered explicitly |
| User mode | 👤 | USER | Set if your WP 43S is in user mode |
| Low battery | 🔋 | LOWBAT | Set if the battery voltage is low |
| “Special” results | — | SPCRES | Set for allowing special results ($\pm\infty$ and NaN) |

| Purpose | <i>SBI</i> | <i>Flag</i> ²⁹ | Remarks |
|---------------------|------------|---------------------------|---|
| Processor speed | — | SLOW | Clear as <i>startup default</i> and kept for fresh batteries unless the user intervenes, set for battery voltage <2.5V. Speed will be reduced to 50% with this flag set. |
| Stack size | — | SSIZE | Set for eight, clear for four <i>stack registers</i> . Note <i>register</i> contents will remain unchanged in this operation (as well as if <i>stack size</i> is modified by any other operation – e.g. by RCLCFG). |
| Beeper | — | QUIET | Set for disabled beeper |
| Radix mark | — | DECIM. | Set for a decimal point, clear for a comma |
| Multiplication mark | — | MULT× | Set for multiplication symbol ×, clear for · |
| Overflow from ALL | — | ALLSCI | Set if numbers exceeding the range displayable in ALL or FIX will be shown in SCientific format, clear for ENGineer's format. |
| Matrix grow mode | — | GROW | Set (e.g. by M.GROW) if matrices may grow, else clear (e.g. by M.WRAP). See the command J+ above and Section 2 of the OM; see also GROW in the HP-42S Owner's Manual, p. 213. |
| Automatic OFF | — | AUTOFF | Set if automatic shutdown is enabled (default); else your WP 34S will continue being ON until you turn it off manually or battery voltage drops below the limit. |
| Automatic execution | — | AUTXEQ | Like <i>flag 11</i> of HP-42S |
| Printer activated | — | PRTACT | Like <i>flag 21</i> of HP-42S |

| Purpose | SBI | Flag ²⁹ | Remarks |
|------------------------------|-----|--------------------|--|
| Error handling | — | IGN1ER | If set, your WP 43S ignores just 1 arbitrary error and clears IGN1ER then. The operation causing the error will not be executed. This works like flag 25 of HP-42S |
| AGRAPH control | — | xxx | Works like flags 34 and 35 of HP-42S – see p. xxix. |
| Disable automatic stack lift | — | ASL.BLK | Set by ENTER, CLX, $\Sigma+$, and $\Sigma-$, cleared by all other functions (see the OM, Sect. 1) |
| Data entry | — | NUM.IN, ALP.IN | Set for numeric or alphanumeric entry (like flags 22 and 23 of HP-42S). |
| Solving | — | SOLVIN | Set if the solver is computing a root |
| Integrating | — | INTING | Set if the integrator is running |
| Variable menu displayed | — | VMDISP | Set while the variable menu is displayed |

Nonprogrammable Commands and Keys

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

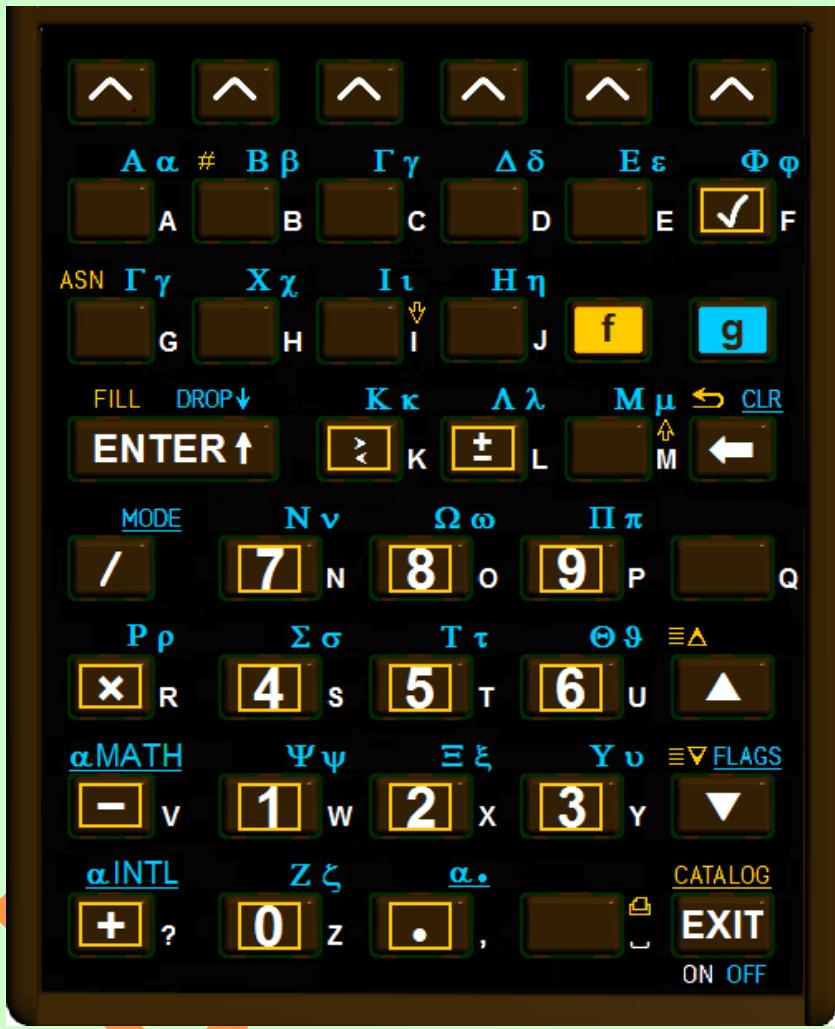
Furthermore, all *catalog* and *menu* calls themselves as well as the operations called by **EXIT**, **P/R**, **α** , **G** , **$\text{M}\Delta$** , **Δ** , **$\text{M}\nabla$** , and **∇** are neither programmable nor will they show any input echo in the top numeric row as the other commands do (cf. the OM, Sect. 2). See also Section 2 (on pp. 117ff) for more about this topic.

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

Command Parameter Input and Closing It

The following table shows what will happen when particular keys are pressed while command parameter input is not finished yet (see pp. 113ff for input in X instead). Note that characters include digits and punctuation marks as well. The table lists the respective keys beginning top left on the keyboard:

| Keystrokes | Situation | Remarks |
|---------------------|-------------------------------------|--|
| [A] ... [Z] | addressing | Register or flag input. See the <i>virtual keyboard</i> in Section 1 of the OM for the letters applicable. |
| [A] ... [Z] | entering a label or a variable name | Appends the corresponding Latin or Greek letter or digit to the label or variable <i>name</i> pending. Use [▼] and [▲] to switch cases for letters. See the <i>virtual keyboard</i> on p. 112 (and cf. Section 2 of the OM). |
| [g] [A] ... [g] [O] | | |
| [f] [0] ... [f] [9] | | |
| [ENTER↑] | arbitrary parameter input pending | If there is no input yet, assumes the default, if applicable. Closes pending input, interprets it as a register or flag address or a variable <i>name</i> or a label or alike, and executes the command. Cf. Section 1 of the OM. |
| [◀] | 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. |
| [0] ... [9] | addressing | Numeric parameter input. See Section 1 of the OM for the valid number ranges. |
| [.] | addressing | Header for <i>local registers</i> or <i>flags</i> . |
| [EXIT] | arbitrary parameter input pending | If there is an open <i>menu</i> , closes it. Else cancels pending command input, returning to the status of your WP 43S as it was before that command was called. |



Virtual keyboard in *alpha input mode* (AIM). AIM is also active when a catalog is entered, so you can use all accessible characters for alphabetic searching (see pp. 121f).

Alphanumeric Input in X and Closing It

The following table shows what will happen when particular keys are pressed with alphanumeric or numeric input in X being open still (turn to pp. 111f for command parameter input instead). The table lists the respective keystrokes top left to bottom right on the keyboard:

| Keystrokes in mode(s) | Remarks |
|------------------------|--|
| f # base | ¬ (A, α) Closes input of a <i>short integer</i> |
| f d.ms | sexagesimal angle |
| f .d | date |
| f h.ms | sexagesimal time in X. ³⁰ |
| A ... Z | A, α Appends the corresponding Latin or Greek letter to the <i>alpha string x</i> . Use ▾ and ▾ to switch cases. See the picture on previous page and cf. Section 2 of the OM. |
| a [A] ... g [O] | A, α |
| f # | A, α Appends # to the <i>alpha string x</i> . |
| f ✓ | A, α Appends a checkmark ✓ to the <i>alpha string x</i> . |
| CC | ¬ (A, α) Closes input of the first part of a complex number in X and waits for input of its second part (see the Key Response Table and Section 2 of the OM). |
| f (R↓) (S↓) | A, α Prefix for the next character becoming a subscript, if applicable. |

³⁰ See Section 2 of the OM. At closure, input will be checked – illegal digits (e.g. 8 in octal input or C in decimal), bases, numbers (e.g. 72 minutes in a time), or characters found, or out-of-range conditions detected will cause an error thrown (see also the description of **ENTER↑** on next page and the error messages in App. C).

| Keystrokes in mode(s) | Remarks |
|-----------------------|--|
| ENTER↑ | <p>arbitrary input pending</p> <p>If there was input expected but not entered, cancels entry.</p> <p>Else closes input (in X) and checks the following conditions top-down:</p> <ul style="list-style-type: none"> • If this input is <u>alphanumeric</u> (i.e. if it contains at least one non-numeric character except ,), takes it as an <i>alpha string</i>. • Else (i.e. if this input is purely numeric) if it contains one CC, takes it as a complex number. • Else if it contains two ,, takes it as a <i>fraction</i>. • Else if it contains one , or one E, takes it as a <i>real number</i>. • Else (i.e. if it contains neither a CC nor a , nor an E), tests it for #: <ul style="list-style-type: none"> ◦ If it contains one # and a valid base trailing it then takes it as a <i>short integer</i>; ◦ 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>. <p>Then checks the new input (according to the condition met) as outlined in footnote 30 and interprets it. Finally, unless an error had to be thrown, copies x into Y.</p> |
| f xz | A, α Appends z to the <i>alpha string</i> x . |
| +/- | $\neg(A, \alpha)$ Changes the sign of the mantissa or exponent in numeric input as explained in <i>Section 1</i> of the OM. |
| f +/- | A, α Appends ± to the <i>alpha string</i> x . |
| E | $\neg(A, \alpha)$ Closes input of the mantissa and waits for input of the exponent (see <i>Section 1</i> of the OM). |

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

| Keystrokes | in mode(s) | Remarks |
|------------|----------------------------|--|
| ? | A, α | Appends ? to the alpha string x . |
| . | \neg (A, α) | Inserts a radix mark as selected. Separates <i>degrees</i> from <i>minutes</i> , <i>seconds</i> , and <i>hundredths of seconds</i> in angular input, so input format is dddd.dd.mmmsshh d.ms for sexagesimal angles (cf. p. 113 and <i>Section 2</i> of the OM). Separates <i>hours</i> from <i>minutes</i> , <i>seconds</i> , and fractions of <i>seconds</i> in time input, so input format is hhhh.ffff.mmmssffff h.ms for sexagesimal times (cf. p. 113 and <i>Section 2</i> of the OM). |
| Second . | \neg (A, α) | A second . in input indicates a fraction. See <i>Section 2</i> of the OM for examples. The second . just separates the nominator and the denominator in input. Note you cannot enter E after you entered . twice – but you may delete the second dot while editing the input. |
| , | A, α | Appends , to the alpha string x . |
| f . | A, α | Appends ! to the alpha string x . |
| R/S | !, program waits for input | Closes input and starts its checks and interpretation like ENTER 1 above. Resumes program execution. |
| | A, α | Appends a blank space to the alpha string x . |
| f R/S | A, α | Appends █ to the alpha string x . |
| EXIT | arbitrary input pending | If there is an open menu, closes it. Else closes pending numeric or alphanumeric input and releases it for interpretation. |

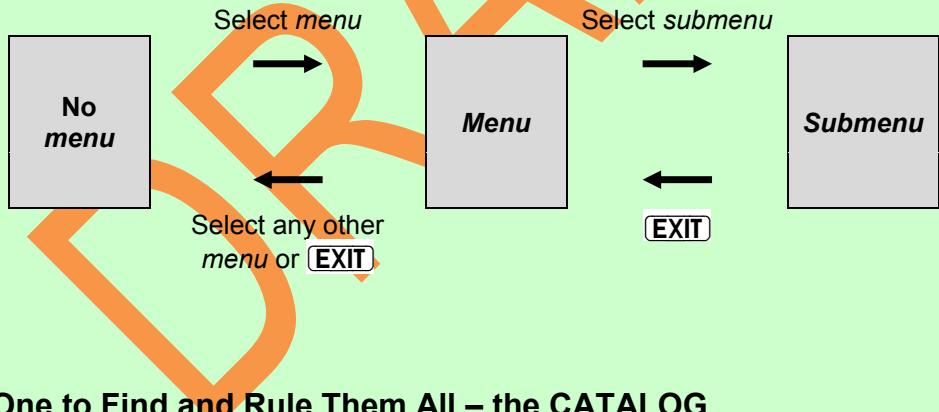
There are many more characters you can enter via the three alpha menus or **CATALOG CHARS**. See pp. 118 and 129ff for these menus and FBR for browsing the entire character sets provided.

SECTION 2: MENUS AND CATALOGS

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

Catalogs are a special kind of *menus* with their contents sorted alphabetically. Your *WP 43S* provides two *catalogs*, CATALOG and CNST. Also some *submenus* of CATALOG are treated as *catalogs* (i.e. A...Z, DIGITS, FCNS, MENUS, aINTL, and the *submenus* of VARS, see next chapter). Within *catalogs*, some special operations ease your path accessing the *items* stored there (as shown on pp. 121f).

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



One to Find and Rule Them All – the CATALOG

CATALOG calls a very particular *menu*: CATALOG contains all the *items* defined on your *WP 43S* and visible for the user. Many of them are sorted alphabetically in different branches: these *items* we call *cataloged*. Individual *cataloged items* may be accessed quickly in a way demonstrated on pp. 121f.

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

| | | | | | | | Remarks |
|-----------------|---|---|--------|--------|-----------------------------|---|---|
| CATALOG: | FCNS | DIGITS | CHARS | PROGS | VARS | MENUS | top branches |
| FCNS: | $^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$ | $^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$ | 10^x | 1COMPL | $1/x$ | 2^x | contains 678 functions provided |
| | 2COMPL | $\sqrt[3]{x}$ | ABS | ACOS | $\text{ac} \rightarrow m^2$ | $\text{ac}_{\text{us}} \rightarrow m^2$ | |
| | AGM | AGRAPH | ALL | AND | arccos | arcosh | |
| | ... | | | | | | |
| | | #B | | | | | |
| DIGITS: | 0 | 1 | 2 | 3 | 4 | 5 | digits defined |
| | 6 | 7 | 8 | 9 | A | B | |
| | C | D | E | F | i | | |
| CHARS: | A...Z | A...Ω | αINTL | αMATH | Myα | α• | character branches |
| A...Z: | A | B | C | D | E | ... | plain Latin letters |
| | | | | | | | |
| αINTL: | Ā | Á | Ă | À | ... | | additional (international) Latin letters, see p. 129 |
| | | | | | | | |
| αMATH: | < | ≤ | = | ... | | | mathematical operators and symbols, see p. 130 |
| | | | | | | | |
| A...Ω: | A | B | Γ | Δ | ... | | Greek letters, see p. 130 |
| | | | | | | | |
| α•: | ! | : | ; | ... | | | punctuation marks, see p. 131 |
| | | | | | | | |
| PROGS: | RAM | | | | | FLASH | global labels currently defined |
| RAM: | ... | | | | | | both branches are empty at startup; they will be filled with your creations |
| FLASH: | ... | | | | | | |

| | | | | | | | Remarks |
|---------|--------|--------|--------|------|--------|--------|--|
| VARS: | L.INTS | S.INTS | REALS | CPXS | STRING | MATRS | branches for various types of variables |
| | DATES | TIMES | ANGLES | | | | |
| ANGLES: | ... | | | | | | all variables currently defined, placed following their <i>data types</i> – all these <i>submenus</i> are empty at startup but will be filled and grow with your creations |
| CPXS: | ... | | | | | | |
| DATES: | ... | | | | | | |
| L.INTS: | ... | | | | | | |
| MATRS: | ... | | | | | | |
| REALS: | ... | | | | | | |
| STRING: | ... | | | | | | |
| S.INTS | ... | | | | | | |
| TIMES: | ... | | | | | | |
| MENUS: | ANGLES | A....Z | A: | BITS | Binom: | Cauch: | <i>menus</i> and <i>submenus</i> 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 | CNST | CPX | CPXS | |
| | DATES | DIGITS | DISP | EQN | EXP | Expon: | |
| | ... | | | | | | <i>(sub-) menus</i> provided unless mentioned above already, see pp. 123ff for predefined contents – here your creations will be inserted as new entries |
| | ... | 4→ | | | | | |
| A: | ... | | | | | | |
| Binom: | ... | | | | | | |
| BITS: | ... | | | | | | |
| ... | | | | | | | |
| ... | | | | | | | |

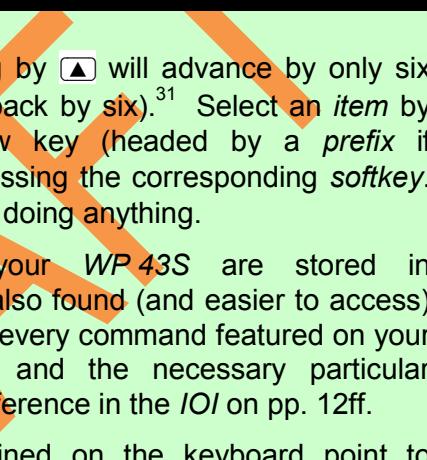
Three branches of **CATALOG** are expandable (**MENUS** and the *submenus* of **PROGS** and **VARS**) since you may create *items* of these kinds (cf. the OM, Sect. 6); the other are fixed size (**FCNS**, **DIGITS**, and **CHARS**) since all functions, digits, and characters are predefined.

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



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

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



| | AGM | AGRAPH | ALL | AND | arccos | arcosh |
|---|---|--------|--------|----------------------|---------------------------|--------|
| 2COMPL | $\sqrt[3]{x}$ | ABS | ACOS | $ac \rightarrow m^2$ | $ac_{us} \rightarrow m^2$ | |
| ${}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}$ | ${}^{\circ}\text{F} \rightarrow {}^{\circ}\text{C}$ | 10^x | 1COMPL | $1/x$ | 2^x | |

Within **CATALOG** branches, browsing by **▲** will advance by only six *items* per keystroke (and **▼** will go back by six).³¹ Select an *item* by pressing the corresponding top row key (headed by a *prefix* if applicable); e.g. call a function by pressing the corresponding softkey. **EXIT** will just leave **CATALOG** without doing anything.

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

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

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

³¹ Navigating in 'CATALOG, AIM is set as explained in the OM. So you may as well use the alphabetic searching method known from *WP 34S catalogs*, but the matching *item* will be displayed together with its up to 17 successors if applicable. See next chapter.

Accessing Cataloged Items Rapidly

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

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

| | | | | | | | | | | | | | | | | | | | |
|---|--|--------|--------|----------------------|---------------------------|--------|--------|--------|---------------|-----|------|----------------------|---------------------------|---|---|--------|--------|-------|-------|
| 1 User input | CATALOG FCNS Your WP 43S displays the first view in this catalog ³² | | | | | | | | | | | | | | | | | | |
| Echo | <table border="1"><tbody><tr><td>AGM</td><td>AGRAPH</td><td>ALL</td><td>AND</td><td>arccos</td><td>arcosh</td></tr><tr><td>2COMPL</td><td>$\sqrt[3]{x}$</td><td>ABS</td><td>ACOS</td><td>$ac \rightarrow m^2$</td><td>$ac_{us} \rightarrow m^2$</td></tr><tr><td>${}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}$</td><td>${}^{\circ}\text{F} \rightarrow {}^{\circ}\text{C}$</td><td>$10^x$</td><td>1COMPL</td><td>$1/x$</td><td>$2^x$</td></tr></tbody></table> | AGM | AGRAPH | ALL | AND | arccos | arcosh | 2COMPL | $\sqrt[3]{x}$ | ABS | ACOS | $ac \rightarrow m^2$ | $ac_{us} \rightarrow m^2$ | ${}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}$ | ${}^{\circ}\text{F} \rightarrow {}^{\circ}\text{C}$ | 10^x | 1COMPL | $1/x$ | 2^x |
| AGM | AGRAPH | ALL | AND | arccos | arcosh | | | | | | | | | | | | | | |
| 2COMPL | $\sqrt[3]{x}$ | ABS | ACOS | $ac \rightarrow m^2$ | $ac_{us} \rightarrow m^2$ | | | | | | | | | | | | | | |
| ${}^{\circ}\text{C} \rightarrow {}^{\circ}\text{F}$ | ${}^{\circ}\text{F} \rightarrow {}^{\circ}\text{C}$ | 10^x | 1COMPL | $1/x$ | 2^x | | | | | | | | | | | | | | |
| 2 User input | First character of the <i>item</i> desired (e.g. F) | | | | | | | | | | | | | | | | | | |
| Echo | Your WP 43S displays a view starting with the first <i>item</i> starting with this character ³³ | | | | | | | | | | | | | | | | | | |

³² ... 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.

³³ This search is case independent (i.e. specifying **A** will find **a** as well). Note, however, that **A** and **a** remain different letters nevertheless. Remember you can also enter Greek letters in such a search using prefix **g**, e.g. **g + A** for α – though watch the sorting order printed at the beginning of the *IOI*. Also some other characters can be specified in a search – please see the *virtual keyboard* printed on p. 110. Note the *items* in the *catalog* you search may be displayed at positions in the *menu section* deviating from the ones you see in simple browsing using just \blacktriangledown or \blacktriangle .

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

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

| | | | | | |
|--------------|---|---------------------|---------------------|-------------------------|---------------------|
| | | | | | e.g. |
| | FLOOR | FP | FP? | $F_p(x)$ | FS? |
| | $F_e(x)$ | FF | FIB | FILL | FIX |
| | FB | FBR | FC? | FC?C | FC?F |
| 3 User input | Second character of the <i>item</i> desired (e.g. S) | | | | |
| Echo | Your WP 43S displays a view starting with the first item starting with this sequence e.g. | | | | |
| | $fz_{us} \rightarrow m^3$ | $f'(x)$ | $f''(x)$ | GAP | GaussF |
| | $fm. \rightarrow m$ | $fr \rightarrow dB$ | $ft. \rightarrow m$ | $ft_{us} \rightarrow m$ | $ft. \rightarrow m$ |
| | FS? | FS?C | FS?F | FS?S | $F(x)$ |
| 4 User input | Press the corresponding softkey e.g. for FS?S | | | | |
| Echo | Your WP 43S executes or inserts the command, recalls the constant, or inserts the letter selected. | | | | |
| | Result (in this example after specifying the flag number): | | | | |
| | true 1 | | | | |

At the bottom line, this means that ...

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

Further Menus and Their Contents

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

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

| Menu | | | | | | | Remarks |
|-------------|-------------------|--------------------|--------------------|------------------|----------------|----------------------|--|
| ADV | SOLVE | SLVQ | $f'(x)$ | Π_n | Σ_n | $\int f dx$ | advanced operations, see Sect. 4 of the OM |
| | | | $f''(x)$ | | | | |
| | $\int f dx$ | | ACC | \downarrow Lim | \uparrow Lim | \int | |
| BITS | AND | OR | XOR | NOT | MASKL | MASKR | contains all the Boole's and bit operations (first two views) and settings (third view) of <i>HP-16C</i> and <i>WP 34S</i> |
| | NAND | NOR | XNOR | | MIRROR | ASR | |
| | SB | BS? | #B | FB | BC? | CB | |
| | SL | RL | RLC | RRC | RR | SR | |
| | LJ | | | | | RJ | |
| | 1COMPL | 2COMPL | UNSIGN | SIGNMT | | WSIZE | |
| | | | | | | | |
| | | | | | | | |
| CLK | DATE | \rightarrow DATE | DATE \rightarrow | WDAY | TIME | $x \rightarrow$ DATE | date and time functions (first view) and settings (2 nd view) |
| | J \rightarrow D | D \rightarrow J | | DAY | MONTH | YEAR | |
| | SETTIM | TDISP | SETDAT | D.MY | Y.MD | M.DY | |
| | | | | | | J/G | |
| | | | | | | | |
| CLR | CLΣ | CLP | CF | CLMENU | CLCVAR | CLX | almost as in <i>HP-42S</i> |
| | CLREGS | CLPall | CLFall | | CLLCD | CLSTK | |
| | CLall | | | | | RESET | |
| CNST | | | | | | | catalog of constants, see pp. 131ff |

| Menu | | | | | | | Remarks |
|--------|------------------|--------|--------------------|--------|-------------------|----------------|---|
| CPX | dot | cross | UNITV | Re | conj | Re>Im | special complex functions and settings (third row) |
| | CX→RE | RE→CX | sign | Im | x | * | |
| | | | | | | | |
| DISP | FIX | SCI | ENG | ALL | ROUND1 | ROUND | display rounding and shifts, formats and settings, mostly for reals |
| | SDL | SDR | | | RDP | RSD | |
| | | | | | | | |
| | GAP | | | | | DSTACK | |
| | CHINA | EUROPE | INDIA | JAPAN | UK | USA | |
| EQN | NEW | EDIT | f'' | f' | f | Solver | equations (see the OM, Sect. 4) |
| | DELETE | | | | | | |
| Solver | | | | | | | show the names of all variables of the current equation and more |
| ff | | | | | | | |
| f' | | | | | | | |
| f'' | | | | | | | |
| EQ.EDI | ← | () | ^ | : | = | → | Equation Editor |
| EXP | x ³ | √y | log _x y | lb x | 2 ^x | x ² | exponential, logarithmic, and hyperbolic functions |
| | ³√x | | | ln 1+x | e ^x -1 | | |
| | sinh | arsinh | cosh | arcosh | tanh | artanh | |
| FIN | % | %MRR | %T | %Σ | %+MG | TVM | financial functions and settings (see the OM, Section 5) |
| TVM | n _{PER} | i%/a | per/a | PV | PMT | FV | |
| | Begin | | | | | End | |
| FLAGS | SF | FS? | FF | STATUS | FC? | CF | |
| | FS?S | FS?C | FS?F | FC?F | FC?S | FC?C | |
| | | | | | | CLFall | |
| INFO | SSIZE? | MEM? | RM? | SMODE? | WSIZE? | KTYP? | system information |
| | LocR? | FLASH? | ULP? | NEIGHB | SDIGS? | BATT? | |
| | WHO? | VERS? | DIM? | ±∞? | αPOS? | αLENG? | |
| | | | | | | | |

| Menu | | | | | | | Remarks |
|---------------|--------|-------------------|--------|------------------|--------|--------|---|
| <u>INTS</u> | 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 | |
| <u>I/O</u> | BEEP | LOAD | LOADP | LOADR | LOADSS | LOADΣ | data exchange incl. the PRINT commands of HP-42S |
| | | TONE | | | RECV | SEND | |
| | ✉ADV | ✉CHAR | ✉DLAY | ✉LCD | ✉MODE | ✉PROG | |
| | ✉r | ✉REGS | ✉STK | ✉TAB | ✉USER | ✉WIDTH | |
| <u>LOOP</u> | ✉Σ | ✉# | | | | | |
| | DSE | DSZ | DSL | ISE | ISZ | ISG | |
| | DEC | | | | | INC | |
| | | | | | | | |
| <u>MATX</u> | NEW | [M] ⁻¹ | M | [M] ^T | SIM EQ | EDIT | matrix operations (almost as in HP-42S) |
| | dot | cross | UNITV | DIM | INDEX | EDITN | |
| | ENORM | | STOEL | RCLEL | PUTM | GETM | |
| | I+ | I- | STOIJ | RCLIJ | J- | J+ | |
| | RSUM | RNORM | M.LU | DIM? | | RΣR | |
| | EIGVAL | | | | | EIGVEC | |
| | M.EDIT | ← | ↑ | OLD | GOTO | ↓ | |
| | | INSR | | DELR | | WRAP | |
| <u>M.SIMQ</u> | Mat A | Mat B | | | | Mat X | solver for systems of linear equations |
| <u>MODE</u> | DEG | RAD | GRAD | MULπ | SETSIG | DENMAX | mode settings; SYSTEM is not available on the simulator |
| | | | RM | | | | |
| | SYSTEM | | | | | | |
| <u>MyMenu</u> | | | | | | | will show up out of AIM ³⁴ |
| | | | | | | | |
| | | | | | | | |

| Menu | | | | | | | Remarks |
|--------------|------------|--------------------|-----------------|-----------------|--------------------|---------------------|---|
| <u>Mya</u> | | | | | | | will show up in AIM ³⁴ |
| | | | | | | | |
| | | | | | | | |
| <u>PARTS</u> | IP | FP | MANT | EXPT | sign | DECOMP | some overlaps with HP-42S CONVERT |
| | ROUNDI | ROUND | | | x | 4 | |
| | | | | | Re | Im | |
| <u>PROB</u> | Norml: | t: | C _{yx} | P _{yx} | F: | χ^2 : | combinations, permutations, random number generator and 15 probability distributions. Selecting one (e.g. Norml) opens a submenu featuring entries for its PDF (or PMF), CDF, error probability & quantile function |
| | LgNrm: | Cauch: | | Expon: | Logis: | Weibl: | |
| | | NBin: | Geom: | Hyper: | Binom: | Poiss: | |
| | RAN# | SEED | | | lnΓ | $\Gamma(x)$ | |
| | Binom: | Binom _p | Binom | | Binom _e | Binom ⁻¹ | |
| | Cauch: | Cauch _p | Cauch | | Cauch _e | Cauch ⁻¹ | |
| | Expon: | Expon _p | Expon | | Expon _e | Expon ⁻¹ | |
| | F: | F _p (x) | F(x) | | F _e (x) | F ⁻¹ (p) | |
| | Geom: | Geom _p | Geom | | Geom _e | Geom ⁻¹ | |
| | Hyper: | Hyper _p | Hyper | | Hyper _e | Hyper ⁻¹ | |
| | LgNrm: | LgNrm _p | LgNrm | | LgNrm _e | LgNrm ⁻¹ | |
| | Logis: | Logis _p | Logis | | Logis _e | Logis ⁻¹ | |
| | NBin: | NBin _p | NBin | | NBin _e | NBin ⁻¹ | |
| | Norml: | Norml _p | Norml | | Norml _e | Norml ⁻¹ | |
| | Poiss: | Poiss _p | Poiss | | Poiss _e | Poiss ⁻¹ | |
| | t: | t _p (x) | t(x) | | t _e (x) | t ⁻¹ (p) | |
| | Weibl: | Weibl _p | Weibl | | Weibl _e | Weibl ⁻¹ | |
| | χ^2 : | $\chi^2_p(x)$ | $\chi^2(x)$ | | $\chi^2_e(x)$ | $(\chi^2)^{-1}$ | |

³⁴ ... as long as no other menu is called (see Section 6 of the OM).

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

| Menu | | | | | | | Remarks |
|----------|---|---|-------------------------------------|-------------------------------------|---|---|---|
| TRI | sin | arcsin | cos | arccos | tan | arctan | trigonometric & hyperbolic functions (cf. EXP). |
| | | | | | | | |
| | sinh | arsinh | cosh | arcosh | tanh | artanh | |
| <u>U</u> | E: | P: | year \Rightarrow s | F&p: | m: | x: | unit conversions (see pp. 141ff). |
| | $^{\circ}\text{C} \rightarrow ^{\circ}\text{F}$ | $^{\circ}\text{F} \rightarrow ^{\circ}\text{C}$ | s \Rightarrow year | | V: | A: | |
| | power ratio \rightarrow dB | dB \rightarrow power ratio | | | field ratio \rightarrow dB | dB \rightarrow field ratio | |
| A: | acre \rightarrow m ² | m ² \rightarrow acre | ha \rightarrow m ² | m ² \rightarrow ha | acre _{US} \rightarrow m ² | m ² \rightarrow acre _{US} | units of area |
| E: | cal \rightarrow J | J \rightarrow cal | Btu \rightarrow J | J \rightarrow Btu | Wh \rightarrow J | J \rightarrow Wh | units of energy |
| F&p: | lbf \rightarrow N | N \rightarrow lbf | bar \rightarrow Pa | Pa \rightarrow bar | psi \rightarrow Pa | Pa \rightarrow psi | units of force and pressure |
| | in.Hg \rightarrow Pa | Pa \rightarrow in.Hg | torr \rightarrow Pa | Pa \rightarrow torr | atm \rightarrow Pa | Pa \rightarrow atm | |
| m: | lb. \rightarrow kg | kg \rightarrow lb. | cwt \rightarrow kg | kg \rightarrow cwt | oz \rightarrow kg | kg \rightarrow oz | units of mass |
| | stone \rightarrow kg | kg \rightarrow stone | short cwt \rightarrow kg | kg \rightarrow sh.cwt | tr.oz \rightarrow kg | kg \rightarrow tr.oz | |
| | ton \rightarrow kg | kg \rightarrow ton | short ton \rightarrow kg | kg \rightarrow short ton | carat \rightarrow kg | kg \rightarrow carat | |
| P: | hp _E \rightarrow W | W \rightarrow hp _E | hp _{UK} \rightarrow W | W \rightarrow hp _{UK} | hp _M \rightarrow W | W \rightarrow hp _M | units of power |
| V: | gl _{UK} \rightarrow m ³ | m ³ \rightarrow gl _{UK} | qt. \rightarrow m ³ | m ³ \rightarrow qt. | gl _{US} \rightarrow m ³ | m ³ \rightarrow gl _{US} | units of volume |
| | floz _{UK} \rightarrow m ³ | m ³ \rightarrow floz _{UK} | barrel \rightarrow m ³ | m ³ \rightarrow barrel | floz _{US} \rightarrow m ³ | m ³ \rightarrow floz _{US} | |
| X: | au \rightarrow m | m \rightarrow au | ly \rightarrow m | m \rightarrow ly | pc \rightarrow m | m \rightarrow pc | units of length |
| | mi. \rightarrow m | m \rightarrow mi. | nmi. \rightarrow m | m \rightarrow nmi. | ft. \rightarrow m | m \rightarrow ft. | |
| | in. \rightarrow m | m \rightarrow in. | | | yd. \rightarrow m | m \rightarrow yd. | |
| | fathom \rightarrow m | m \rightarrow fathom | point \rightarrow m | m \rightarrow point | survey foot _{US} \rightarrow m | m \rightarrow survey foot _{US} | |

| Menu | | | | | | | Remarks |
|--------------|--------------------|----------------|------------------------------|------------------|-----------------|-----------------|--|
| <u>X.FN</u> | AGM | B _n | B _n * | erf | erfc | Orthog | advanced mathematical functions like Beta, Bessel, etc. |
| | FIB | g _d | g _d ⁻¹ | I _{xyz} | IΓ _p | IΓ _q | |
| | J _y (x) | lnβ | lnΓ | max | min | NEXTP | |
| | sinc | W _m | W _p | W ⁻¹ | β(x,y) | γ _{xy} | |
| | Γ _{xy} | ζ(x) | (-1) ^x | →DP | →SP | | |
| | | | | | | | |
| Orthog | H _n | L _m | L _{ma} | P _n | T _n | U _n | orthogonal polynomials |
| | H _{np} | | | | | | |
| <u>αINTL</u> | Ā ā | Á á | Ă ĕ | À à | Ä ä | Ã ã | [α] catalog of international letters. ³⁵ All letters except one in this menu will change when case is switched in AIM – note you will see the individual letters displayed in either case only at one time. |
| | Â â | Â â | Æ æ | Ą ą | Ć ć | Č č | |
| | Ç ç | Đ đ | Đ đ | Ē ē | É é | Ě ě | |
| | È è | Ë ë | Ê ê | È è | Ë ë | Ę ę | |
| | Ğ ğ | İ ī | İ ī | İ ī | İ ī | İ ī | |
| | Î î | İ î | İ î | I î | Ł ł | Ľ ľ | |
| | Ľ ľ | Ń ñ | Ń ñ | Ń ñ | Ó ó | Ó ó | |
| | Ӧ Ӧ | Ӯ Ӯ | Ӯ Ӯ | Ӯ Ӯ | Ӯ Ӯ | Ӯ Ӯ | |
| | Œ œ | Ŕ ŕ | Ŕ ŕ | Ŗ ŗ | Ş ş | Ş ş | |
| | Ş ş | Ͳ Ͳ | Ͳ Ͳ | Ͳ Ͳ | Ӱ Ӱ | Ӱ Ӱ | |
| | ܶܶ | ܷܷ | ܷܷ | ܷܷ | ܷܷ | ܷܷ | |
| | ܸܸ | | | | | | |

³⁵ See https://de.wikipedia.org/wiki/Liste_lateinischer_Alphabete#Erweiterungen.

| Menu | | | | | | | Remarks |
|-----------------------|---------------------|-----|-----|-----|--------|-----|--|
| αMATH | < | ≤ | = | ≈ | ≥ | > | [α] for comparison symbols, parentheses & brackets, as well as more mathematical and related symbols. You can reach every character by 3 keystrokes maximum. |
| | { | [| (|) |] | } | |
| | x / . ³⁶ | ÷ | ∫ | ∞ | ∞ | ∞ | |
| | ¬ | Λ | ¥ | ≠ | | & | |
| | ✗ | ✉ | ⊥ | ³√ | ✓ | ✗ | |
| | ✗ | ȳ | Ӯ | ȳ | Ӯ | ȳ | |
| | := | ≈ | ≡ | E | C | R | |
| | ⊗ | ◎ | ⊕ | | | | |
| | ± | ^ | T | -1 | ℏ | | |
| α.FN | x→α | αRL | αRR | αSL | αPOS? | α→x | dedicated functions for <i>alpha strings</i> , plus font browser |
| | | | | | αLENG? | | |
| | FBR | | | | | | |
| | | | | | | | |
| Α...Ω | Α α | Β β | Γ γ | Δ δ | Ε ε | Ζ ζ | [α] Greek letters. The keyboard grants direct access to 24 of them. ³⁷ Note the two kinds of lower case Σ. See αINTL for more. |
| | Η η | Θ θ | Ι ι | Κ κ | Λ λ | Μ μ | |
| | Ν ν | Ξ ξ | Ο ο | Π π | Ρ ρ | Σ σ | |
| | Ϛ | Ͳ τ | Ƴ ӯ | Փ Փ | Խ Խ | Փ Փ | |
| | Ω ω | ά | έ | ή | ի | ՛ | |
| | Ի Ւ | օ | ւ | յ Ւ | ւ | ա | |

³⁶ With startup default settings, the multiplication dot is found here and the multiplication cross is called via in AIM. If MULT· is set, however, this dot is called via in AIM and the multiplication cross via [αMATH](#).

³⁷ 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. Note ancient Greek Η, Θ, and Υ are pronounced like Finnish ÅÄ, T, and Y – modern Greek Θ like English Th, H and Y both like Finnish I. Finnish Y is pronounced like German Ü or French U. Think of Nils Holgersson's goose Yksi (coming first before Kaksi, Kolme, Neljä, Viisi, and Kuusi for obvious reasons – these suffice: there is no goose named Seitsemän, Kahdeksan, Yhdeksän, nor Kymmenen in that novel).

| Menu | | | | | | Remarks | |
|------|------|------|-------|--------|--------|---------|------------------------------------|
| | ! | : | ; | ' | " | e | |
| | i | ż | s | _ | ~ | \ | |
| | \$ | € | % | & | £ | ¥ | |
| | ← | ↑ | ↓ | ↓ | → | ↑ | |
| | « | » | ø | ⌚ | • | * | |
| | ⌚ | ⌚ | ⌚ | ⌚ | ⌚ | * | |
| | →DEG | →RAD | →GRAD | | →D.MS | →MULπ | angular conversions, cf. pp. 148f. |
| | DEG→ | RAD→ | GRAD→ | | D.MS→ | MULπ→ | |
| | D→R | R→D | | D→D.MS | D.MS→D | | |

Constants

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

| | | | | | |
|-------|-------|-------|-------|---------------|--------------|
| G | G_0 | G_c | g_e | GM_{\oplus} | g_{\oplus} |
| c_1 | c_2 | e | e_E | F_{α} | F_{δ} |
| 1/2 | a | a_0 | a_M | a_{\oplus} | c |

Names of astronomical and mathematical constants are printed on colored background in the table starting overleaf. Values of physical constants (including their relative standard deviations in *red print* below) are printed on light background if they are exactly defined or almost exactly known – the darker the background, the less precisely the particular value is known.³⁸

³⁸ For most of the physical constants, their precise numeric values (incl. their units) and their relative standard deviations (SD) are from CODATA 2018, copied in May 2019. These are the best values known in the scientific community, agreed on by the national standards institutes worldwide (e.g. by NIST and PTB). Note that the **fundamental** constants (printed **bold** in the table) of physics all feature less than 16 significant digits.

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

| Name | Numeric value and <i>rel. SD</i> | Remarks |
|---------------------------------|--|---|
| $\frac{1}{2}$ (0) ³⁹ | 0,5 | Trivial but helpful constant for some iterations. |
| a | 365,242 5 d (<i>per definition</i>) | <i>Gregorian year</i> |
| a_0 | $5,291\ 772\ 109\ 03 \cdot 10^{-11} \text{ m}$ $(1,5 \cdot 10^{-10})$ | <i>Bohr radius</i> $a_0 = \alpha / 4\pi R_\infty$ |
| a_{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> ≈ 499 <i>light seconds</i> ≈ 8 <i>light minutes</i> . |

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

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

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

³⁹ The counting numbers in parentheses are to support determination of parameters for CONST – see the *IOI*.

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

| Name | Numeric value and rel. SD | Remarks |
|------------------------|---|---|
| GM_{\oplus} | $3,986\,004\,418 \cdot 10^{14} \text{ m}^3/\text{s}^2$ $(2,0 \cdot 10^{-9})$ | Newtonian constant of gravitation times the Earth's mass with its atmosphere included (according to WGS84 ⁴⁰) |
| g_{\oplus} | $9,806\,65 \text{ m/s}^2$ (per def.) | Standard earth acceleration |
| h | $6,626\,070\,15 \cdot 10^{-34} \text{ J s}$ (exact) | Planck constant |
| \hbar (20) | $1,054\,571\,817 \dots \cdot 10^{-34} \text{ J s}$ (exact) | Reduced Planck constant $\hbar = h/2\pi$ |
| k | $1,380\,649 \cdot 10^{-23} \text{ J/K}$ (exact) | Boltzmann constant $k = R/N_A$ |
| K_J | $4,835\,978\,484 \dots \cdot 10^{14} \text{ Hz/V}$ (exact) | Josephson constant $K_j = 2e/h$ |
| l_{PL} | $1,616\,255 \cdot 10^{-35} \text{ m}$ $(1,1 \cdot 10^{-5})$ | Planck length $l_{PL} = t_{PL}c$ |
| m_e | $9,109\,383\,701\,5 \cdot 10^{-31} \text{ kg}$ $(3,0 \cdot 10^{-10})$ | Electron mass $\simeq 511,00 \text{ keV}$ |
| M_{Moon} (25) | $7,349 \cdot 10^{22} \text{ kg}$ $(5 \cdot 10^{-4})$ | Mass of the Moon |
| m_n | $1,674\,927\,498\,04 \cdot 10^{-27} \text{ kg}$ $(5,7 \cdot 10^{-10})$ | Neutron mass $\simeq 939,57 \text{ MeV}$ |
| m_n/m_p | $1,001\,378\,419\,31$ $(4,9 \cdot 10^{-10})$ | Neutron to proton mass ratio |
| m_p | $1,672\,621\,923\,69 \cdot 10^{-27} \text{ kg}$ $(3,1 \cdot 10^{-10})$ | Proton mass $\simeq 938,27 \text{ MeV}$ |

⁴⁰ See http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html

| Name | Numeric value and <i>rel. SD</i> | Remarks |
|-------------------|---|--|
| m_{PL} | $2,176\,435\cdot 10^{-8} \text{ kg}$ $(1,1\cdot 10^{-5})$ | Planck mass $m_{PL} = \sqrt{\hbar c/G} \approx 22 \mu\text{g}$ |
| m_p/m_e (30) | $1\,836,152\,673\,43$ $(6,0\cdot 10^{-11})$ | Proton to electron mass ratio |
| m_u | $1,660\,539\,066\,60\cdot 10^{-27} \text{ kg}$ $(3,0\cdot 10^{-10})$ | Atomic mass constant $\approx 10^{-3} \text{ kg}/N_A$ |
| $m_u c^2$ | $1,492\,418\,085\,60\cdot 10^{-10} \text{ J}$ $(3,0\cdot 10^{-10})$ | Energy equivalent of the atomic mass constant $\approx 931,49 \text{ MeV}$ |
| m_μ | $1,883\,531\,627\cdot 10^{-28} \text{ kg}$ $(2,2\cdot 10^{-8})$ | Muon mass $\approx 105,66 \text{ MeV}$ |
| M_\odot | $1,989\,1\cdot 10^{30} \text{ kg}$ $(5\cdot 10^{-5})$ | Mass of the Sun |
| M_\oplus (35) | $5,973\,6\cdot 10^{24} \text{ kg}$ $(5\cdot 10^{-5})$ | Mass of the Earth. See GM_\oplus above for a more precise value. |
| N_A | $6,022\,140\,76\cdot 10^{23} / \text{mol}$ <i>(exact)</i> | Avogadro's number |
| NaN | Not a number | See the corresponding entry in Section 5 of the OM. |
| p_0 | 101 325 Pa <i>(per def.)</i> | Standard atmospheric pressure |
| R | $8,314\,462\,618\dots \text{ J/mol K}$ <i>(exact)</i> | Molar gas constant |
| r_e (40) | $2,817\,940\,326\,2\cdot 10^{-15} \text{ m}$ $(4,5\cdot 10^{-10})$ | Classical electron radius $r_e = \alpha^2 a_0$ |
| R_K | $25\,812,807\,45\dots \Omega$ <i>(exact)</i> | Von Klitzing constant $R_K = h/e^2$ |

| Name | Numeric value and rel. SD | Remarks |
|-------------------|---|--|
| R_{Moon} | $1,737\,530 \cdot 10^6 \text{ m}$ $(5 \cdot 10^{-7})$ | Mean radius of the Moon |
| R_{∞} | $10\,973\,731,568\,160 / \text{m}$ $(1,9 \cdot 10^{-12})$ | Rydberg constant $R_{\infty} = \frac{\alpha^2 m_e c}{2 h}$ |
| R_{\odot} | $6,96 \cdot 10^8 \text{ m}$ $(5 \cdot 10^{-3})$ | Mean radius of the sun |
| R_{\oplus} (45) | $6,371\,010 \cdot 10^6 \text{ m}$ $(5 \cdot 10^{-7})$ | Mean radius of the Earth |
| S_a | $6,378\,137\,0 \cdot 10^6 \text{ m}$ <i>(per definition)</i> | Semi-major axis |
| S_b | $6,356\,752\,314\,2 \cdot 10^6 \text{ m}$ $(1,6 \cdot 10^{-11})$ | Semi-minor axis |
| $S e^2$ | $6,694\,379\,990\,14 \cdot 10^{-3}$ $(1,5 \cdot 10^{-12})$ | First eccentricity squared |
| $S e'^2$ | $6,739\,496\,742\,28 \cdot 10^{-3}$ $(1,5 \cdot 10^{-12})$ | Second eccentricity squared |
| $S f^{-1}(50)$ | $298,257\,223\,563$ <i>(per def.)</i> | Flattening parameter |
| T_0 | $273,15 \text{ K}$ <i>(per definition)</i> | = 0°C , standard temperature |
| T_p | $1,416\,785 \cdot 10^{32} \text{ K}$ $(1,1 \cdot 10^{-5})$ | Planck temperature $T_P = \frac{c^2}{k} \sqrt{\frac{\hbar c}{G}} = \frac{M_P c^2}{k} = \frac{E_P}{k}$ |
| t_{PL} | $5,391\,245 \cdot 10^{-44} \text{ s}$ $(1,1 \cdot 10^{-5})$ | Planck time $t_{PL} = l_{PL}/c$ |

| Name | Numeric value and <i>rel. SD</i> | Remarks |
|----------------------|--|---|
| V_m | 0,022 413 969 54... m ³ /mol <i>(exact)</i> | Molar volume of an ideal gas at standard conditions $V_m = \frac{RT_0}{p_0} \approx 22,4 \text{ l/mol}$ |
| Z_0 (55) | 376,730 313 668 Ω <i>(1,5·10⁻¹⁰)</i> | Characteristic impedance of vacuum |
| α | 7,297 352 569 3·10 ⁻³ <i>(1,5·10⁻¹⁰)</i> | Fine-structure constant $\alpha = \frac{e^2}{2\epsilon_0 h c} \approx \frac{1}{137}$ |
| γ | 6,674 30·10 ⁻¹¹ m ³ /kg s ² <i>(2,2·10⁻⁵)</i> | Newtonian constant of gravitation; also known as G from other authors. See GM _⊕ below for a more precise value. |
| γ_{EM} | 0,577 215 664 901 532 9... | Euler-Mascheroni constant |
| γ_p | 2,675 221 874 4·10 ⁸ Hz/T <i>(4,2·10⁻¹⁰)</i> | Proton gyromagnetic ratio $\gamma_p = 4\pi \mu_p / h$ |
| $\Delta\nu_{Cs}(60)$ | 9 192 631 770 Hz (exact) | Hyperfine transition frequency of ¹³³ Cs |
| ϵ_0 | 8,854 187 812 8·10 ⁻¹² A s/V m <i>(1,5·10⁻¹⁰)</i> | Vacuum electric permittivity $\epsilon_0 = 1/\mu_0 c^2$ (note the so-called Coulomb's constant is just $1/4\pi\epsilon_0 \approx 8,987 55 \cdot 10^9 \text{ V m/A s})$ |
| λ_c | 2,426 310 238 67·10 ⁻¹² m <i>(3,0·10⁻¹⁰)</i> | Compton wavelengths of the electron |
| λ_{Cn} | 1,319 590 905 81·10 ⁻¹⁵ m <i>(5,7·10⁻¹⁰)</i> | $\lambda_C = h/m_e c$, neutron $\lambda_{Cn} = h/m_n c$, and proton $\lambda_{Cp} = h/m_p c$, respectively |
| λ_{Cr} | 1,321 409 855 39·10 ⁻¹⁵ m <i>(3,1·10⁻¹⁰)</i> | |

| Name | Numeric value and rel. SD | Remarks |
|---------------|---|---|
| μ_0 (65) | $1,256\,637\,062\,12 \cdot 10^{-6} \frac{\text{V s}}{\text{A m}}$ $(1,5 \cdot 10^{-10})$ | Vacuum magnetic permeability |
| μ_B | $9,274\,010\,078\,3 \cdot 10^{-24} \frac{\text{J}}{\text{T}}$ $(3,0 \cdot 10^{-10})$ | Bohr magneton $\mu_B = e\hbar/2m_e$ |
| μ_e | $-9,284\,764\,704\,3 \cdot 10^{-24} \frac{\text{J}}{\text{T}}$ $(3,0 \cdot 10^{-10})$ | Electron magnetic moment |
| μ_e/μ_B | $-1,001\,159\,652\,181\,28$ $(1,7 \cdot 10^{-13})$ | Ratio of electron magnetic moment to Bohr's magneton |
| μ_n | $-9,662\,365\,1 \cdot 10^{-27} \frac{\text{J}}{\text{T}}$ $(2,4 \cdot 10^{-7})$ | Neutron magnetic moment |
| μ_p (70) | $1,410\,606\,797\,36 \cdot 10^{-26} \frac{\text{J}}{\text{T}}$ $(4,2 \cdot 10^{-10})$ | Proton magnetic moment |
| μ_u | $5,050\,783\,746\,1 \cdot 10^{-27} \frac{\text{J}}{\text{T}}$ $(3,1 \cdot 10^{-10})$ | Nuclear magneton $\mu_u = e\hbar/2m_p$ |
| μ_μ | $-4,490\,448\,30 \cdot 10^{-26} \frac{\text{J}}{\text{T}}$ $(2,2 \cdot 10^{-8})$ | Muon magnetic moment |
| σ_B | $5,670\,374\,419 \dots 10^{-8} \frac{\text{W}}{\text{m}^2 \text{K}^4}$ (exact) | Stefan-Boltzmann constant $\sigma_B = \frac{2\pi^5 k^4}{15 h^3 c^2}$ |
| Φ | $1,618\,033\,988\,749\,894\,8\dots$ | Golden ratio $\Phi = \frac{1}{2}(1 + \sqrt{5})$ |
| Φ_0 (75) | $2,067\,833\,848 \dots 10^{-15} \text{ V s}$ (exact) | Magnetic flux quantum $\Phi_0 = \frac{h}{2e}$ |

| Name | Numeric value and <i>rel. SD</i> | Remarks |
|--|---|--|
| ω | $7,292\,115 \cdot 10^{-5}$ rad/s $(2 \cdot 10^{-8})$ | Angular velocity of the Earth according to WGS84 (see footnote 40 on p. 134) |
| $-\infty$ | $-\infty$ | Note both these 'constants' are counted as numeric values in your WP 43S. |
| ∞ | ∞ | |
| $\gamma_{c00} \dots$ γ_{c21} | xxx | Auxiliary numeric constants, featuring 54 decimals unless specified differently below |
| 180 | 180,000... | Semicircle in <i>degrees</i> , <i>gradians</i> , <i>radians</i> , and <i>multiples of π</i> |
| 200 | 200,000... | |
| π | 3,141 592 653 589 793... | Quadrant in <i>degrees</i> , <i>gradians</i> , <i>radians</i> , and <i>multiples of π</i> |
| 1 | 1,000... | |
| 90 | 90,000... | One-eighth of a circle in <i>degrees</i> , <i>gradians</i> , <i>radians</i> , and <i>multiples of π</i> |
| 100 | 100,000... | |
| $\pi/2$ | 1,570 796 326 794 896... | 41 unit conversion factors (see next chapter) |
| 0_5 | 0,500... | |
| 45 | 45,000... | |
| 50 | 50,000... | |
| $\pi/4$ | 0,785 398 163 397 448... | |
| $\frac{1}{4}$ | 0,250 000... | |
| ... | | |
| -4 | -4,000... | |
| -1 | -1,000... | |
| $1E-37$ | $1,000 \dots \cdot 10^{-37}$ | |
| $1E-24, 1E-6, 1E-4, 1/10$ | | |
| 1/3 | 0,333 333 333 333 333... | |
| $e\gamma$ | 0,577 215 664 901 532... | |

| Name | Numeric value and <i>rel. SD</i> | Remarks |
|--|----------------------------------|---|
| $\ln 2$ | 0,693 147 180 559 945... | |
| $\sqrt{2}/2$ | 0,707 106 781 186 547... | |
| $9/10, \sqrt[3]{5}, 2$ | | |
| $\ln 10$ | 2,302 585 092 994 046... | |
| $3\pi/4$ | 2,356 194 490 192 345... | |
| $3, 5, 2\pi, 10, 20, 21$ | | |
| γ_R | 23,118 910 000... | |
| $32, 36, 47$ | | |
| $180/\pi$ | 57,295 779 513 082 33... | |
| 60 | 60,000... | |
| $200/\pi$ | 63,661 977 236 758 14... | |
| $204, 360, 400, 1000, 3600, 9999, 10000, 1E6$ | | |
| 2^{p32} | 4 294 967 296,000... | |
| 2π | 6,283 185 307 179 586... | 459 digits of 2π |
| $0, 1E-4, 1, 2\pi, 1000, 1E6$ | | Auxiliary constants featuring 16 digits |
| $0, 1E-6, 1E-4, \frac{1}{2}, 1, 2\pi, 1000, 1E6$ | | Auxiliary constants featuring 34 digits |

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

Radius of an atomic nucleus

$\sim 10^{-15} \text{ m}$

Radius of an atom⁴¹

$\sim 10^{-10} \text{ m}$

⁴¹ So the nucleus takes far less than a billionth of the volume of an atom. Electrons are even smaller. Thus, an atom is almost completely empty space. Our world as we know and see it every day is built of atoms. Think about it!

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

| | |
|--|--|
| Radius of the observable universe | $\approx 45 \times 10^9$ l.y. $\approx 4.3 \times 10^{26}$ m |
| Amount of stars in observable universe | $\sim 10^{23}$ |
| Amount of atoms in the Sun | $\sim 10^{57}$ |
| Amount of atoms in observable universe | $\sim 10^{80}$ |
| Baryonic mass in observable universe | $\sim 10^{53}$ kg |

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

Unit Conversions

Your *WP 43S* features 14 angular conversions provided in 4→ (see p. 131) and 88 unit conversions in U→. The structure of U→ follows various branches as explained in the OM, Section 5. Its top view looks like this:



with **E:** standing for the *submenu* of energy unit conversions, **P:** for power, **F&p:** for force and pressure, **m:** for mass, **x:** for length, **A:** for area, and **V:** for volume. See pp. 128f for further details of the structure.

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

| Quantity | Unit | Symbol and formula |
|-----------------------|-----------------------|--|
| Temperature | <i>degree Celsius</i> | $\vartheta[\text{ }^{\circ}\text{C}] = \text{T[K]} - 273.15$ |
| 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> | $1 \text{ F} = 1 \text{ C/V} = 1 \text{ A s/V}$ |
| 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> | $1 \text{ Wb} = 1 \text{ V s}$ |
| Magnetic flux density | <i>tesla</i> | $1 \text{ T} = 1 \text{ Wb/m}^2 = 1 \text{ V s/m}^2$ |
| Inductance | <i>henry</i> | $1 \text{ H} = 1 \text{ Wb/A} = 1 \text{ V s/A}$ |
| Frequency | <i>hertz</i> | $1 \text{ Hz} = 1/\text{s}$ |
| Absorbed dose | <i>gray</i> | $1 \text{ Gy} = 1 \text{ J/kg}$ |

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

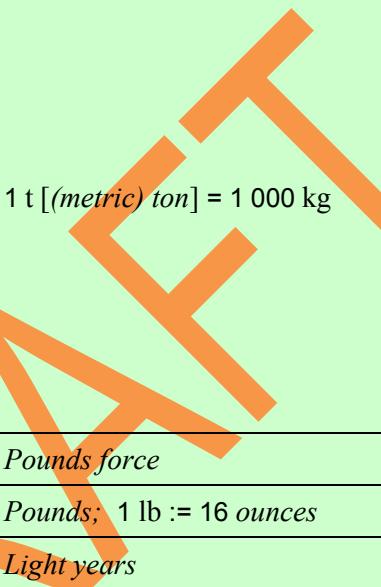
| Prefix symbol | Name | Factor |
|---------------|--------|-----------|
| h | hecto- | 10^2 |
| k | kilo- | 10^3 |
| M | mega- | 10^6 |
| G | giga- | 10^9 |
| T | tera- | 10^{12} |
| P | peta- | 10^{15} |
| E | exa- | 10^{18} |

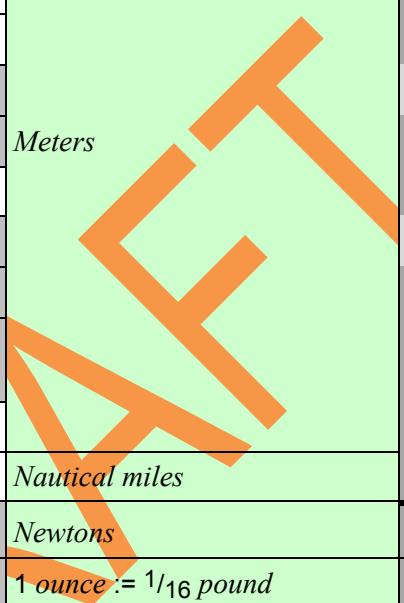
| Prefix symbol | Name | Factor |
|---------------|--------|------------|
| d | deci- | 10^{-1} |
| c | centi- | 10^{-2} |
| m | milli- | 10^{-3} |
| μ | micro- | 10^{-6} |
| n | nano- | 10^{-9} |
| p | pico- | 10^{-12} |
| f | femto- | 10^{-15} |
| a | atto- | 10^{-18} |

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

| Softkey | Calculation | Remarks | Branch |
|--|-----------------------------------|--|--------------------------------|
| ${}^\circ\text{C} \rightarrow {}^\circ\text{F}$ | $\times 1,8 + 32$ | These <i>acres</i> are based on the ' <i>international feet</i> ', see below | $\text{U}\rightarrow$ |
| ${}^\circ\text{F} \rightarrow {}^\circ\text{C}$ | $- 32) / 1,8$ | | |
| $\text{acre} \rightarrow \text{m}^2$ | $\times 4\,046,86$ | These <i>acres</i> are based on the ' <i>U.S. survey feet</i> ', see below | $\text{U}\rightarrow$ f $A:$ |
| $\text{acre}_{\text{US}} \rightarrow \text{m}^2$ | $\times 4\,046,87$ | | |
| $\text{atm} \rightarrow \text{Pa}$ | $\times 1,013\,25 \times 10^5$ | <i>Atmospheres</i> | $\text{U}\rightarrow$ $F\&p:$ |
| $\text{au} \rightarrow \text{m}$ | $\times 1,495\,98 \times 10^{11}$ | <i>Astronomic units</i> | $\text{U}\rightarrow$ $x:$ |
| $\text{barrel} \rightarrow \text{m}^3$ | $\times 0,158\,987$ | <i>Barrels (U.S.) of oil, abbr. bbl</i> | $\text{U}\rightarrow$ f $V:$ |
| $\text{bar} \rightarrow \text{Pa}$ | $\times 10^5$ | 1 mbar = 1 hPa | $\text{U}\rightarrow$ $F\&p:$ |

| Softkey | Calculation | Remarks | Branch |
|-------------------------------------|-----------------------------|--|--------|
| Btu → J | × 1 055,06 | British thermal units | E: |
| cal → J | × 4,186 8 | Calories | |
| carat → kg | × 0,000 2 | | m: |
| cwt→kg | × 50,802 4 | (Long) hundredweight = 112 lbs | |
| dB → field ratio | $10^{R_{dB}/20}$ | Decibels | |
| dB → power ratio | $10^{R_{dB}/10}$ | | ▼ |
| fathom → m | × 1,828 8 | 1 fathom := 6 feet | |
| ft.→m | × 0,304 8 | The so-called 'international feet' of 1959 1 foot := 1/3 yard | x: |
| field ratio→dB | $20 \lg(a_1/a_2)$ | Also known as amplitude ratio | ▼ |
| floz _{UK} → m ³ | × 2,841 31×10 ⁻⁵ | Fluid ounces | |
| floz _{US} → m ³ | × 2,957 35×10 ⁻⁵ | | f v: |
| gl _{UK} →m ³ | × 4,546 09×10 ⁻³ | Gallons | f A: |
| gl _{US} →m ³ | × 3,785 42×10 ⁻³ | | |
| ha → m ² | × 10 000 | hectares | f A: |
| hp _E →W | × 746 | Electric horsepower | |
| hp _M →W | × 735,498 8 | So-called 'metric' horsepower (equivalent to PS in German) | P: |
| hp _{UK} →W | × 745,699 9 | British Imperial horsepower | |
| in.→ m | × 0,025 4 | 1 inch := 1/12 foot and 1 inch := 1 000 mil | x: |
| in.Hg → Pa | × 3 386,39 | Inches of mercury | F&p: |

| Softkey | Calculation | Remarks | Branch |
|-------------------------------------|-----------------------------|---|---------|
| J → Btu | / 1 055,06 | Joules | U- E: |
| J → cal | / 4,186 8 | | |
| J → Wh | / 3 600 | | |
| kg → carat | / 0,000 2 |  1 t [(metric) ton] = 1 000 kg | U- m: |
| kg → cwt | / 50,802 4 | | |
| kg → oz | / 0,028 349 5 | | |
| kg → lb. | / 0,453 592 | | |
| kg → sh.cwt | / 45,359 2 | | |
| kg → short ton | / 907,185 | | |
| kg → stone | / 6,350 29 | | |
| kg → ton | / 1 016,05 | | |
| kg → tr.oz | / 0,031 103 5 | | |
| lbf → N | × 4,448 22 | Pounds force | U- F&p: |
| lb.→kg | × 0,453 592 | Pounds; 1 lb := 16 ounces | U- m: |
| ly → m | × 9,460 73×10 ¹⁵ | Light years | U- x: |
| m ² → acre | / 4 046,86 | Square meters; 1 a [are] = 100 m ² , 1 ha [hectare] = 10 000 m ² , 1 km ² = 100 ha = 1 000 000 m ² | U- f A: |
| m ² → acre _{us} | / 4 046,87 | | |
| m ² → ha | / 10 000 | | |
| m ³ → barrel | / 0,158 987 | | |
| m ³ → floz _{uk} | / 2,841 31×10 ⁻⁵ | Cubic meters; 1 l [liter] = 10 ⁻³ m ³ , 1 ml [milliliter] = 1 cm ³ | U- f V: |
| m ³ → floz _{us} | / 2,957 35×10 ⁻⁵ | | |
| m ³ → gl _{uk} | / 4,546 09×10 ⁻³ | | |
| m ³ → gl _{us} | / 3,785 42×10 ⁻³ | | |
| m ³ → qt. | / 1,1365×10 ⁻³ | | |

| Softkey | Calculation | Remarks | Branch |
|---|-----------------------------------|---|---|
| mi. \rightarrow m | $\times 1\,609,344$ | $1 \text{ mile} = 1\,760 \text{ yards}$ | |
| m \rightarrow au | $/1,495\,98 \times 10^{11}$ | | |
| m \rightarrow fathom | $/1,828\,8$ | | |
| m \rightarrow ft. | $/0,304\,8$ | | |
| m \rightarrow in. | $/0,025\,4$ | | |
| m \rightarrow ly | $/9,460\,73 \times 10^{15}$ | | |
| m \rightarrow mi. | $/1\,609,344$ | |  Meters   |
| m \rightarrow nmi. | $/1\,852$ | | |
| m \rightarrow pc | $/3,085\,68 \times 10^{16}$ | | |
| m \rightarrow point | $/352,778 \times 10^{-6}$ | | |
| m \rightarrow survey foot _{us} | $/0,304\,801$ | | |
| m \rightarrow yd. | $/0,914\,4$ | | |
| nmi. \rightarrow m | $\times 1\,852$ | <i>Nautical miles</i> | |
| N \rightarrow lbf | $/4,448\,22$ | <i>Newton</i> s |   |
| oz \rightarrow kg | $\times 0,028\,349\,5$ | <i>1 ounce := 1/16 pound</i> |   |
| Pa \rightarrow atm | $/1,013\,25 \times 10^5$ | | |
| Pa \rightarrow bar | $/10^5$ | | |
| Pa \rightarrow in.Hg | $/3\,386,39$ | | |
| Pa \rightarrow psi | $/6\,894,76$ | | |
| Pa \rightarrow torr | $/133,322$ | | |
| pc \rightarrow m | $\times 3,085\,68 \times 10^{16}$ | <i>Parsecs</i> |   |
| point \rightarrow m | $\times 352,778 \times 10^{-6}$ | (Typographical) points | |
| power ratio \rightarrow dB | $10 \lg(p_1/p_2)$ | |   |

| Softkey | Calculation | Remarks | Branch |
|----------------------------------|---------------------------|--|-------------|
| psi → Pa | × 6 894,76 | Pounds per square inch | [U-] F&p: |
| qt. → m ³ | × 1,1365×10 ⁻³ | (Imperial) quarts | [U-] f [V:] |
| short cwt → kg | × 45,359 2 | 1 short hundredweight = 100 lbs | |
| short ton → kg | × 907,185 | 1 short ton = 2 000 lbs | [U-] m: |
| stone → kg | × 6,350 29 | | |
| survey foot _{US} → m | × 0,304 801 | 1 U.S. survey foot := $\frac{1200}{3937}$ m | [U-] x: |
| s → year | / 31 556 952 | | [U-] |
| ton → kg | × 1 016,05 | 1 Imperial ton = 200 (long) cwt = 2 240 lbs | [U-] m: |
| torr → Pa | × 133.322 | 1 torr = 1 mm Hg | [U-] F&p: |
| tr.oz → kg | × 0,031 103 5 | Troy ounces | [U-] m: |
| Wh → J | × 3 600 | Watt-hours | [U-] E: |
| W → hp _E | / 746 | | |
| W → hp _M | / 735,498 8 | | [U-] P: |
| W → hp _{UK} | / 745,699 9 | | |
| yd. → m | × 0,914 4 | 1 yard := 3 feet and 2 yards := 1 fathom | [U-] x: |
| year → s | × 31 556 952 | = 365,242 5 × 24 × 60 ² | [U-] |

|  ... | Remarks |
|---|---|
| DEG→ | Takes an integer or real ⁴² x as an angular input in <i>decimal</i> or <i>sexagesimal degrees</i> , respectively, and converts it to the current <i>ADM</i> . |
| D.MS→D | Takes an integer or real ⁴² x as an angular input in <i>sexagesimal degrees</i> (formatted dddd.dmmsshh) and converts it to an <i>angle</i> in <i>decimal degrees</i> (corresponding to the old command H.MS→H). |
| D→R | Takes an integer or real ⁴² x as an angular ... radians. ⁴³ |
| D→D.MS | input in <i>decimal degrees</i> ... <i>sexagesimal degrees</i> (corresponding and converts it to ... to the old command H→H.MS). |
| GRAD→ | ... grad/gon ... |
| MULπ→ | Takes an integer or real ⁴² x as an angular ... multiples of π ... to the current input in ... ADM. |
| RAD→ | ... radians ⁴³ ... |
| R→D | Takes an integer or real ⁴² x as an angular input in <i>radians</i> and converts it to <i>decimal degrees</i> (equaling the old command R→D). ⁴³ |

⁴² If x is neither integer nor real (i.e. neither *data type* 1, 2, nor 11), error 24 will be thrown. Conversions of integer values to *angles* in *sexagesimal degrees* do not make real sense but are allowed nevertheless.

⁴³ Note that real angles given in *radians* cannot represent full circles (or simple fractions of π like $\pi/2, \pi/4, \pi/5, \pi/8, \pi/10$, etc.) exactly but with an accuracy of 16 or 34 digits 'only'. If you want to avoid rounding errors caused by that, *multiples of π* may be a better choice here. This applies especially to large numeric inputs in trigonometric functions since those will be reduced to values between $-\pi$ and $+\pi$ before calculating (as mentioned in Section 2 of the OM).

|  ... | Remarks |
|--|---|
| →DEG | If x is an integer or real (<i>data type</i> 1, 2, or 11), takes it as an angular input in the current <i>ADM</i> and converts it to <i>decimal degrees, sexagesimal degrees, grad/gon, multiples of π, or radians</i> , respectively. ⁴³ |
| →GRAD | If x is a tagged real (<i>data type</i> 4), on the other hand, this information is used in conversion (e.g. if $x = 1.5\pi$ then →GRAD will return 300° regardless of current <i>ADM</i>). |
| →MULπ | |
| →RAD | If x is neither of <i>data type</i> 1, 2, 4, nor 11, error 24 will be thrown ('illegal input data type for this operation'). |

Angular output is tagged always.

DRAFT

SECTION 3: CALLING AND EXECUTING OPERATIONS

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

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

Furthermore, we will summarize the functions requiring parameters.

Using XEQ for Executing Operations

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

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

Operations Requiring Trailing Parameters

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

Operations requiring one trailing parameter

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

Operations requiring one trailing parameter

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

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

XYZ → ST.X

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

Operations requiring two trailing parameters

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

Operation requiring four trailing parameters

First to fourth parameter

| | |
|---|------------------------|
| ➤ | Name of stack register |
|---|------------------------|

Operations Changing Data Types

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

| Input DT | Operation(s) | Output DT | Output registers involved |
|----------|--|-----------|---------------------------|
| 1 | $1/x$ $\sqrt[3]{x}$ AGM ALL cos ENG erf erfc e^x FIX f' f'' gd gd^{-1} $J_y(x)$ LN LN β LNF LOG_{10} LOG_2 LOG_{xy} MANT POISS... SCI sin tan W_m W_p W^{-1} $\sqrt[y]{y}$ $\beta(x,y)$ Γ_{xy} γ_{xy} $\Gamma(x)$ $\Delta\%$ $\rightarrow\text{REAL}$ % %MRR %T % Σ %+MG \sqrt{x} as well as all unit conversions and all orthogonal polynomials | 2^{44} | X |
| | $\rightarrow\text{POL}$ $\rightarrow\text{REC}$ | 2 | X, Y |
| | SLVQ | 2 or 3 | X, Y, Z |
| | $f'(x)$ $f''(x)$ SOLVE | 2 | X, Y, Z, T |
| | all angular conversions | 4 | X |
| | $\rightarrow\text{H.MS}$ | 5 | X |
| | $J\rightarrow D$ $\rightarrow\text{DATE}$ | 6 | X |
| | $x\rightarrow\alpha$ | 7 | X |
| | M.GET M.NEW | 8 or 9 | X |
| | $\rightarrow\text{INT}$ | 10 | X |

⁴⁴ The functions printed on yellow background will return *long integers (data type 1)* wherever possible.

| Input DT | Operation(s) | Output DT | Output registers involved |
|----------|---|-----------|---------------------------|
| 2 | AND CEIL DATE→ DAY D→J EXPT FLOOR IDIV IDIVR 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 |
| | →INT | 10 | X |
| 3 | →DP | 11 | X |
| | ABS CROSS IM RE x 4 | 2 | X |
| | CX→RE | 2 | X, Y |
| | SLVQ | 2 or 3 | X, Y, Z |
| 4 | →DP | 12 | X |
| | cos sin tan | 2 | X |
| | →HR | 2 | X |
| 6 | DAY D→J MONTH WDAY YEAR | 1 | X |
| | DATE→ | 1 | X, Y, Z |
| | →REAL | 2 | X |

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

APPENDIX A: HARDWARE

Overall dimensions: wedge-shaped: 77 mm × 144 mm × 13 mm or 8 mm (see p. 157)

Mass with battery: ~100 g

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

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

Memory: 1 MB *FM*, 128 kB *RAM* (see App. B on pp. 161ff),
8 MB additional *FM* on a QSPI chip;
user *RAM* is some 75 kB, user *FM* is 6 MB.

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

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

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

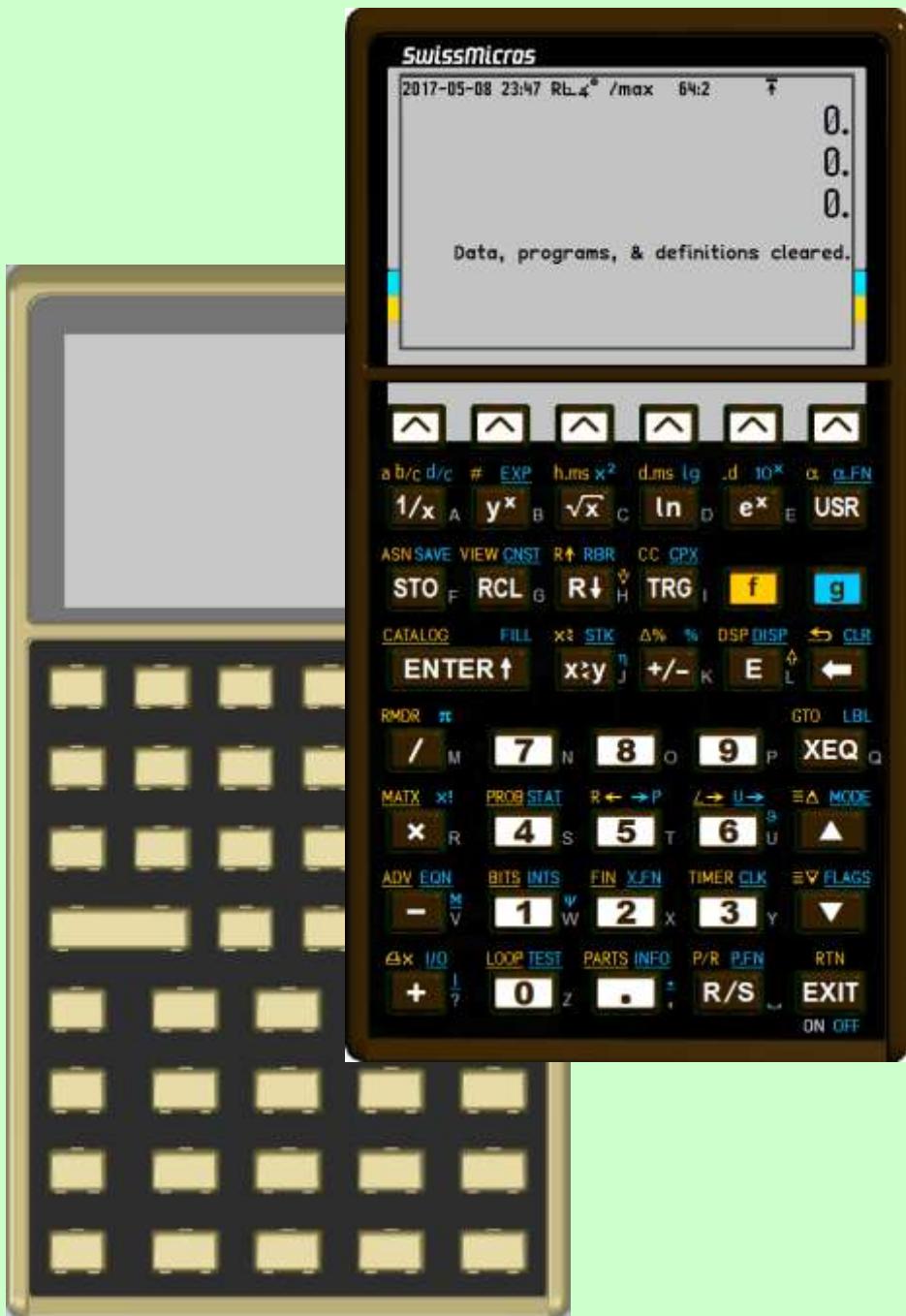
Self-test: initiated by **xxx**

Keyboard overlays: Three short slots on either side of the keyboard are provided in the calculator case for easy fixing overlay sheets with your personal layouts printed on them. See App. F for more (pp. 207f).



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







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

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



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



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

DR

APPENDIX B: MEMORY MANAGEMENT

Data Types

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

- 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*),
- 39-digit reals for internal calculations not exposed to the user,⁴⁵
- *flag* words for storing 128 (i.e. 112 global plus 16 local) *user flags* and the same amount of *system flags*,⁴⁶
- two *data types* for two kinds of *menus*,
- a *data type* of variable length for storing *configurations* (modes and user assignments, see STOCFG and RCLCFG),
- another one for *expressions* in EQN (see Section 4 of the OM),
- two more for program steps and routines (see Section 3 of the OM).

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

| | | | | | | | | | | | | | | | |
|------------------------------|----|----|----|----|----|--------------------------------|----|----|----|----|---|----|----|----|----|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| pointer to the data | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| pointer to the variable name | | | | 0 | 0 | data information ⁴⁷ | | | | | <i>data type</i> (as specified below) - 1 | | | | |

⁴⁵ There are also longer (i.e. more precise) reals used in internal computations. See further below.

⁴⁶ Up to 256 flags would be possible.

⁴⁷ E.g. base of a *short integer*, angular unit for an *angle*.

| Data type number and meaning | | Size [bytes] |
|------------------------------|--|----------------------------------|
| 1 | \mathbb{Z} Long integer ⁴⁸ | $\geq 4 + 2 + 4 = 14 \dots 1030$ |
| 2 | \mathbb{R} Real number ⁴⁹ (<i>real16</i>) | $4 + 8 = 12$ |
| 3 | \mathbb{C} Complex number (<i>complex16</i>) | $4 + 2 \times 8 = 20$ |
| 4 | Angle ⁵⁰ (<i>angle16</i>) | $4 + 8 = 12$ |
| 5 | Time ⁵¹ | $4 + 8 = 12$ |
| 6 | Date ⁵² | $4 + 4 = 8$ |
| 7 | Alpha string (each character requires 16 bits) ⁵³ | $4 + 2 + n \times 2$ |
| 8 | Real matrix (featuring n rows and m columns) | $4 + n \times m \times 8$ |
| 9 | Complex matrix (featuring n rows and m columns) | $4 + n \times m \times 16$ |
| 10 | Short integer ⁵⁴ | $\leq 4 + 8 = 8 \text{ or } 12$ |
| 11 | Double precision real number (<i>real34</i>) | $4 + 2 \times 8 = 20$ |
| 12 | Double precision complex number (<i>complex34</i>) | $4 + 2 \times 16 = 36$ |
| 13 | Double precision angle (<i>angle34</i>) | $4 + 2 \times 8 = 20$ |

⁴⁸ This *data type* is for number theory kind of problems. 2 *bytes* are for the size (in *bits*) of the integer following. 4 *bytes* allow for signed integers up to $2^{31} \approx 2 \times 10^9$, 8 *bytes* for $2^{63} \approx 9 \times 10^{18}$. Size is increased in steps of 4 *bytes* if required (look up the display limits further below). Maximum integer size is 3328 *bits* (= 416 *bytes*) equivalent to 1002 decimal digits.

⁴⁹ As in the *WP 34S*, standard *SP* reals feature 64 *bits* and 16 digits precision. See the chapter after next.

⁵⁰ A tagged *angle* is stored as a real number, just with a specific header.

⁵¹ A *time* or time interval is stored as a real number of *seconds* internally, just with a specific header. A day corresponds to 86 400 s, a year to 31 556 952 s.

⁵² A *date* is stored as its Julian day number internally. Four *bytes* do for $> 10^7$ years.

⁵³ 2 *bytes* are for the size (in *bytes*) of the string following, including the trailing zero. The size must be even.

⁵⁴ This *data type* is for computer science problems. Most probably, such a storage space will be either 4 + 4 or 4 + 8 *bytes* long.

| Data type number and meaning | | Size [bytes] |
|------------------------------|--|----------------------|
| 14 | Double precision mathematical constant ⁵⁵ | 4 + 0 = 4 |
| 15 | Extended precision real (39 digits, exclusively for internal use) | 4 + 32 = 36 |
| 16 | <i>Label</i> (each character requires 16 bits) | 4 + 7 × 2 = 18 |
| 17 | System integer (for internal use only) | 4 + 4 = 8 |
| 18 | System and <i>user flags</i> (128 flags each) | 4 + 2 = 6 |
| 19 | User-created <i>menu</i> (limited to 1 view) | 4 + 18 × 7 × 2 = 256 |
| 20 | Predefined <i>menu</i> (featuring <i>n</i> views) | 4 + n × 18 × 14 |
| 21 | <i>Configuration</i> (as stored by STOCFG) ⁵⁶ | 4 + M |
| 22 | Program step, may be stored as <i>alpha string</i> (7) ⁵⁷ | 4 + M |
| 23 | Program, containing <i>n</i> program steps | 4 + M |
| 24 | <i>Expression</i> (for members of EQN), may be stored as <i>alpha string</i> (7) | 4 + M |
| 25 | <i>Directory</i> (proposed by P. 2012-12) | 4 + M |
| 26 | | |

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

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

⁵⁵ The other constants are far within SP. A pointer is sufficient in any case.

⁵⁶ The size will vary according to the number of user assignments being part of the configuration (see Section 6 of the OM).

⁵⁷ The size will vary depending on parameters. Exact limits and methods are not decided yet.

Statistical Summation Registers

Your *WP 43S* features a block of 23 special *registers* for storing statistical sums (like the *WP 34S* and *WP 31S* had 14 before). These statistical *registers* neither overlap nor interfere with any general purpose *registers* unlike they did on *HP's* pocket calculators. The contents of these *registers* can be recalled using their names; please see pp. 57 and 91f.

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

Range of Standard (SP) Real Numbers

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

Within this range, your *WP 43S* calculates with 16 digits precision (thus, it can display up to 16 digits in *startup default* display format). Results should be accurate within $\pm 1 \times 10^{-15}$ (e.g. **$n \text{ } 1/x \text{ } 2n \text{ } x$** returns a plain 2 for all primes < 500 – just **$7 \text{ } 1/x \text{ } 14 \text{ } x$** returns $2 + 1 \times 10^{-15}$; the same results for 79 and 89, and for 97 a $2 - 1 \times 10^{-15}$ is returned). Results $|x| < 10^{-398}$ are set to zero. For results $|x| \geq 10^{+385}$, error 4 or 5 will appear unless SPCRES is set (see App. C).

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

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

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

- The most significant (64th) bit takes the sign of the mantissa.
- The remaining 13 bits are used for the exponent and the leftmost digit of the mantissa. Of those 13, the lowest 8 are reserved for the exponent. For the top 5 bits it becomes complicated.⁵⁸ If they read
 - 00ttt, 01ttt, or 10ttt then ttt takes the leftmost digit of the *significand* ($0 - 7_{10}$), and the top two bits will be the most significant bits of the exponent;
 - 11uut then t will be added to 1000_2 and the result (8_{10} or 9_{10}) will become the leftmost digit of the *significand*. If uu reads 00, 01, or 10 then these two will be the most significant bits of the exponent. If uu reads 11 instead, there are codes left for encoding special numbers (e.g. infinities).

In total, we get 16 digits for the mantissa and a bit less than 10 bits for the exponent: its maximum is $10\ 1111\ 1111_2$ (i.e. 767_{10}). For reasons becoming obvious below, 398 must be subtracted from the value in this field to get the true exponent of the number represented. The 16 digits of the *significand* allow for a range from 1 to almost 10^{16} .

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

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

⁵⁸ Don't blame us – this part follows the standard IEEE 754.

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

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

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

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

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

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

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

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

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

An exponent is not applicable here. These ‘three special reals’ may be legal results of your WP 43S if SPCRES is set – no error will be thrown then. ‘Not a number’ (NaN) covers outputs exceeding real domain or being undefined (like poles) – see the corresponding entry in Section 5 of the OM and examples in next chapter. Note that $+\infty$ and $-\infty$ may be also legal inputs while NaN is not.

Calculations with Double Precision (DP) Real Numbers

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

 Matrix commands will not work with DP numbers.

 **DP** allows for more precise calculations. While some computations will reach high accuracy, we do not warrant 34 digit precision in all calculations with DP reals.⁵⁹

DP reals are stored coarsely following *decimal128* packed coding, though with some exceptions. The lowest 110 bits take the rightmost 33 digits of the *significand*. Going left, a 12 bit exponent field follows, then

⁵⁹ Not all functions are expanded to DP, some stay in *single precision* or merely a little bit more.

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

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

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

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

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

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

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

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

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

5 bits used and coded exactly as in *SP*, and finally the sign bit. The maximum absolute value of the stored exponent is $10\ 1111\ 1111\ 1111_2 = 12\ 287_{10}$. For reasons analogous to those explained on pp. 164ff, 6176 must be subtracted from this value to get the true exponent of the floating point number represented. Thus, *data type 11* could support 34-digit numbers within $10^{-6143} \leq |x| < 10^{+6145}$ (keyboard input is limited to $10^{-999} \leq |x| < 10^{+999}$, cf. p. 141 for reasons). Coding works in full analogy to the way described for *SP* in previous chapter.

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

Divide this by 1.999 999 999 999 999 999 999 999 999 999 999 and the result will remain 10^{-6176} . Divide it by 2 instead and the result will become zero.

Full 34-digit precision of a *DP* number in *X* may be displayed by *SHOW* as a *temporary information* in small font (see p. 71). Remember not every such number may be true to 34 digits – cf. p. 168. And errors accumulate as explained in footnote 38 on pp. 131f.

Returning to *SP* (via →*SP*) with input exceeding the *SP* number range explained on pp. 164ff will cause 0 or $\pm\infty$ (or an overflow) being displayed instead.

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

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

Special Results

Within this chapter, flag *SPCRES* is presumed to be set. Thus, infinities and non-numeric results are legal – no error message will be thrown if such results happen to occur. **NaN** covers poles as well as regions where a function result is not defined at all.

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

| Input x | Operation(s) | Output ⁶⁰ |
|---------------------------------|--|---|
| 0. | $\frac{1}{x}$ | ∞ |
| 0 or 0. | \ln , \lg , $\operatorname{lb} x$ | $-\infty$ |
| $-\infty \leq x < 0$ | | NaN |
| 0 or 0. | $\Gamma(x)$ | NaN |
| $ \operatorname{Re}(x) > 1$ | \arccos , \arcsin | NaN |
| $\operatorname{Re}(x) < 1$ | arcosh | NaN |
| $\operatorname{Re}(x) \geq 1$ | artanh | NaN |
| 90° or equivalents in other ADM | \tan | $-\infty$ (WP 34S returns NaN at this pole) |
| $-\infty$ | arctan | -90.° or equivalents |
| ∞ | | 90.° or equivalents |
| $-\infty$ | e^x , 10^x , 2^x | 0. |
| $-\infty$ or ∞ | $\frac{1}{x}$, sinc | 0. |
| $-\infty$ or ∞ | x^2 | ∞ |
| ∞ | \tanh | 1. |
| ∞ | \ln , e^x , \sqrt{x} , \lg , 10^x , $\operatorname{lb} x$, \sinh , \cosh | ∞ |
| $-\infty$ or ∞ | \cos , \sin , \tan , arcosh , arsinh , artanh | NaN |

⁶⁰ In this chapter, results were crosschecked against the WP 34S wherever possible. Deviations are highlighted. Red results are considered wrong although they may concur with the WP 34S.

And this is the respective table for dyadic functions:

| Input y | x | Operation | Output |
|-----------------------|----------------------------|------------------|----------------------------|
| ∞ | arbitrary $x \neq -\infty$ | + | ∞ ⁶¹ |
| $-\infty$ | arbitrary $x \neq \infty$ | | $-\infty$ ⁶¹ |
| $-\infty$ | ∞ | + | NaN ⁶¹ |
| ∞ | arbitrary $x \neq \infty$ | | ∞ ⁶² |
| $-\infty$ | arbitrary $x \neq -\infty$ | - | $-\infty$ ⁶² |
| $-\infty$ | $-\infty$ | | NaN |
| ∞ | ∞ | \times | ∞ ⁶¹ |
| $-\infty$ | arbitrary $x > 0$ | | $-\infty$ ⁶¹ |
| $-\infty$ | arbitrary $x < 0$ | \times | ∞ ⁶¹ |
| ∞ | arbitrary $x < 0$ | | $-\infty$ ⁶¹ |
| $-\infty$ | arbitrary $x > 0$ | \times | NaN ⁶¹ |
| 0 or $0.$ | $-\infty$ or ∞ | | NaN ⁶¹ |
| $0 < y \leq \infty$ | $0.$ | / | ∞ |
| $-\infty \leq y < 0$ | $0.$ | | $-\infty$ |
| $-\infty$ or ∞ | $-\infty$ or ∞ | / | NaN |
| 0 or $0.$ | $0.$ | | NaN |
| $-\infty < y < 0$ | non-integer x | y^x | NaN |
| $-\infty$ or ∞ | $0.$ or 0 | | NaN |
| $-\infty$ | odd $x > 0$ | y^x | $-\infty$ |
| $-\infty$ | even $x > 0$ | | ∞ |
| ∞ | arbitrary $x > 0$ | y^x | ∞ |
| arbitrary $y \neq 0$ | $-\infty$ | | $0.$ |
| | ∞ | | ∞ |
| $0.$ | $0 < x < \infty$ | $\log_{\infty}y$ | $-\infty$ |

⁶¹ Swapping x and y will return the same result here.

⁶² Swapping x and y will return the result times -1.

The functions printed on light yellow background in the two tables above will return ***NaN*** also with complex results allowed. Others will change their output when **C** is lit (i.e. CPXRES set). Some particular returns of elementary transient functions operating near $\pm\infty$ are listed here:⁶³

| Input | Re(x) | Im(x) | r(x) | $\varphi(x)$ | Op. | Output |
|-------------|------------|------------|------------|--------------|---------------|---|
| $-\infty$ | — | — | — | — | \sqrt{x} | $\infty \neq 90^\circ = 0.+i\infty$ |
| | 0 | ∞ | ∞ | 180° | | $\text{NaN}+i\infty$ (WP 34S returns $0.+i\infty$) |
| -10^{999} | 0 | 10^{999} | 10^{999} | 180° | x^2 | $\rightarrow \infty \neq 90^\circ = 0.+i\infty$ |
| | 10^{999} | 10^{999} | 10^{999} | 90° | | $\rightarrow \infty \neq 180^\circ = -\infty+i\cdot 0.$ |
| $0.$ | 10^{999} | 10^{999} | 10^{999} | 90° | x^2 | $-\infty+i\cdot \text{NaN}$ (see remark 2 below) |
| | ∞ | ∞ | ∞ | 90° | | $-\infty$ |
| $-\infty$ | — | — | — | — | $\sqrt[3]{x}$ | $\infty \neq 45^\circ = \infty+i\cdot\infty$ (34S: $\text{NaN}+i\cdot\text{NaN}$) |
| | 0 | ∞ | ∞ | 180° | | $1.\times 10^{333} \neq 60^\circ =$ $5.\times 10^{332} + i\times 8.660\ 254\ 037\ 8\times 10^{332}$ $= 5 \times 10^{332} (1 + i \times \sqrt{3})$ |
| -10^{999} | 0 | 10^{999} | 10^{999} | 180° | x^3 | $1.\times 10^{999} \neq -180^\circ = -1.\times 10^{999} + i\cdot 0.$ |
| | 10^{999} | 10^{999} | 10^{999} | 60° | | $-\infty$ |
| $-\infty$ | — | — | — | — | x^3 | $\text{NaN}+i\cdot \text{NaN}$ (see remark 3 below) |
| | 0 | ∞ | ∞ | 180° | | $-1.\times 10^{2997} + i\cdot 0. \rightarrow -\infty + i\cdot 0$ |
| ∞ | — | — | — | — | \ln | ∞ |
| | 0 | ∞ | ∞ | 0° | | $\infty+i\cdot\infty$ (WP 34S returns $\infty+i\cdot 0.$) |
| 10^{999} | 0 | 10^{999} | 10^{999} | 0° | | $2\ 300.282\ 507\ 9+i\cdot 0. \rightarrow \infty + i\cdot 0$ |

⁶³ Following an article of HP about the HP-71, infinities should be treated in polar notation (see <http://hparchive.com/Journals/HPJ-1984-07.pdf>, p. 27, left column for the reasons).

| Input | | | | | Output |
|-----------|-----------|----------|--------------|----------------|--|
| Re(x) | Im(x) | r(x) | $\varphi(x)$ | Op. | |
| -10^999 | 0 | 10^999 | 180° | | 2 300.282+i×3.141 592 → ∞ + iπ |
| -∞ | | ∞ | | In | i+0 (WP 34S = ∞ + iπ) |
| | - | - | - | | NaN |
| ∞ | ∞ | ∞ | 45° | In | ∞+i×∞ |
| ∞ | -∞ | ∞ | -45° | In | ∞-i×∞ |
| -∞ | ∞ | ∞ | 135° | In | ∞+i×∞ |
| -∞ | -∞ | ∞ | -135° | In | ∞-i×∞ |
| 0. | 10^999 | 10^999 | 90° | In | → ∞ + iπ/2 |
| | ∞ | ∞ | | | ∞+i×∞ |
| 0. | -∞ | ∞ | -90° | In | ∞-i×∞ |
| 0. | 0. | 0. | 0. | | NaN+i×NaN |
| 0. | - | - | - | In | -∞ |
| 0. | 00 | 00 | | | NaN+i×NaN (see remark 2 below) |
| 0. | 10^999 | 10^999 | 90° | e ^x | 1.0 + -45° (WP 34S: NaN+i×NaN) = 0.707 106 781 186... - i×0.707 1... = $\frac{1}{2}(\sqrt{2} - i\sqrt{2})$ |
| 0. | -∞ | ∞ | | | NaN+i×NaN (see remark 2 below) |
| 0. | -10^999 | 10^999 | -90° | e ^x | 1.0 + 45° (WP 34S: NaN+i×NaN) = 0.707 106 781 186... + i×0.707 1... = $\frac{1}{2}(\sqrt{2} + i\sqrt{2})$ |
| -∞ | 0 | ∞ | | | 0.+i×0. |
| -10^999 | 10^-999 | 10^999 | 180° | e ^x | 0.+i×0. (see remark 2 below) |
| -∞ | | ∞ | | | NaN+i×NaN (see remark 2 below) |
| -∞ | 00 | ∞ | 135° | e ^x | NaN+i×NaN |
| -∞ | -∞ | ∞ | -135° | e ^x | NaN+i×NaN |

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

1. Note that $f^{-1}(f(x)) = x$ may not hold in such special cases since $\pm\infty$ is not a usual number (so inversions may include operations with non-numeric results).
2. $\lim_{x \rightarrow \infty} f(x) \approx f(10^{999})$ may deviate significantly from $f(x = \infty)$; the same applies to $\lim_{x \rightarrow 0} f(x) \approx f(10^{-999})$ and $f(0)$ as well as to $\lim_{x \rightarrow -\infty} f(x) \approx f(-10^{999})$ and $f(x = -\infty)$.
3. And although $x \equiv x + i \times 0$, there may be $f(x) \neq f(x + i \times 0)$ above (this may be a bug though).

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

Program Step Size

Program step size is assumed to be 4 bytes typically. But compare data type 22 on p. 163.

APPENDIX C: MESSAGES AND ERROR CODES

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

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

| | EC | Explanations, countermeasures and examples |
|---|----|--|
| An argument exceeds the function domain | 1 | {1, 2, 3, 4, 10, 11, 12} 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. ⁶⁴ |
| Bad time or date input | 2 | {2, 5, 6, 11} Invalid date format or incorrect date or time in input, e.g. month > 12, day > 31. Will be thrown as soon as the input is closed. |
| Cannot delete a predefined item | 27 | Self-explanatory. |
| Distribution parameter out of valid range | 16 | {1, 2, 11} A parameter specified in I , J , or K is out of valid range for the distribution function called (e.g. if LGNRM is called with $j < 0$). |
| Flash memory is full | 23 | Delete a program from <i>FM</i> to regain space. |

⁶⁴ Note that e.g. $\tan(90^\circ)$ and logs of 0 are legal operations on {1, 2, 3, 11, 12} if SPCRES is set. See the end of this appendix.

| | EC | Explanations, countermeasures and examples |
|---|----|--|
| Flash memory is write protected | 19 | There was an attempt to edit or delete program steps in FM. See PRCL and PSTO to circumvent. |
| Function to be coded for that data type | 30 | Functions may not be coded yet during FW development. |
| Illegal digit in integer input for this base | 9 | {10} E.g. 2 in binary or 9 in octal input. Will be thrown as soon as the respective base is entered (i.e. as soon as input is closed). |
| Illegal input data type for this operation | 24 | ... called. Convert what is necessary. Cf. " <i>operation is undefined in this mode</i> ". |
| Input is too long | 10 | Keyboard input is too long for the buffer. (This error is not used currently. Only alpha input is limited presently.) |
| Invalid or corrupted data | 18 | Set when there is a checksum error either in FM or as part of a serial download. Also set if a FM segment is otherwise not usable. |
| Item to be coded | 29 | Functions may not be coded yet during FW development. |
| I/O error | 17 | See Section 3 of the OM. |
| Matrix mismatch | 21 | {8, 9} <ul style="list-style-type: none">• A matrix isn't square although it should be.• Matrix sizes aren't miscible. |
| No root found | 20 | {2, 11} The Solver did not converge. |
| No such function | 7 | Returned when calling a nonexistent function via XEQ α ... ENTER↑ (check for typos!) or running a routine containing a nonprogrammable command. |

| | EC | Explanations, countermeasures and examples |
|-------------------------------------|----|---|
| No such label found | 6 | Attempt to address an undefined label. |
| Operation is undefined in this mode | 13 | Caused e.g. by calling a real number operation in AIM. Cf. " <i>illegal input data type for this operation</i> ". |
| Out of range | 8 | <p>{1, 2, 3, 10, 11, 12}</p> <ul style="list-style-type: none"> A number exceeds the valid range. This can be caused by specifying decimals > 16, word size > 64, negative flag numbers, short integers $\geq 2^{64}$, hours or degrees > 9 000, invalid dates or times, denominators $\geq 9\,999$, etc. A register or flag address exceeds the valid range of currently allocated registers or flags. May also happen in indirect addressing or when calling nonexistent local addresses. An R-operation (e.g. R-COPY) attempts accessing invalid register addresses. |
| Overflow at $+\infty$ | 4 | <p>{1, 2, 3, 8, 9, 11, 12} unless SPCRES is set</p> <ul style="list-style-type: none"> Division of a number > 0 by 0. Divergent sum or product or integral. Positive overflow (see p. 164). |
| Overflow at $-\infty$ | 5 | <p>{1, 2, 3, 8, 9, 11, 12} unless SPCRES is set</p> <ul style="list-style-type: none"> Division of a number < 0 by 0. Divergent sum or product or integral. Negative overflow (see p. 164). Logarithm of 0 (note a logarithm of -0 returns NaN). |
| Please enter a NEW name | 26 | Trying to define a new variable or user menu with a name already in use. |

| | EC | Explanations, countermeasures and examples |
|--|----|---|
| RAM is full | 11 | May be caused by attempts to write too large routines, allocate too many variables, and the like (see pp. 161ff for the space required by different <i>data types</i>). May happen also in program execution due to dynamic allocations (see Sect. 3 of the OM). |
| Singular matrix | 22 | {8, 9} <ul style="list-style-type: none"> Attempt to use a LU decomposed matrix for solving a system of equations. Attempt to invert a matrix which isn't of full rank. |
| Stack clash | 12 | STOS or RCLS attempts using <i>registers</i> that would overlap the <i>stack</i> (see Section 1 of the OM). Will happen with e.g. SSIZE set and STOS 93 . |
| Too few data points for this statistic | 15 | {2} A statistical calculation was attempted with too few data, e.g. <i>regression</i> or <i>standard deviation</i> for less than 2 points. |
| Undefined op-code | 3 | An instruction with an undefined operation code occurred. Should never happen – but who knows? |
| Word size is too small | 14 | {10} Input or <i>register</i> content is too great to be handled by the word size currently set. |
| | 25 | Left unused for WP 34S compatibility |

If SPCRES is set, errors 4 and 5 will not occur at all, and error 1 will happen less frequently, since $\pm\infty$ and NaN are legal results then (cf. the corresponding entries in CNST on pp. 131ff 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. 186, one for the *HP-21S* on p. 188, and another one for the *WP 34S* on p. 189. Functions newly introduced with *WP* calculators are compiled on pp. 193ff.

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

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

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

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

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

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

Corresponding Operations on HP-16C

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

| HP-16C | WP 43S | Remarks |
|-------------------------------|---------------------------|--|
| RL , RLn | RL | |
| RR , RRn | RR | |
| RLC , RLCn | RLC | In <u>BITS</u> |
| RRC , RRCn | RRC | |
| ÷ | / | |
| DBL÷ | DBL/ | In <u>INTS</u> (see also ISO 80000-2: "The symbol \div should not be used.") |
| x\geq(i) | | |
| x\geq | | Any register may be used for indirection. |
| SHOW HEX | | |
| SHOW DEC | | |
| SHOW OCT | | |
| SHOW BIN | | |
| B? | BS? | In <u>BITS</u> |
| GSB | XEQ | |
| HEX | # H | |
| DEC | # D | |
| OCT | # 8 | |
| BIN | # 2 | |
| SF [3] | SF LEAD.0s | In <u>FLAGS</u> . Control display of leading zeros. |
| CF [3] | CF LEAD.0s | |
| SF [4] , CF [4] | SF C , CF C | Carry. SF and CF live in <u>FLAGS</u> . |
| SF [5] , CF [5] | SF B , CF B | Overflow. |
| F? | FS? | In <u>FLAGS</u> |

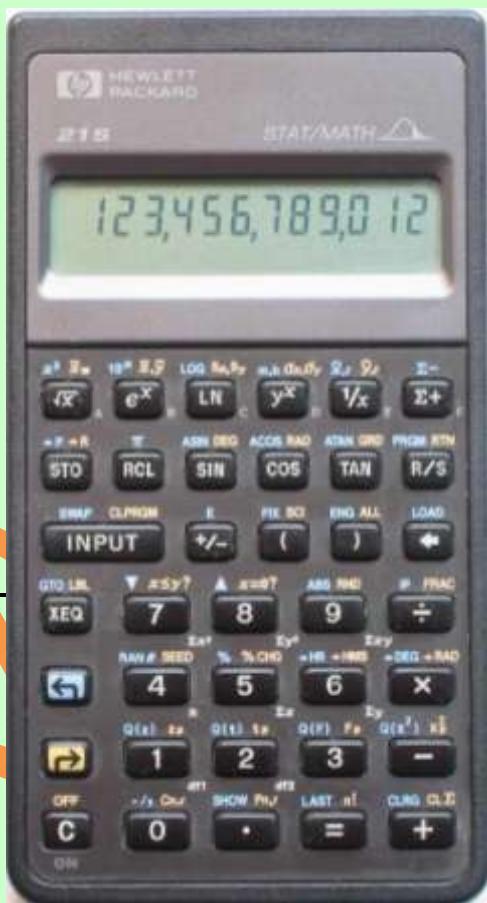
| HP-16C | WP 43S | Remarks |
|-----------------|------------|---|
| (i) | Disposable | Any register may be used for indirection. |
| I | | |
| CLEAR PRGM | CLP | In CLR. Note here is also CLPALL. |
| CLEAR REG | CLREGS | In CLR |
| CLEAR PREFIX | Disposable | See Section 2 of the OM. |
| WINDOW | Disposable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

Corresponding Operations on HP-21S

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

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

| <i>HP-21S</i> | <i>WP 43S</i> | Remarks |
|--|-----------------------|--|
| \bar{x}_w | \bar{x}_w | |
| \bar{x}, \bar{y} | \bar{x} | |
| S_x, S_y | S | |
| m.b | L.R. | In STAT |
| σ_x, σ_y | σ | |
| \hat{x}, r | r, \hat{x} | |
| \hat{y}, r | r, \hat{y} | |
| PRGM | P/R | |
| SWAP | $x \leftrightarrow y$ | |
| CLPRGM | CLP | In CLR |
| LOAD | 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. |
| ABS | x | In PARTS |
| RND | ROUND | |



| HP-21S | WP 43S | Remarks |
|---------------------------|--------------------------------------|--|
| [FRAC] | FP | |
| [÷] | [/] | Cf. ISO 80000-2: "The symbol \div should not be used." |
| [SEED] | SEED | In <u>PROB</u> |
| [%CHG] | [Δ %] | |
| [Q(z)] | Norm_e | In submenus of <u>PROB</u> . |
| [Zp] | Norm_l⁻¹ | |
| [Q(t)] | t_e(x) | |
| [t_p] | t⁻¹(p) | |
| [Q(F)] | F_e(x) | |
| [F_p] | F⁻¹(p) | |
| [Q(x²)] | x²_e(x) | |
| [X² p] | (x²)⁻¹ | |
| [Cn.r] | COMB | |
| [Pn.r] | PERM | In <u>PROB</u> |
| [LAST] | [RCL] L | |
| [n!] | [x!] | |
| [CLRG] | CLREGS | 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*.

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

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

| WP 34S | WP 43S | Remarks |
|------------------------------------|-----------------------------|---|
| SENDA, SENDP, SENR, SENDΣ | SEND | SEND combines all those four commands of the WP 34S. |
| SEPOFF, SEPON | GAP | |
| SHOW | RBR | |
| sRCL | Dispensable | Your WP 43S features various <i>data types</i> . |
| TRANSP | [M]^T | |
| TSOFF | GAP 0 | |
| TSON | GAP 3 | |
| $t_u(x)$ | $t_e(x)$ | |
| VIEW α , VW α + | Dispensable | Simply use VIEW instead; <i>alpha strings</i> are just another <i>data type</i> . You can combine text and numeric data easily using + as shown in Sect. 2 of the OM. |
| Weibl $_u$ | Weibl$_e$ | |
| XEQ α | Dispensable | Use XEQ with an appropriate parameter instead. |
| XTAL? | Dispensable | A quartz crystal is installed by default. |
| YDOFF, YDON | Dispensable | Your WP 43S displays y whenever possible and wanted. |
| α DATE, α DAY | Dispensable | You can combine text and numeric data easily using + as shown in Section 2 of the OM. |
| α GTO | Dispensable | Use GTO with an appropriate parameter instead. |
| α IP, α MONTH | Dispensable | You can combine text and numeric data easily using + as shown in Section 2 of the OM. |
| α RCL, α RC# | Dispensable | Your WP 43S features various <i>data types</i> and 'knows' which type is in the <i>register</i> specified. Appending <i>alpha strings</i> is done by + . |
| α STO | Dispensable | Simply press STO instead (any <i>register</i> can take an <i>alpha string</i>). |

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

New Commands on your WP 43S

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

| Command | WP 43S | WP 31S | WP 34S |
|---|----------|--------|----------|
| 2 ^x AGM | ● | — | new |
| ALL | ● | ● | extended |
| AND ASR NOT OR XOR | ● | — | extended |
| BACK CASE SKIP | ● | — | new |
| BATT? | ● | ● | new |
| BC? FB | ● | — | new |
| BestF | extended | ● | ● |
| Binom Binom _p (of Binomial distribution) | ● | ● | new |
| B _n B _n * CEIL FLOOR | ● | — | new |
| Cauch Cauch _p Cauch _e Cauch ⁻¹ | ● | ● | new |
| CauchF GaussF HypF ParabF RootF | new | — | — |
| CLCVAR | new | — | — |
| CLFall CLPall CONJ CONVG? COV | ● | — | new |
| CX→RE RE→CX | new | — | — |
| DATE TIME | ● | — | (●) |
| DATE→ DAY MONTH YEAR →DATE | ● | — | new |
| DBL? | modified | — | new |
| DEC DSL INC ISE | ● | — | new |
| DECOMP | ● | ● | new |
| DEG→ D.MS→ GRAD→ RAD→ | ● | — | new |
| DROP | ● | — | new |
| DROPy DSTACK | new | — | — |
| D→J J→D | ● | — | new |
| EIGVAL EIGVEC | new | — | — |
| ENTRY? | ● | — | new |
| EQ.DEL EQ.EDI EQ.NEW | new | — | — |
| erf erfc ERR MSG | ● | — | new |
| EVEN? ODD? | ● | — | new |

| Command | WP 43S | WP 31S | WP 34S |
|--|----------|--------|--------|
| Expon Expon _p Expon _e Expon ⁻¹ | ● | ● | new |
| EXPT MANT | ● | — | new |
| FBR | new | — | — |
| FC?F FC?S FF FS?F FS?S | ● | — | new |
| FIB | ● | — | new |
| FILL | ● | ● | new |
| FLASH? FP? | ● | — | new |
| F _p (x) F(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 Geom _p Geom _e Geom ⁻¹ | ● | — | new |
| H _n H _{np} L _m L _{mx} P _n T _n U _n | ● | — | new |
| Hyper Hyper _p Hyper _e Hyper ⁻¹ | new | — | — |
| IDIV | ● | — | new |
| IDIVR IM RE | new | — | — |
| INT? I _{xyz} IΓ _p IΓ _q | ● | — | new |
| J _y (x) | new | — | — |
| J/G | extended | ● | new |
| KEY? KTyp? LBL? LEAP? | ● | — | new |
| LgNrm LgNrm _p LgNrm _e LgNrm ⁻¹ | ● | — | new |
| LNβ LNF LOADP LOADR LOADSS LOADΣ LocR LocR? LOG ₂ LOG _{xy} | ● | — | new |
| LOAD SAVE | ● | ● | new |
| Logis Logis _p Logis _e Logis ⁻¹ | ● | ● | new |
| max min MIRROR | ● | — | new |

| Command | WP 43S | WP 31S | WP 34S |
|---|----------|--------|----------|
| MOD | ● | ● | new |
| MUL π MUL π → | new | — | — |
| M.LU M.SQR? NAND NaN? NEIGHB NOR | ● | — | new |
| NBin NBin _p NBin _e NBin ⁻¹ | new | — | — |
| NEXTP PRIME? | ● | ● | new |
| Norml Norml _p Norml _e Norml ⁻¹ | ● | ● | new |
| nΣ (callable by name) | ● | ● | new |
| OrthoF PLOT POINT | new | — | — |
| PAUSE | ● | — | extended |
| Poiss Poiss _p Poiss _e Poiss ⁻¹ | ● | ● | new |
| PopLR PRCL PSTO PUTK | ● | — | new |
| RBR | ● | ● | new |
| RCLCFG STOCFG | extended | — | new |
| RCLS STOS | ● | — | new |
| RCL↑ RCL↓ STO↑ STO↓ | ● | — | new |
| RDP RECV SEND | ● | — | new |
| Re \Im m | 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 |
| SL SR | ● | — | extended |
| SLVQ SMODE? SPEC? | ● | — | new |

| Command | WP 43S | WP 31S | WP 34S |
|--|----------|--------|----------|
| $s_m \ s_{mw} \ s_w$ | ● | ● | new |
| SSIZE? | ● | ● | new |
| STATUS | extended | — | extended |
| s_{xy} | ● | — | new |
| TDISP | new | — | — |
| TICKS | ● | — | new |
| TIMER | ● | — | (●) |
| TOP? ULP? | ● | — | new |
| $t_p(x) \ t(x)$ (of <i>t distribution</i>) | ● | ● | new |
| $t_x \ y_x \ z_x \ \bar{x}$ | ● | — | new |
| undo (UNDO) | ● | new | — |
| V_x | new | — | — |
| VERS? WDAY WHO? | ● | ● | new |
| Weibl Weibl _p Weibl _e Weibl ⁻¹ | ● | ● | new |
| $W_m \ W_p \ W^{-1}$ WSIZE? \bar{x}_G XNOR | ● | — | new |
| x>DATE | new | — | — |
| $x < ? \ x \leq ? \ x = ? \ x \neq ? \ x \geq ? \ x > ?$ | ● | — | extended |
| $x = +0? \ x = -0? \ x \approx ?$ | ● | — | new |
| Y.MD | ● | ● | new |
| αLENG? | extended | — | ● |
| αPOS? | extended | — | — |
| αRL αRR αSL αSR | ● | — | extended |
| $\beta(x,y) \ \Gamma_{xy} \ \gamma_{xy} \ \epsilon \ \epsilon_m \ \epsilon_p \ \zeta(x) \ \Pi \ \Sigma \ \sigma_w$ | ● | — | new |
| $\Sigma^1/x \ \Sigma^1/x^2 \ \Sigma^1/y \ \Sigma^1/y^2 \ \Sigma \ln y/x \ \Sigma x^2/y$ $\Sigma x^3 \ \Sigma x^4 \ \Sigma x/y$ | new | — | — |
| $\Sigma \ln^2 x \ \Sigma \ln^2 y \ \Sigma \ln x \ \Sigma \ln xy \ \Sigma \ln y \ \Sigma x \ \Sigma x^2$ $\Sigma x^2 y \ \Sigma x \ln y \ \Sigma xy \ \Sigma y \ \Sigma y \ln x \ \Sigma y^2$ (callable by names) | ● | ● | new |
| $\chi^2_p(x) \ \chi^2(x)$ (of <i>chi-square distribution</i>) | ● | ● | new |
| $(-1)^x \ x\text{MOD} \ ^x\text{MOD}$ | ● | — | new |

| Command | WP 43S | WP 31S | WP 34S |
|--|----------|--------|--------|
| $\pm\infty?$ | new | — | — |
| $\rightarrow\text{DEG}$ $\rightarrow\text{RAD}$ | ● | ● | new |
| $\rightarrow\text{DP}$ $\rightarrow\text{SP}$ | new | — | — |
| $\rightarrow\text{D.MS}$ $\rightarrow\text{MUL}\pi$ | new | — | — |
| $\rightarrow\text{GRAD}$ | ● | — | new |
| $\rightarrow\text{INT}$ $\rightarrow\text{REAL}$ | new | — | — |
| $\blacksquare\text{ADV}$ $\blacksquare\text{CHAR}$ $\blacksquare\text{r}$ $\blacksquare\text{REGS}$ $\blacksquare\text{TAB}$ $\blacksquare\#$ $\blacksquare\text{MODE}$ | ● | — | (new) |
| $\blacksquare\text{WIDTH}$ | extended | — | (new) |
| | ● | ● | new |

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

Reference Literature

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

| Topic | Recommended literature |
|---|--|
| General calculation examples and applications | All vintage HP calculator manuals can be recommended |
| Root finding and numeric integration | <i>HP-34C OH and Programming Guide</i> <i>HP-15C Owner's Handbook</i> <i>HP-15C Advanced Functions Handbook</i> <i>HP-42S Programming Examples and Techniques</i> |

| Topic | Recommended literature |
|---|---|
| Statistical distributions and their application | <i>HP-21S Owner's Manual</i> |
| Financial calculations | <i>HP-17BII+ User's Guide</i> |
| Manipulating short integers | <i>HP-16C Owner's Handbook</i> |
| Programming | <i>HP-42S Owner's Manual</i> ⁶⁵ <i>HP-42S Programming Examples and Techniques</i> ⁶⁶ |

Depending on your educational background and professional qualification, textbooks about various mathematical, scientific, or engineering topics may be helpful in addition. Ensure you know enough about what you compute (and check footnote 72 on p. 221 below as well as the last paragraph on p. 16 of the OM).

DRAFT

⁶⁵ If you want this manual only, you can download it for free at
<http://www.hp41.net/forum/fileshp41net/manual-hp42s-us.pdf>.

⁶⁶ If you just want this manual, you can download it for free at
<http://www.hp41.net/forum/fileshp41net/hp42s-programming-examples.pdf>.

APPENDIX E: EMULATING A WP 43S ON YOUR COMPUTER

Under Windows, you can ...

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

cd wp43s for changing to the proper directory.
git pull for pulling the changed files from gitlab repository.⁶⁷
make for building a new `wp43s.exe`.⁶⁸
rm backup.bin for starting with the simulator reset to default.
./wp43s for starting the simulator.

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

- b) alternatively do the following:

Open the folder

https://gitlab.com/Over_score/wp43s/tree/master/windows%20binaries.

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

Eventually run `wp43s.exe`.

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

⁶⁷ Sometimes, this step may terminate with an error due to conflicting local changes. The message reads “Please commit or stash your changes before you merge” (or a bad translation of this into your language). Then enter **git reset --hard** and try again thereafter.

⁶⁸ There may be files updated by **git pull** but no new build possible sometimes. Then **make** will throw a corresponding message. – There may be also other obstacles; then **make mrproper** will clean the field for a subsequent **make**.

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

Operate the simulator with the mouse. Digits, **.**, **ENTER↑**, **+**, **-**, **x**, and **/** may also be entered via the numeric keypad directly, **←** via [**Backspace**], **▲** and **▼** via the cursor keys. Further computer keyboard shortcuts to simulator keys are listed overleaf.



| | | | | | |
|------------|-------|--------|------|-------|---------|
| ↑ | ↑ | ↑ | ↑ | ↑ | ↑ |
| F1 | F2 | F3 | F4 | F5 | F6 |
| \sqrt{x} | y^x | TRI | In | e^x | $\ln x$ |
| i | y | t | l | e | q |
| STO | RCL | R↓ | CC | f | g |
| s | r | Page ↑ | C | f | g |
| ENTER↑ | x>y | +/- | E | ← | |
| | tab | c | E | | |
| 7 | 7 | 8 | 9 | XEQ | |
| | | | | X | |
| x | 4 | 5 | 6 | ▲ | |
| - | 1 | 2 | 3 | ▼ | |
| + | 0 | . | R/S | EXIT | |
| | | . or , | ctrl | esc | |

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

... **x** copies the full content of X to the clipboard.

... **z** copies the full contents of all 12 lettered registers to the clipboard.

... **Z** copies the full contents of all 112 global registers to the clipboard.

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

APPENDIX F: FLASHING AND UPDATING YOUR WP 43S

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

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

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

How to Flash Your *WP 43S*

1) Under Windows:

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



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

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

- 6** Activate *USB* Disk

Start the internet browser on your computer and go to <https://gitlab.com/Over score/wp43s/tree/master/DM42%20binary>.

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

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

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

The two files Key_stickers.xcf and WP43S_overlay.xcf are GIMP images to make your life easier. Print them, cut, and apply (see the picture) as long as you converted a DM42 to get your WP 43S.

To leave the WP 43S program, enter **g 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).

To retrieve the original DM42 keyboard layout (cf. p. 157), copy the file original_DM42_key map.bin to the DM42 flash disk, rename it



keymap.bin and RESET the DM42. Look here for more information:
http://www.swissmicros.com/dm42-devel/dmcp_devel_manual/

2) Under OSX (Mac):

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

- a) Install XCode from the App Store.
- b) Clone the source code of the WP 43S project by opening Xcode and clone it using <https://gitlab.com/Over score/wp43s.git>. Cloning the project has some advantages over downloading the code. It makes sure XCode tracks the changes, for example.
- c) Install MacPorts using
<https://guide.macports.org/chunked/installing.macports.html>
- d) Thereafter install the following MacPorts one by one:
 - sudo port install gcc9
 - sudo port install gtk3
 - sudo port install freeType
 - sudo port install pkgconfig
 - sudo port install x11
 - sudo port install dbus
- e) Then run the *makefile* form the root directory of the project (probably **wp43s**)
- f) When the project has successfully compiled, run the program, for example like this: **./wp43s**

In the terminal window the following warning may appear:

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

Solve this by entering:

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

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

If you get this error:

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

use this:

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

After that I get no more warnings or error messages.

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

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

add:

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

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

```
cp wp43s_pre.css ~
```

Let me know if this does not work.

How to Update Your WP 43S

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

Else there is *WP 43S* installed on your calculator: Start your computer. Take your calculator and turn it on. Leave *WP 43S* pressing **g MODE** **▲ g SYSTEM** to return to the *DMCP* system. If you had copied `keymap.bin` of *WP 43S* before last flashing, key assignments will stay as they were when navigating in the *DMCP* system – else the *Free42* assignments will become valid (cf. p. 157).

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

6 Activate *USB* Disk

Start the internet browser on your computer and go to
<https://gitlab.com/Over score/wp43s/tree/master/DM42%20binary>.

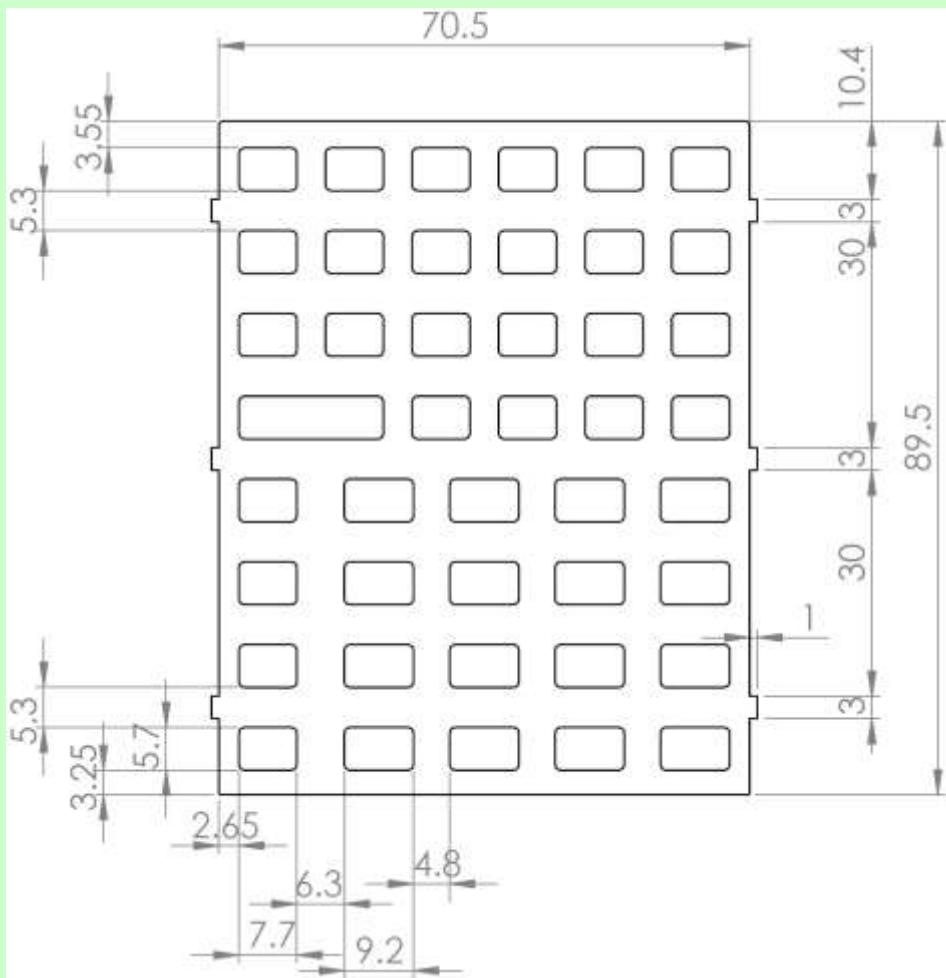
Option: Copy `keymap.bin` from there to the *DM42* flash disk. This will reassign keys to match the *WP 43S* layout also when leaving *WP 43S*.

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

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

Overlays

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



APPENDIX G: TROUBLESHOOTING GUIDE

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

1. Open your calculator by unfastening the two bolts at the top of its backside. You will probably find a printed circuit board (*PCB*) whose top looks like this →
(cf. p. 160 for a *PCB* of an early *DM42*)

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

The other one is called **PGM**.



2. Now, do the following:
 - a. Press and hold the PGM button.
 - b. Press and release the RESET button.
 - c. Release the PGM button.

This sequence shall reset your *DM42* and put it in bootloader mode.⁶⁹

3. Then you can reflash your calculator using `dm_tool.exe` as described in https://www.swissmicros.com/dm42/doc/dm42_user_manual/.

⁶⁹ If this method should not work, however, this may point to a real hardware problem. We recommend contacting *SwissMicros* then.

APPENDIX H: ADVANCED MATHEMATICAL FUNCTIONS AND TASKS

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

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

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

Number Generating Functions

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

| Name | Remarks (see pp. 12ff for general information) |
|---------|--|
| B_n | B_n returns the Bernoulli number for an integer $n > 0$ given in X : $B_n = (-1)^{n+1} \cdot n \cdot \zeta(1 - n)$ B_n^* works with the old definition instead: |
| B_n^* | See p. 245 for $\zeta(x)$. $B_n^* = 2 \cdot \frac{(2n)!}{(2\pi)^{2n}} \cdot \zeta(2n)$ |

| Name | Remarks (see pp. 12ff for general information) |
|---------------|--|
| COMB, PERM | <p>For $y \geq x \geq 0$ and $x, y \in \mathbb{N}$, $C_{y,x} = \binom{y}{x} = \frac{y!}{x!(y-x)!}$ is the number of <i>combinations</i> and $P_{y,x} = \frac{y!}{(y-x)!} = x! \cdot C_{y,x}$ the number of <i>permutations</i> of x and y as explained in the IOP (see pp. 26 and 59, respectively).</p> <p>Note $C_{y,0} = 1$, $C_{y,1} = y$, and $C_{y,2} = \frac{1}{2}y(y-1)$.</p> <p>$C_{y,x}$ applies to the <i>binomial distribution</i> (see p. 212): In a <i>Galton box</i>⁷⁰ (a.k.a. <i>bean machine</i>) featuring y rows of pins and fed with 2^y balls, $C_{y,x}$ is the number of balls expected in column x of that box (start column counting with zero).</p> <p>$P_{y,x} = \frac{\Gamma(y+1)}{\Gamma(y-x+1)}$ and $C_{y,x} = \frac{\Gamma(y+1)}{\Gamma(x+1) \cdot \Gamma(y-x+1)}$ work also for non-integer numbers and in complex domain, too.</p> |
| FIB | <p>For integers, FIB returns the Fibonacci number f_n with $n = x$. These numbers are defined as $f_0 = 0$, $f_1 = 1$, and $f_n = f_{n-1} + f_{n-2}$ for $n \geq 2$. With UNSIGNED, f_{93} is the maximum before an overflow occurs.</p> <p>Else FIB returns the extended Fibonacci number</p> $F_x = \frac{1}{\sqrt{5}} [\Phi^x - \Phi^{-x} \cos(x\pi)]$ <p>for an arbitrary real or complex number x, with $\Phi = \frac{1+\sqrt{5}}{2}$ denoting the golden ratio.</p> |

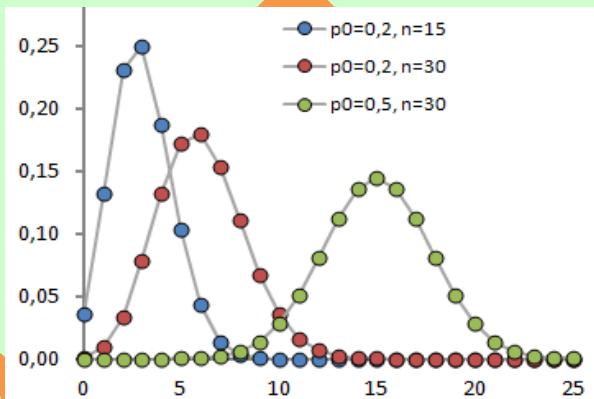
⁷⁰ Translator's note: This is called «Planche de Galton» in French, “Galtonbrett” in German, and “macchina di Galton” in Italian. Note the subtle differences in naming. Galton invented his box in 1889.

Statistical Distributions

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

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

Binom: *Binomial distribution* with the *number of successes g* in **X**, the *gross probability of a success p_o* in **I** and the *sample size n* in **J**.



BINOM_P returns

$$p_B(g; n; p_0) = \binom{n}{g} \cdot p_0^g \cdot (1 - p_0)^{n-g} = C_{n,g} \cdot p_0^g \cdot (1 - p_0)^{n-g} \quad (\text{see COMB on p. 211 for the explanation of the notation}).$$

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

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

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

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

returning 0.633 – so the odds are almost two out of three that you will not detect any defect in your sample! ⁷¹

Read here for more information:

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

Geom: Geometric distribution:

GEOM_P returns

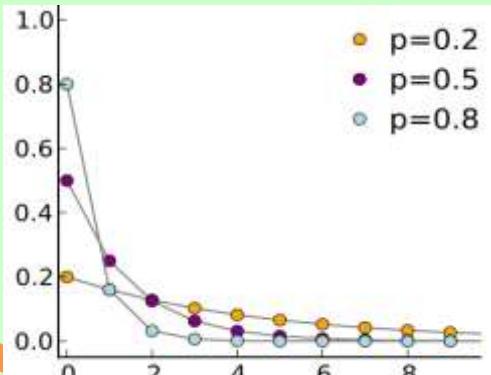
$$p_{Ge}(n) = p_0(1 - p_0)^n$$

GEOM returns

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

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

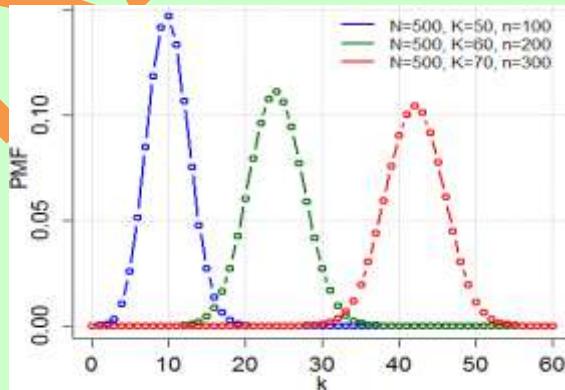
The probability p_0 for a success in each such experiment must be specified in I.



Start reading here for more:

http://en.wikipedia.org/wiki/Geometric_distribution.

~~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 $n_0=N$).~~



⁷¹ The exact result for said boundary conditions is 0.626, calculated using the hypergeometric distribution. These results show nicely that two significant digits are a typical accuracy of theoretical statistical statements – frequently the (often simplified) statistical model used matches reality no better than that.

HYPER_P 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. 211 for the explanation of the notation).

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

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

NBIN_P returns $p_{NB}(f; n; p_0) = \binom{n-1}{f-1} \cdot p_0^f \cdot (1-p_0)^{n-f}$
 $= C_{n-1, f-1} \cdot p_0^f \cdot (1-p_0)^{n-f}$ (see COMB on p. 211 and cf. BINOM).

Start reading here for more:

http://en.wikipedia.org/wiki/Negative_binomial_distribution.

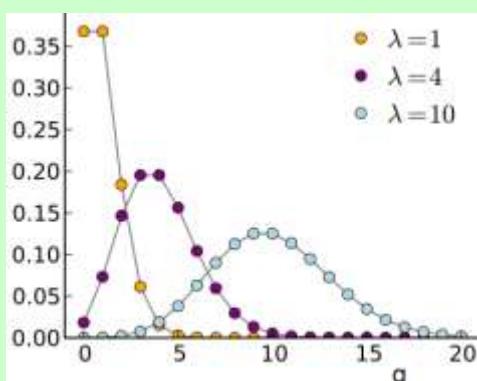
Poiss: Poisson distribution with the number of successes g in \mathbf{X} and the Poisson parameter λ in \mathbf{J} .

POISS_P 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



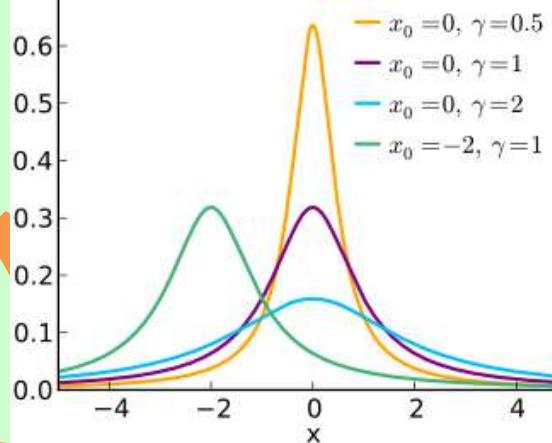
simplest model for industrial sampling tests – use $\lambda = np_0$ with the gross error probability p_0 and the sample size n (cf. BINOM). For the example introduced with BINOM above, POISS returns 0.638.

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 γ in J.



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

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

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

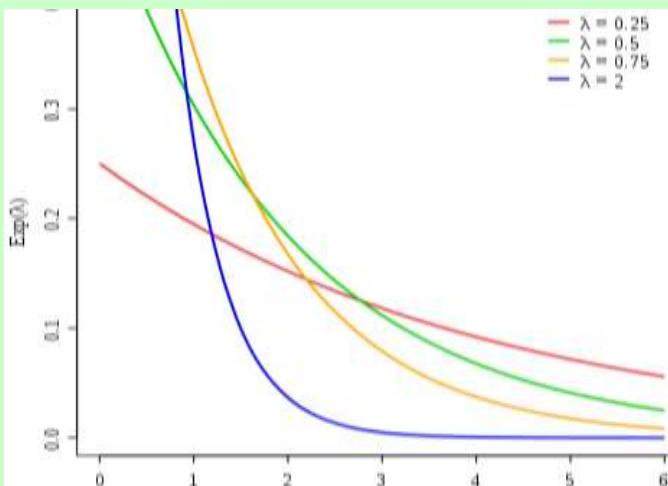
This distribution is quite popular in physics. It is a special case of Student's t distribution. Start reading here for more:

http://en.wikipedia.org/wiki/Cauchy_distribution.

Expon: Exponential distribution with the rate λ in **I**.

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

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



Read here for more information:

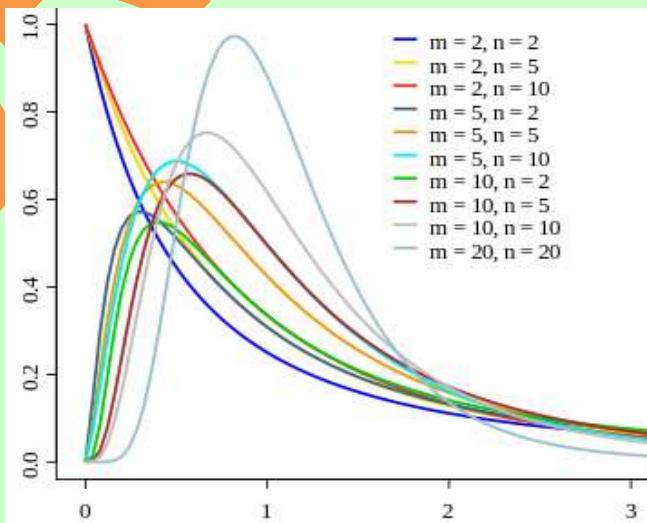
<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3667.htm>

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

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

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

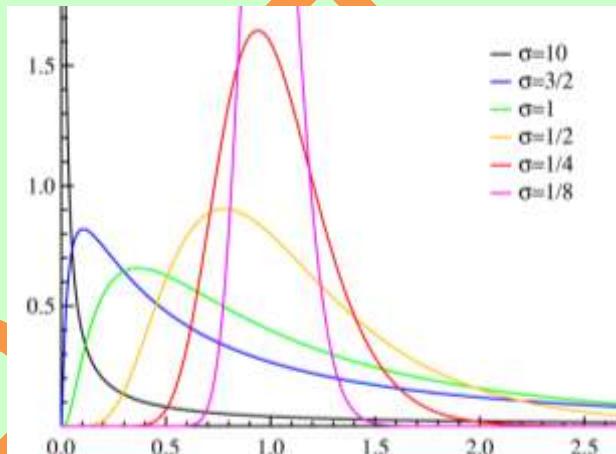
Read here for more information:



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

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

LGNRM returns $F_{Ln}(x) = \Phi\left(\frac{\ln(x)-\mu}{\sigma}\right)$ with $\Phi(z)$ denoting the *standardized normal CDF* as presented on p. 220.



Read here for more information:

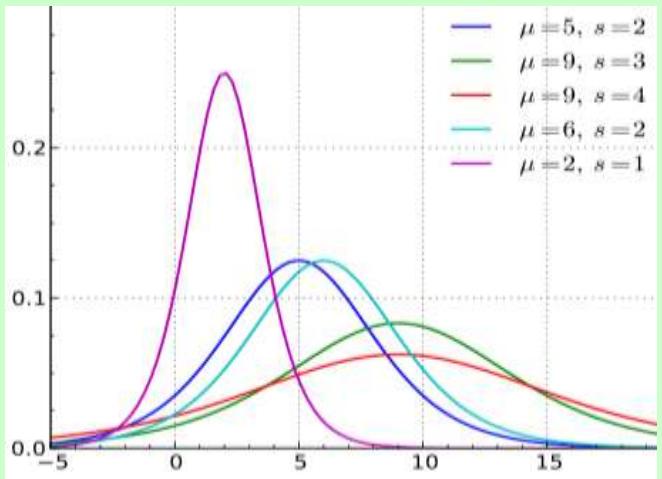
Logis: Logistic distribution with an arbitrary mean μ given in **I** and a scale parameter s in **J**.

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

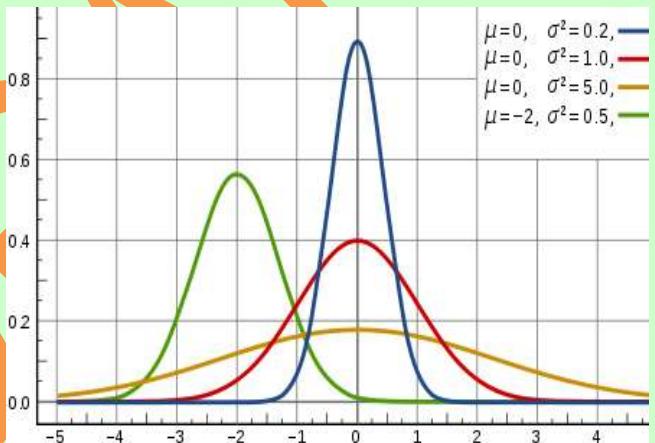
LOGIS_P returns $f_{Lg}(x) = \frac{e^{-\xi}}{(1+e^{-\xi})^2 s}$ (plotted overleaf) and

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

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



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



NORML_P returns

$$f_N(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} = \varphi\left(\frac{x-\mu}{\sigma}\right) \text{ and}$$

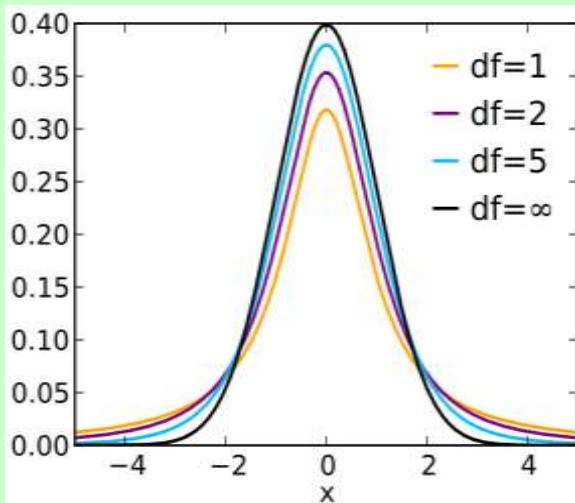
NORML returns $F_N(x) = \Phi\left(\frac{x-\mu}{\sigma}\right)$ with $\Phi(z)$ denoting the standard normal (or Gaussian) CDF as presented on p. 220.

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.

I. It is used for hypothesis testing and calculating confidence intervals e.g. for means. The picture shows its *PDF* plotted for different *degrees of freedom*. For $df \rightarrow \infty$, the shoulders of $t(x)$ shrink and it approaches the *PDF* of the *standard normal distribution* (compare the red *Gaussian* curve at NORML on p. 218).



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

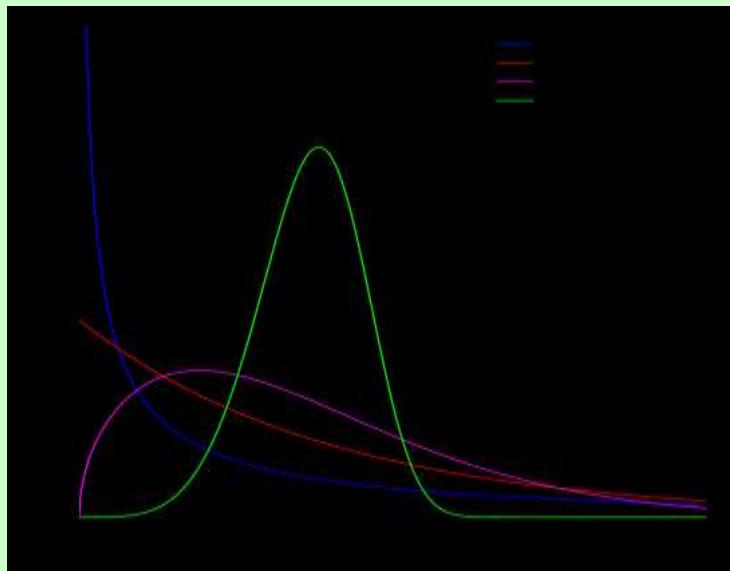
WEIBL returns $F_W(t) = 1 - e^{-(t/T)^b}$

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

Read here for more information:

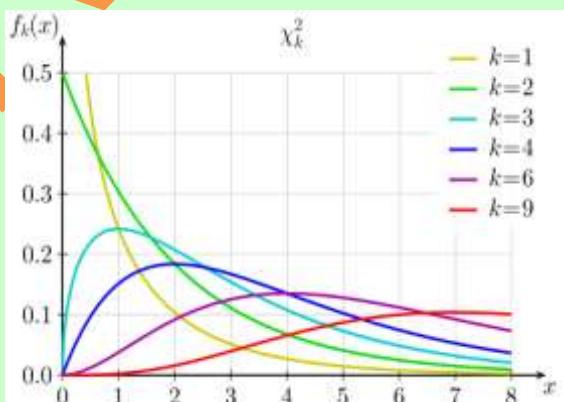
<http://www.itl.nist.gov/div898/handbook/eda/section3/eda3668.htm>.

You may even find some more application fields mentioned in https://en.wikipedia.org/wiki/Weibull_distribution#Applications.



$\varphi(x)$ and $\Phi(x)$: $\varphi(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$ is the *standardized normal PDF* (i.e. the famous *Gaussian bell curve* as drawn in red under NORML on p. 218), while $\Phi(x) = \int_{-\infty}^x \varphi(\tau) d\tau$ is the corresponding *CDF* (cf. the *error function* on p. 242). Take NORML instead.

$\chi^2(x)$: *Chi-square distribution with its degrees of freedom given in I.* It is used for calculating confidence intervals for standard deviations, variances, process and machine capabilities, and the like. The diagram shows PDF's for different degrees of freedom.



Read here for more information:

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

More Statistical Formulas, also for Fitting

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

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

Be assured not everything is *Gaussian* in real world! ⁷² Process features can be detected (and should be checked well in advance of calculating e.g. means) using suitable tests – turn to applicable statistical reference literature.

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

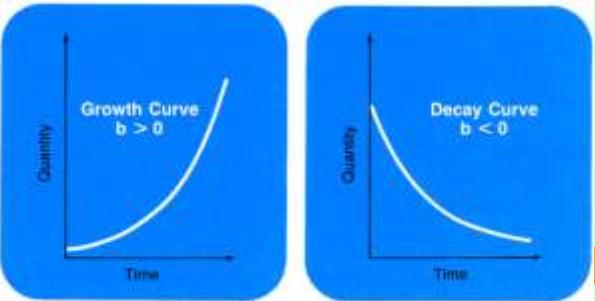
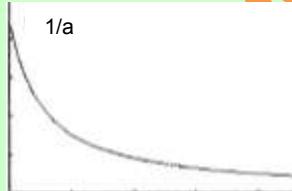
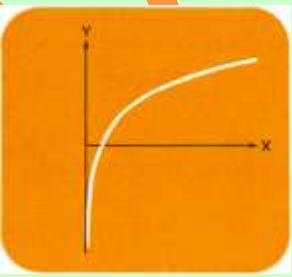
⁷² Generally, the statistical model shall be chosen that matches observations best – within their statistical errors. In real life cases, however, dramatic deviations from the model distribution are frequently found – then you cannot expect the calculated consequences matching reality any better.

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

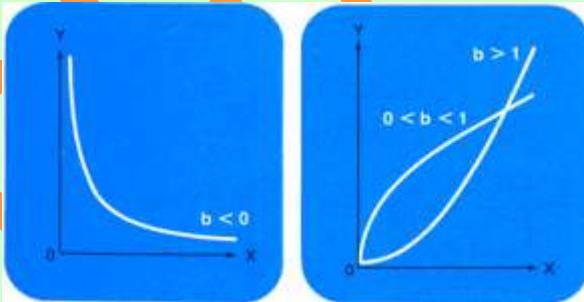
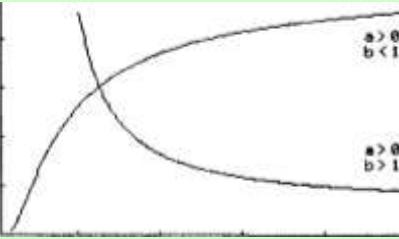
By the way: Since the *PDF* of the *Gaussian* distribution will never reach zero, this statistical model tells you to expect individual items far, far away from the mean value when your sample becomes large enough. This, however, does not match reality. So we must conclude nothing at all is really *Gaussian*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

| Name | Remarks (see pp. 12ff for general information) |
|--------|--|
| CauchF | Selects a Cauchy (a.k.a. Lorentz, Breit-Wigner) peak fit model $R(x) = \frac{1}{[a_0(x + a_1)^2 + a_2]}$ for least squares regression. ⁷³ See p. 215 for the shapes of such peaks. |
| CORR | <p>For any set of data points (x_i, y_i), the <i>coefficient of correlation</i> is $r = \frac{s_{xy}}{s_x \cdot s_y}$. See s_{XY} and s below.</p> <p>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.</p> <p>A two-parameter regression (like the majority of the fit models provided on your WP 43S) is said being (statistically) <i>significant</i> if</p> $\sqrt{\frac{r^2}{1 - r^2}(n - 2)} > t_{n-2}^{-1}(0.99)$ <p>with the right side being the inverse of the <i>t distribution</i> for the <i>degrees of freedom</i> $n - 2$ and <i>confidence level</i> 99% (see p. 219).</p> |
| COV | <p>For any set of data points (x_i, y_i), the <i>population covariance</i> is</p> $COV_{xy} = \frac{1}{n^2} \left(n \sum x_i y_i - \sum x_i \sum y_i \right)$ <p>Compare s_{XY} below.</p> |

⁷³ Note that *least squares regression* is best for data point errors in direction y being significantly greater than errors in direction x . See pp. 219ff for the formulas and more.

| Name | Remarks (see pp. 12ff for general information) |
|--------|---|
| ExpF | Selects the exponential curve fit model $R(x) = a_0 e^{a_1 x}$ for least squares regression. ⁷³ Generally, this will be a good choice if the measured data follow the shape of one of the two curves pictured here (think of human population growth or nuclear decay, for instance). ⁷⁴  <p>The first graph shows a curve labeled "Growth Curve" with a positive slope, labeled $b > 0$. The second graph shows a curve labeled "Decay Curve" with a negative slope, labeled $b < 0$. Both graphs have "Quantity" on the vertical axis and "Time" on the horizontal axis.</p> |
| GaussF | Selects a Gauss peak fit model $R(x) = a_0 e^{\frac{(x-a_1)^2}{a_2}}$ for least squares regression. ⁷³ See p. 218 for the shapes of such peaks. |
| HypF |  <p>1/a</p> Selects the hyperbolic fit model $R(x) = \frac{1}{(a_0 + a_1 x)}$ for least squares regression. ⁷³ |
| LinF | Selects the linear fit model $R(x) = a_0 + a_1 x$ for least squares regression. ⁷³ Generally, this will be a good choice if the measured data follow a straight line, raising or falling (but compare ORTHOF). |
| LogF |  Selects the logarithmic curve fit model $R(x) = a_0 + a_1 \ln(x)$ for least squares regression. ⁷³ Generally, this will be a good choice if the measured data follow a curve looking like drawn at left. |

⁷⁴ Color plots on this page and the next are taken from the HP-27 manual; $b = a_1$ on your WP 43S.

| Name | Remarks (see pp. 12ff for general information) |
|--------|--|
| L.R. | <p>Uses the fit model selected and computes the two or three parameters of the regression for the data accumulated.</p> <p>For all curve fit models provided on your WP 43S, a regression parameter is (statistically) <i>significant</i> if</p> $\left \frac{a_i}{s(a_i)} \right > t_{n-2}^{-1}(0.995),$ <p>with the right side being the inverse of the <i>t distribution</i> for the <i>degrees of freedom</i> $n - 2$ and 99% <i>confidence</i> (cf. p. 219).</p> |
| OrthoF | Selects the linear fit model $R(x) = a_0 + a_1 x$ like LINF, but assuming data point errors in x are equal to those in y (precisely: their variances are equal). The sum of squared distances of the data points to the fit line will be minimized. This model is called <i>orthogonal regression</i> . See pp. 227ff and the OM for more. |
| ParabF | Selects a parabolic fit model $R(x) = a_0 + a_1 x + a_2 x^2$ for least squares regression. ⁷³ |
| PowerF | <p>Selects the power curve fit model $R(x) = a_0 x^{a_1}$ for least squares regression.⁷³</p>  <p>Generally, this will be a good choice if measured data follow the shape of one of the curves pictured here (look for <i>Tower of Pisa</i> in the OM).⁷⁴</p> |
| RootF |  <p>Selects the root curve fit model $R(x) = a * b^{1/x} = a_0 * a_1^{1/x}$ for a least squares regression.⁷³</p> |

| Name | Remarks (see pp. 12ff for general information) |
|-----------------|--|
| s_{XY} | For any set of data points (x_i, y_i) , the <i>sample covariance</i> is $s_{xy} = \frac{1}{n(n-1)} \left(n \sum x_i y_i - \sum x_i \sum y_i \right)$ <p style="text-align: right;">Compare COV above.</p> |
| s, s_m | 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 \bar{x}</i>) is $s_{mx} = s_x / \sqrt{n}$</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 $\Sigma +$) is $s_w = \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i (\sum y_i - 1)}}$ <p>And the corresponding <i>standard error</i> (the <i>SD</i> of the <i>mean \bar{x}_w</i>) is $s_{mw} = \frac{1}{\sum y_i} \sqrt{\frac{\sum y_i \sum y_i x_i^2 - (\sum y_i x_i)^2}{\sum y_i - 1}}$</p> |
| \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 $\bar{x}_H = \frac{n}{\sum \frac{1}{x_i}} \cdot$ |
| \bar{x}_{RMS} | The <i>quadratic mean</i> is calculated as $\bar{x}_{RMS} = \sqrt{\frac{1}{n} \sum x_i^2}$. |

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

About the Curve Fitting Models Provided

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

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

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

1. It accumulates the 22 sums listed on pp. 91f and increments n .
2. The evaluation depends on the fit model you select (cf. pp. 223ff):
 - a. If you choose LINF then the least squares regression line parameters a_0 and a_1 will be computed following the formulas:

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

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

Their *standard errors* can be calculated using the formulas

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

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

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

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

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

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

The standard errors of $a_{0,tEXP}$ and $a_{1,tEXP}$ can be calculated using the formulas for LINF on p. 227 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. 227 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. 227 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 *DOI*). The model delivering the greatest absolute r value will be selected.
- k. If you choose **ORTHOF** then the least squares regression line parameters a_0 and a_1 will be computed following the formulas:

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

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

About Error Propagation

Experimental data are always attended with errors (cf. footnote 38), caused by e.g. the uncertainty of the measuring method, the instrument used, and environmental variations. Even under controlled environmental and measuring conditions, random errors remain. These errors must be taken into account for a proper estimation of the uncertainty of your results computed using those experimental data. For about 200 years, *Gauß' least squares method* can be employed for this task.

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

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

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

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

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

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

Being through with all n parameters, you will end with

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

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

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

1. Program the function $R = f(x_1, x_2, \dots, x_n)$ in a way you can vary its parameters easily.

2. Let your WP 43S compute $= f(x_1, x_2, \dots, x_n)$.
3. Let it compute $R_1 = f(x_1 + \Delta x_1, x_2, \dots, x_n)$ and $\Delta R_1 = R_1 - R$.
4. Let it compute $R_2 = f(x_1, x_2 + \Delta x_2, \dots, x_n)$ and $\Delta R_2 = R_2 - R$.
5. Repeat the last step for each remaining parameter.

Being through with all n parameters, you will end with

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

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 one-dimensional problems of the kind

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

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

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

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

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

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

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

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

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

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

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

Proceeding from time zero in small steps Δt again, we get

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

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

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

Let us drop the restriction for b now. Replacing a in the previous set of equations by the right side of the differential equation on p. 234, we will get the following new set:

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

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

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

Proceeding from time zero in small steps Δt again, we get

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

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

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

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

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

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

~~$$\left(\frac{df}{dt}\right)_{1/2} = \left(\frac{df}{dt}\right)_0 + h(t_0, f_0, \left[\frac{df}{dt}\right]_0) \frac{\Delta t}{2}$$~~

~~$$\left(\frac{df}{dt}\right)_{i+1/2} = \left(\frac{df}{dt}\right)_{i-1/2} + h(t_{i-1/2}, f_{i-1/2}, \left[\frac{df}{dt}\right]_{i-1/2}) \Delta t$$~~

~~$$f_{i+1} = f_i + \left[\frac{df}{dt}\right]_{i-1/2} \Delta t$$~~

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

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

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

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

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

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

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

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

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

DRAFT

Orthogonal Polynomials

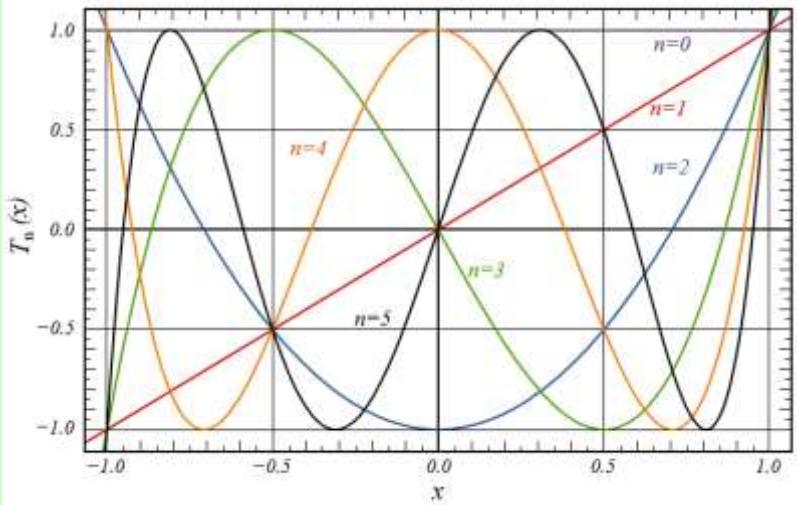
The following polynomials are all collected in [X.FN'ORTHOG](#).

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

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

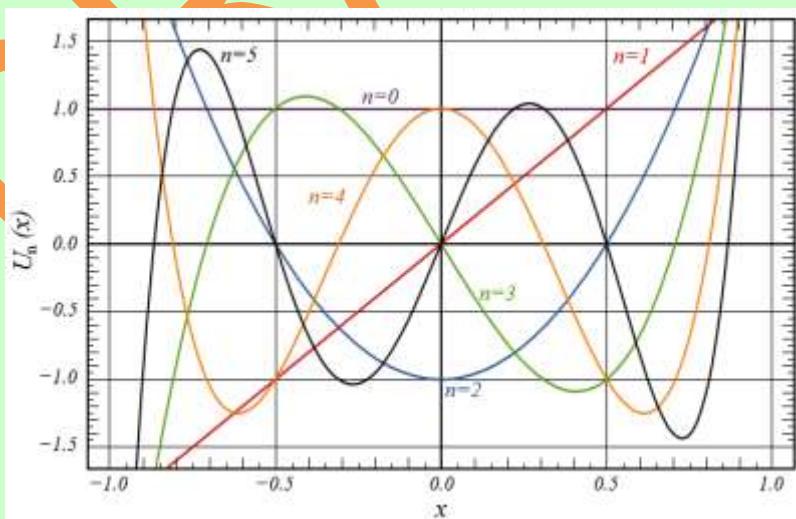
| Name | Remarks (see pp. 12ff for general information) |
|-------|---|
| P_n | <p>Legendre polynomials: $P_n(x) = \frac{1}{2^n n!} \cdot \frac{d^n}{dx^n} [(x^2 - 1)^n]$ with n in Y, solving the differential equation</p> $\frac{d}{dx} \left[(1 - x^2) \cdot \frac{d}{dx} f(x) \right] + n(n+1)f(x) = 0.$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

 U_n

Chebyshev polynomials of second kind $U_n(x)$ with n in Y, solving the differential equation

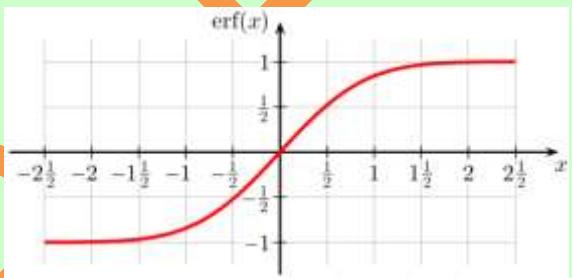
$$f''(x) - \frac{3x}{1-x^2}f'(x) + \frac{n(n+2)}{1-x^2}f(x) = 0$$

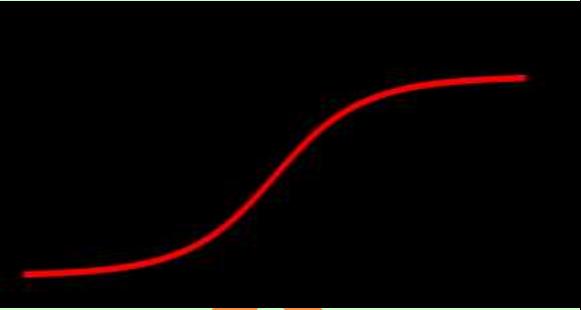
The plot below shows $U_0(x) \dots U_5(x)$:



Even More Mathematical Functions

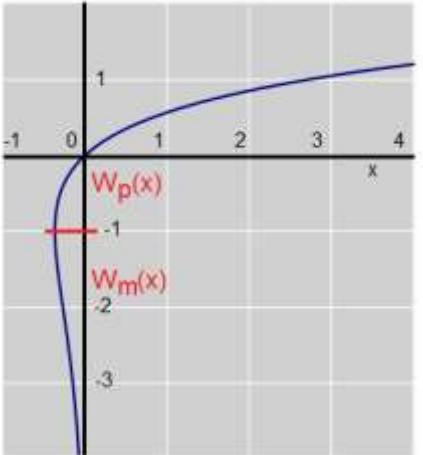
All the following functions are found in X.FN. Some of them are for pure mathematics only but were useful at some stages of the *WP 34S* or *WP 43S* projects, so we made them accessible for the public.

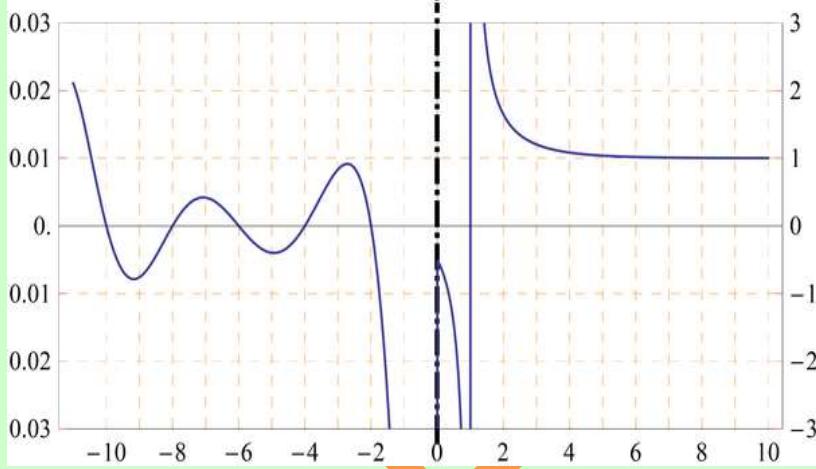
| Name | Remarks (see pp. 12ff for general information) |
|------|---|
| AGM | Returns the <i>arithmetic-geometric mean</i> . Find more about it here: http://mathworld.wolfram.com/Arithmetic-GeometricMean.html . |
| erf | Returns the <i>error function</i> $\text{erf}(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$.  <p>Note that $\text{erf}\left(\frac{x}{\sqrt{2}}\right) = 2 \cdot \Phi(x) - 1$ with $\Phi(x)$ representing the standard normal CDF as described on p. 220. Beyond statistics, the error function 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 standard normal distribution. |

| Name | Remarks (see pp. 12ff for general information) |
|-------------|--|
| g_d | <p>Returns the <i>Gudermannian function</i></p> $g_d(x) = \int_0^x \frac{d\xi}{\cosh \xi}$ <p>linking hyperbolic and trigonometric functions. See the plot for its real values. The <i>inverse Gudermannian function</i> is</p> $g_d^{-1}(x) = \int_0^x \frac{d\xi}{\cos \xi}.$ <p>Start reading here for more: http://en.wikipedia.org/wiki/Gudermannian_function.</p>  |
| I_{xyz} | <p>Returns the <i>regularized (incomplete) Beta function</i> $\frac{\beta_x(x, y, z)}{B(y, z)}$ with</p> $\beta_x(x, y, z) = \int_0^x t^{y-1} (1-t)^{z-1} dt$ <p>being the <i>incomplete Beta function</i> and $B(y, z)$ being <i>Euler's Beta function</i> (see p. 88 and https://en.wikipedia.org/wiki/Beta_function).</p> |
| $I\Gamma_p$ | <p>Returns the <i>regularized Gamma function</i> $P(x, y) = \frac{\gamma(x, y)}{\Gamma(x)}$</p> <p>. See γ_{XY} below for $\gamma(x, y)$ and p. 88 for $\Gamma(x)$.</p> |
| $I\Gamma_q$ | <p>Returns the <i>regularized Gamma function</i> $Q(x, y) = \frac{\Gamma_u(x, y)}{\Gamma(x)}$</p> <p>See Γ_{XY} below for $\Gamma_u(x, y)$ and p. 88 for $\Gamma(x)$.</p> |

See here for more:
https://en.wikipedia.org/wiki/Incomplete_gamma_function

| Name | Remarks (see pp. 12ff for general information) |
|----------|--|
| $J_y(x)$ | <p>Generally, the <i>Bessel functions</i> solve the differential equation $x^2 f''(x) + xf'(x) + (x^2 - \nu^2)f(x) = 0$ with $\nu \in \mathbb{C}$.</p> <p>$J_y(x)$ returns the <i>Bessel function of first kind</i> and order $y = \nu$. For arbitrary ν, 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 ν, 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: http://en.wikipedia.org/wiki/Bessel_function.</p> |

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

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

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

Beyond what is printed in this appendix, you will find lots of information about the special functions implemented in your *WP 43S* in the internet in addition. Generally speaking, *Wikipedia* is a good starter – we recommend checking the articles in different languages since they may well contain different material and use different approaches. For applied statistics, the *NIST Sematech* online handbook (quoted on pp. 212ff) is a competent source. And *Mathworld* (quoted on pp. 242ff) 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 FACT₂ will allocate a local register (**R.00₂**) and store **3** therein. After decrementing x , FACT will call itself again.

Then FACT₃ will allocate a local register (**R.00₃**) and store **2** therein. After decrementing x , FACT will call itself once more.

Then FACT₄ will return to FACT₃ with $x = 1$. This x will be multiplied by **r.00₃** there, returning to FACT₂ with $x = 2$. This x will be multiplied by **r.00₂** there, returning to FACT with $x = 6$, where it will be multiplied by **r.00** and will finally become 24.

Building WP 43S Almost from Scratch

How to build the simulator on Windows:

1. Navigate to <https://www.msys2.org/>. Download and run msys2-x86_64-yyyymmdd.exe
2. Click **Next**
3. Enter the installation folder C:\msys2_64 and click **Next**
4. Tick **Run MSYS2 now** and click **Finish**

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

5. **pacman -Syu** . Confirm each question with ENTER and wait until finished.
6. Close the black window by Alt-F4.
7. Reopen *MSYS2 MinGW 64-bits* (every time you need to open MSYS2, open the 64-bits version).
8. **pacman -Syu** . Confirm each question with ENTER.
9. **pacman -S mingw-w64-x86_64-gcc git base-devel mingw-w64-x86_64-gtk3** . Confirm each question with ENTER.
10. **cd ~** to navigate to your home directory.
11. **git clone https://gitlab.com/Over_score/wp43s.git** to get a local copy of the gitlab source repository on your PC.
12. **cd ~/wp43s** to navigate to the *WP 43S* program sources.
13. **git pull** to get the latest version from gitlab.com.
14. **make mrproper** to clean the build environment (this is not required but recommended).
15. **make** to build the *WP 43S* simulator.
16. **./wp43s** to run the simulator.
17. Return to step 13. (or to *App. F*) to get a new version of the sources.

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

1. Navigate to <http://gnutoolchains.com/arm-eabi/>, download and run **arm-eabi-gcc9.2.1.exe** or a more recent version.
2. Installation directory **C:\msys2_64\arm-eabi** shall be the same base directory as in step 3 on previous page.
3. Select **Current user**
4. Tick **Hardlink duplicate files**
5. Untick **Add binary directory to %PATH%**
6. Tick **I accept the terms of the license agreement**
7. Click **Install**
8. Click **OK** on the Installation succeeded dialog.
9. Start *MSYS2 64 bits* if not yet started.
10. **cd ~/wp43s/DMCP_build** to navigate to the *DMCP* build directory.
11. **./build_GMP_static_ARM_library** this is a long process: about 12 *minutes* on my PC.
12. **cd ~/wp43s/DMCP_build** to navigate to the *DMCP* build directory if not yet there.
13. **git pull** to get the latest version from gitlab.com
14. **./build_WP43S.pgm_for_DM42_hardware** to build *WP43S.pgm* for the *DM42*. Maybe the first time the process ends with an error – then run the same command a second time.
15. Copy the file **~/wp43s/DMCP_build/build/WP43S.pgm** via *USB* to your *DM42* and flash it (cf. *App. F*).
16. Loop to step 12.

APPENDIX J: RELEASE NOTES

| | Date | Release notes |
|-----|-------------------|--|
| 0 | 29.11.12 | Official project start with the first publication of a layout on the forum of the MoHPC (https://www.hpmuseum.org/cgi-sys/cgiwrap/hpmuseum/archv021.cgi?read=234685#234685). There are found, however, far older traces of a '43S' denoting a 'Super HP-42S', though in various more or less fictional cases – pure vapourware™. |
| 0.1 | 2.2.14 23.5.15 | Manual setup based on the one of WP 34S. Passed to <i>Jake Schwartz</i> , <i>Eric Smith</i> , and <i>Richard Ottosen</i> for first information. |
| 0.2 | 3.10.15 | Update based on Jake's feedback and further thoughts, distributed to <i>Eric</i> , <i>Jake</i> , <i>Marcus</i> , and <i>Pauli</i> . |
| 0.3 | 21.3.16 | Split the manual in three; moved LBL onto the keyboard, renamed STOM to STOCFG, RCLM to RCLCFG, SERR to s_m , and SERR _w to s_{mw} ; refined the <i>Key Response Table</i> . Passed to <i>Michael Steinmann</i> for information. |
| 0.4 | 28.3.16 | Renamed LOGS to EXP and EEX to E . Added hardware information from 2 nd manufacturer. |
| 0.5 | 29.10.16 | Returned EEX . Changed the keyboard layout. |
| 0.6 | 22.8.17 | Merged the <i>Applications</i> and <i>Owner's Manual</i> . Changed the input order of complex number parts on <i>Pauli</i> 's request. Changed the keyboard layout introducing D.MS, SST, BST, and % while removing ÿ, RAN#, 'FRC, and 'CFIT. Put 'CFIT into 'STAT and 'FRC into 'MODE. Placed OFF below EXIT for easier customizing. Renamed cc to C5, EEX to E , STOPW to TIMER, SHOW to REGS, 'SOLVE to 'ADV, DLINES to DSTACK, 12h to CLK12, and 24h to CLK24. Replaced IND by →. Deleted %MG since covered by Δ%, added EIGVAL and EIGVEC. Swapped CNST and CONST. Defined the echo rows for alphanumeric and command input. Expanded and modified the character sets for better use of display space. Added the QRG. |
| 0.7 | 2.4.18 | Changed keyboard layout. Replaced the labels BST by ≡▲ , SST by ≡▼ , and UNDO by ↶ ; added some <i>alpha input mode</i> reminders on the keyboard. Added AGRAPH, CLLCD, EQ.xxx, HYP, J/G, M.GOTO, ORTHOF, PIXEL, POINT, TDISP, and ≡USER . Moved the background considerations out of <i>ReM App. D</i> . Introduced K as <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 |
|------|---|
| | 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 HP-42S. |
| 0.8 | Changed keyboard layout: introduced <u>TRG</u> containing trigonometric functions, removed <u>HYP</u> into <u>EXP</u> and $\blacksquare\pi$ to g-shifted $\blacksquare\theta$, swapped some shifted labels. Refined the chapters about register arithmetic, <i>Command Parameter Input</i> , <i>Alphanumeric Input</i> , <i>Matrix Calculations</i> , and <i>Orthogonal Polynomials</i> . Introduced CLCVAR and more vintage examples. Rearranged <i>temporary information</i> on the screen. Renamed REGS to RBR and CLx to CLX. Deleted ANGLE. 7.5.18 20.9.18 Corrected errors and inconsistencies. Added one more example. Moved the key response table into an appendix. |
| 0.9 | Removed the <i>angle data type</i> . Added another industrial application and many more examples. Exchanged keyboard pictures due to changed bezel. Expanded App. B. Added SHOW for displaying full precision of DP numbers and FBR for browsing our two fonts. Split a chapter. Expanded some titles. Added the overlay drawing. Modified functionality of <u>EXIT</u> and $\blacksquare\text{1/x}$ to match HP-42S. Added a chapter about curve fitting. Modified functionalities of <u>ENTER1</u> and $\blacksquare\text{G}$. Moved the printer character to $\blacksquare\text{f}\text{ (R/S)}$. Expanded App. K. Renamed DOUBLE to $\rightarrow\text{DP}$. Added $\rightarrow\text{SP}$ and conversions of <i>quarts</i> . Rearranged X.FN. Replaced <u>USR</u> by <u>UM</u> . Changed keyboard moving <u>UM</u> , $\blacksquare\text{fx}$, and <u>TRI</u> . Added XIN and XOUT. Added a chapter in App. E and information about infinite integers. Extended the domain of GCD and LCM. Refined and corrected. 3.1.19 |
| 0.10 | Returned <i>angle data type</i> and αSR . Added IDIVR and VANGLE. Refined FP, IP, IMPFRC, PROFRC, SDIGS?, $\rightarrow\text{DP}$, $\rightarrow\text{HR}$, $\rightarrow\text{INT}$, $\rightarrow\text{REAL}$, $\rightarrow\text{SP}$, explanation of ALL, the summary of integer functions, and handling of long alpha strings. Modified contents of CPX, MATX, and $\alpha\text{.}$. Added a summary of matrix functions. Removed the <u>ON</u> -key combinations. Modified MEM?. Rewrote the angular conversions. Renamed infinite and finite integers to <i>long</i> and <i>short integers</i> . Added a chapter about $\pm\infty$ and NaN. Modified RBR and the menu for STO and RCL. Removed \blacksquare from the keyboard. Renamed X_u to X_e for the distributions. 3.3.19 |

| | Date | Release notes |
|------|----------|---|
| 0.11 | 8.5.19 | Changed keyboard making CC primary and user mode shifted, removing x^2 , $x\downarrow$, and DSP, adding $ x $, DROP, and SHOW, and moving some shifted labels. Modified <u>BITS</u> , CLREGS, <u>CNST</u> , <u>CPX</u> , <u>DISP</u> , <u>EXP</u> , <u>INTS</u> , <u>MODE</u> , <u>PARTS</u> , <u>SHOW</u> , <u>STAT</u> , <u>U\rightarrow</u> , <u>aMATH</u> , the division matrix, <i>data type</i> conversions, and the <i>Quick Reference Guide</i> . Added conversions of <i>barrels</i> , <i>carats</i> , and <i>fathoms</i> . Deleted DSP. – Separated predefined variables. Refined Sect. 6. Added \bar{x}_H , \bar{x}_{RMS} , nine statistical sums and five curve fit models. Split <u>STAT</u> in <u>STAT</u> and <u>SUMS</u> ; renamed RMDR to RMD, L_n to L_m , L_{na} to L_{ma} , Π to Π_n , Σ to Σ_n , and some constants to avoid search ambiguities. Refined App. J, Sect. 3 and 4, \rightarrow INT, <u>CLR</u> , and the functions of Δ and ∇ . 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>a.FN</u> . Rearranged A...Q and Sect. 2 of the OM. |
| 0.12 | 16.10.19 | Rearranged the appendices of the <i>ReM</i> from App. D on. Expanded App. A of the OM and App. K. Deleted the standardized normal distribution Φ and rearranged <u>PROB</u> . Updated <u>CNST</u> following CODATA 2018. Renamed the angular conversions. Changed the composing and cutting functionality of CC . Refined exiting <i>short integer</i> input. Expanded App. D. Specified maximum size of <i>long integer</i> . Changed keyboard adding \downarrow , moving <u>CPX</u> , <u>FIN</u> , RBR, R \uparrow , and <u>SHOW</u> , removing %. Renamed VANGLE to V \downarrow . Modified <u>CPX</u> , <u>MATX</u> , <u>TRI</u> , and <u>X.FN</u> . Rearranged Section 1 of the OM. Added some internal <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^{x-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>a•</u> , <u>SHOW</u> , and <u>STATUS</u> . Refined sorting order of <i>items</i> , ALL, CX \rightarrow RE, MEM?, RE \rightarrow CX, RBR, RM, SLVQ, and <u>U\rightarrow</u> . Started filling App. F and G. Refined App. 2. Added a <i>long integer</i> example, CPXR?, LZ?, Δv_{Cs} , conversions of <i>hectares</i> , and a proposal for system status information. |
| 0.14 | 8.12.19 | Introduced <i>system flags</i> for status information. Added auxiliary constants and some predefined variables. Changed keyboard swapping <u>MODE</u> and <u>FLAGS</u> , and displaying CF and SF. Refined the addressing tables and <u>BITS</u> , CLALL, CLFALL, <u>CPX</u> , <u>INTS</u> , MAX, MIN, <u>MODE</u> , NEIGHB, <u>STK</u> , $x < ?$, $x \leq ?$, $x \geq ?$, and $x > ?$. Deleted CLK12, CLK24, CPXi, CPXj, CPXRES, CPXR?, DENANY, DENFAC, DENFIX, ENGOVR, |

| | Date | Release notes |
|--|------|--|
| | | FAST, IMPFRC, LZOFF, LZON, LZ?, MULT×, MULT·, POLAR, PROFRC, QUIET, RDX., RDX,, REALRE, RECT, SCIOVR, and SLOW. 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* has more than three rows, its current view is limited by a dashed line indicating that it is a *multi-view menu* and or can be used to display the additional views of this *menu*.

MEMORY

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

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

Variables are named storage locations that may contain any type of data. E.g. for storing x into a variable named **XYZ**, enter **STO** **@ 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. v for more.

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

DATA TYPES

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

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

Complex numbers: A complex number consists of two real numbers combined to represent its real and imaginary part like $1.23-i\times 4.56$ in rectangular mode (set RECT and press **1.23 [CC] 4.56 [+/-] [ENTER]**) or its magnitude and phase like $-7.89 \angle 120^\circ$ in polar mode (CF RECTN and press **7.89 [+/-] [CC] 120 [ENTER]**).

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

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

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

Matrices: see pp. vii f.

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

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

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

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

MODES

| MODE | SYSTEM | | | | | |
|------|--------|-----|------|-----------|--------|--------|
| | | | RM | | | |
| | DEG | RAD | GRAD | MUL π | SETSIG | DENMAX |

| | |
|------------|--|
| DEG | Selects <i>degrees</i> as angular display mode (ADM). |
| RAD | Selects <i>radians</i> as ADM. |
| GRAD | Selects <i>gradians</i> , a.k.a. <i>gon</i> , as ADM. |
| MULT π | Selects <i>multiples of π</i> as ADM. |
| RM | Sets rounding mode. |
| DENMAX | Sets the maximum denominator for calculating with fractions. |
| SETSIG | Sets calculator precision (1 ... 34 significant digits). |
| SYSTEM | Returns the calculator to the <i>DMCP</i> system for updating. |

DISPLAY FORMATS

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

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

EXECUTING FUNCTIONS AND PROGRAMS

Any function or program can be executed via **[XEQ] 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 the current program only.

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

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

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

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

Specifying Function Parameters

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

Alphanumeric parameters: Many functions accept alphanumeric parameters as well. The parameter you want will often be an object already existing, so your WP 43S will display a *menu* for quick entry. If it does not exist yet, type it. E.g. for creating a variable ABC just type **[STO] 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 providing an actual parameter, you can specify the variable or *register* containing the parameter. Just press the softkey **[]**. E.g. to display the contents of the variable or *register* specified in R12, key in **[VIEW] [] 12**. This works with *stack registers* as well.

CLEARING AND DELETING

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

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

CATALOG VARS ...   allows for deleting the user variable selected.

CATALOG MENUS ...   allows for deleting the user *menu* selected.

CATALOG PROGS ...   allows for deleting the user program selected.

PROGRAMMING

Program Entry

- P/R** toggles *program entry mode*.
- GTO**   moves the *program pointer* to a new program space.
- GTO**  *nnnn* moves it to step number *nnnn*.
-  moves it to previous step (use  or  unless a *multi-view menu* is displayed).
-  moves it to next step (use  or  unless a *multi-view menu* is displayed).
-  deletes the *current program step* entirely.

Labels

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

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

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

Local registers

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

Tests (Do if True, Skip if False)

When a binary test step is executed, the program step immediately following said step is executed if the test result is “true”; if the result is “false”, the step following the test step is skipped.

Looping

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

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

Using a Variable Menu

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

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

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

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

Select a variable: Press the corresponding *softkey* without keying in a number

first. (For the *Solver*, this is how you select the unknown variable; for the integrator, this is how you select the variable of integration.)

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

MATRIX OPERATIONS

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

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

[MATX] NEW for a matrix in X or

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

For editing the matrix in X, use [MATX] EDIT .

For editing a named matrix, use [MATX] EDITN name.

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

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

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

Matrix arithmetic: +, -, ×, and / work for matrices just as for individual numbers. Advanced functions often operate on the individual matrix elements. Any time a matrix is used in a mathematical operation with a complex object, the result will be a complex matrix.

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

- Key in [MATX] SIM EQ n with n being the number of unknowns. Your WP 43S will automatically create or re-dimension the matrix variables Mat_A, Mat_B, and Mat_X.
- Press [Mat A]; fill the matrix; press [EXIT].
- Press [Mat B]; fill the matrix; press [EXIT].
- Press [Mat X] to compute the solution matrix.

PROBABILITY

| | RAN# | SEED | | | | $\Gamma(x)$ | |
|--------|--------------------|--------|-----------------|-----------------|--------------------|---------------------|--|
| PROB | | NBin: | Geom: | Hyper: | Binom: | Poiss: | |
| | LgNrm: | Cauch: | | Expon: | Logis: | Weibl: | |
| | Norml: | t: | C _{yx} | P _{yx} | F: | χ^2 : | |
| Binom: | Binom _p | Binom | | | Binom _e | Binom ⁻¹ | |

C_{yx} , P_{yx} Returns the number of possible combinations (or permutations, a.k.a. arrangements) of x items taken out of a set of y items.

RAN# Returns a random real number between 0 and 1.

SEED Stores a seed for RAN#.

$\Gamma(x)$ Returns the *Gamma function* value of x .

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

Binom: d *Binomial d.* ($i = p_0$ = gross probability of a success, $j = n$ = sample size)

Cauch: c *Cauchy-Lorentz* (a.k.a. *Breit-Wigner*) d. (i = location, j = shape)

Expon: c *Exponential d.* (i = rate)

F: c *Fisher's F d.* (i = degrees of freedom 1 (dof_1), j = dof_2)

Geom: d *Geometric d.* ($i = p_0$ = gross probability of a success)

Hyper: d *Hyperbolic d.* ($i = p_0$, $j = n$, k = batch size)

LgNrm: c *Log-normal d.* ($i = \mu$, $j = \sigma$)

Logis: c *Logistic d.* ($i = \mu$, j = scale parameter)

NBin: d *Negative Binomial d.* ($i = p_0$, $j = n$)

Norml: c *(General) normal d.* ($i = \mu$, $j = \sigma$)

Poiss: d *Poisson d.* ($i = n p_0$ = Poisson parameter)

t: c *Student's t d.* (i = dof)

Weibl: c *Weibull d.* (i = shape, j = characteristic lifetime)

χ^2 : c *Chi-square d.* (i = dof)

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

STATISTICS

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

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

Then, accumulate the data:

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

To undo input mistakes or remove erroneous data,

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

Data Evaluation and Analysis

| | OrthoF | GaussF | CauchF | ParabF | HypF | RootF | |
|------|------------|-----------------|---------------|-----------------|-----------------|-------|--|
| | LinF | ExpF | LogF | PowerF | | BestF | |
| | | \bar{x}_{RMS} | | | | | |
| | | \bar{x}_H | cov | | | | |
| | L.R. | r | s_{xy} | \hat{x} | \hat{y} | x^2 | |
| STAT | CLΣ | \bar{x}_G | ε | ε_p | ε_m | PLOT | |
| | Σ^- | \bar{x}_w | s_w | σ_w | s_{mw} | SUM | |
| | Σ^+ | \bar{x} | s | σ | s_m | x^2 | |

\bar{x} , s, σ , 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 , σ_w , s_{mw} Same for weighted data.

\bar{x}_G , ε , ε_p , ε_m Geometric mean value, sample scattering factor (SF), population SF, SF of the mean.

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

SUM Returns Σx and Σy .

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. ORTHOF is not part of the pool BESTF investigates. |

ADVANCED OPERATIONS

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

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

Interactive Operations on Equations



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

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

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

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

Using Advanced Operations in Programs

| ADV | PGMSLV | f''(x) | | | | |
|-------|--------|--------|---------|------------|-------------|--|
| SOLVE | SLVQ | f'(x) | Π_n | Σ_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.

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

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

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

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

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

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

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

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

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

1. Store a value into each of the variables that shall remain constant under derivation.

2. At the position where you need the derivative, put the respective location into **X**, then press **ADV** $f'(x)$ (or $f''(x)$) specifying **EF**.

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

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

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

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

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

OPERATIONS ON SHORT INTEGERS

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

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

NOT Inverts every bit in **X**.

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

MIRROR Reflects all bits.

ASR n Arithmetic shift x right by n places.

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

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

#B Returns the number of bits set in x .

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

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

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

| | |
|-------------------|--|
| A ... F | Digits for short integers of bases >10. |
| IDIV | $\mathbb{R} \mathbb{Z}$ Integer divide – works for real numbers (\mathbb{R}) and long integers (\mathbb{Z}) as well. |
| RMD, MOD | $\mathbb{R} \mathbb{Z}$ Remainder and modulo. |
| \times MOD | $\mathbb{R} \mathbb{Z}$ Returns $(z \cdot y) \bmod x$. |
| \wedge MOD | $\mathbb{R} \mathbb{Z}$ Returns $(z^y) \bmod x$. |
| FLOOR | \mathbb{R} Returns the greatest integer $\leq x$. |
| CEIL | \mathbb{R} Returns the smallest integer $\geq x$. |
| LCM | \mathbb{Z} Returns the least common multiple of <i>x</i> and <i>y</i> . |
| GCD | \mathbb{Z} Returns the greatest common divisor of <i>x</i> and <i>y</i> . |
| DBL /, DBLR, DBL× | Double word length commands for division, remainder, and multiplication. |

OPERATIONS ON ALPHANUMERIC STRINGS

Connect strings by pressing $\boxed{+}$. 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 | | | | | |
|------|------------------------|-------------|-------------|-------------|----------------|------------------------|
| | | | | | α LENG? | α POS? |
| | $x \rightarrow \alpha$ | α RL | α RR | α SL | α SR | $\alpha \rightarrow x$ |

| | |
|---------------------------------|--|
| $x \rightarrow \alpha$ s | Converts a code <i>x</i> 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).

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

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

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

aPOS? *s* Returns the position where substring *x* begins in the string in *s*.

FBR Displays all characters defined in both fonts.

The word "DRAFT" is written in large, bold, orange block letters. The letters are oriented diagonally, sloping upwards from the bottom-left towards the top-right. The letters are slightly overlapping, giving a sense of depth or perspective.

BACKGROUND CONSIDERATIONS AND FACTS

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

Alpha Register

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

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

Angles

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

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

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

reduced modulo 360° , then minus 180° (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 2π suffice to warrant 16 digits accuracy of respective function results for the number range of *SP* reals.⁷⁵

Character Sets

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

The so-called '**numeric**' **font** uses a matrix of up to 16×32 px (variable width, fixed height). Therein, the punctuation space (2008_{16} , 8 px wide) is employed for separating groups of digits in longer numbers – following *ISO 80000-1* for an unambiguous numeric display. This font is generally used for numeric output of the *WP 43S*. It is also employed for echoing numeric input unless too long. It can be used for echoing command input as well – screen space suffices.

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

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

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

All characters of the **standard** (a.k.a. small) **font** of alphanumeric characters as designed and implemented live in a matrix of up to 14×20 px (variable width, fixed height again). Herein, characters usually start at column one and feature two empty columns at their right side. There

⁷⁵ See <https://forum.swissmicros.com/viewtopic.php?f=2&t=350#p4349>.

are exceptions, however: 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 at right with their hexadecimal addresses and their widths). Using them, any spacing is feasible.

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

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

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

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

Turn to the OM for examples where these characters are used.⁷⁶ See here some sample strings in either font, approximately to a common realistic scale:

-1.602 22×10⁻¹⁹ C -1,602 22·10⁻¹⁹ C

-1.602 22×10⁻¹⁹ As

-1,602 22·10⁻¹⁹ As

Complex Infinities

Since infinities are counted as numeric data, also complex infinities are part of the complex number plane the WP 43S operates on. There are eight ‘complex infinities’ possible only:

| Re(z) | Im(z) | r(z) | $\varphi(z)$ |
|-----------|-----------|----------|--------------|
| $-\infty$ | $-\infty$ | ∞ | -135° |
| 0 | $-\infty$ | ∞ | -90° |
| ∞ | $-\infty$ | ∞ | -45° |
| ∞ | 0 | ∞ | 0° |
| ∞ | ∞ | ∞ | 45° |
| 0 | ∞ | ∞ | 90° |
| $-\infty$ | ∞ | ∞ | 135° |
| $-\infty$ | 0 | ∞ | 180° |
| | | | $\pi/4$ |
| | | | $-\pi/2$ |
| | | | $-\pi/4$ |
| | | | 0 |
| | | | $\pi/2$ |
| | | | $3\pi/4$ |

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

Calculating with infinities, any finite numbers may be neglected in comparison; so for $|x| \neq \infty$ any inputs like e.g. $x + i \times \infty$ may be

⁷⁶ 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.

replaced by $0 + i \times \infty$, easing calculations significantly. Actually, you will have to deal with the eight cases listed above only.⁷⁷

Display Limits

Due to the character sizes and their design (cf. pp. xvi f), the screen could take inputs of up to 23 digits, a sign, and an 8-px radix mark:

~~-4.2345678901234567890123 ,~~

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

~~-4.234 567 890 123 456 789 0 ,~~

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

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

taking 395 px ($= 15 + 16 \times 16 + 5 \times 8 + 15 + 16 + 4 \times 13 + 1$) for displaying this number this way.⁷⁸

For double precision numbers, a 33-digit mantissa plus exponent can be shown using the small font:

~~-8.123 456 789 012 345 678 901 234 567 890 12 $\times 10^{-925}$,~~

taking 399 px ($= 34 \times 8 + 10 \times 4 + 9 + 13 + 4 \times 8 + 1$) for displaying.

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:

⁷⁷ Following an article of HP about the HP-71, infinities should be treated in polar notation (see <http://hparchive.com/Journals/HPJ-1984-07.pdf>, p. 27, left column for the reasons).

⁷⁸ One blank pixel column had to be added at right since exponential digits are right adjusted (since used for numerators as well) and the screen is framed in black.

$$\text{Logarithmic*} \quad a_1: -5.234\ 567\ 8 \times 10^{-92}$$

$$y = a_0 + a_1 \ln(x) \quad a_0: -1.234\ 567\ 890\ 12$$

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

~~$$-4.234\ 567\ 89 + j \times 4.234\ 567\ 89$$~~

since $44 + 15 + 2 \times (16 + 8 + 48 + 8 + 48 + 8 + 32) = 397$ px in total. It applies if both real and imaginary parts are in the same order of magnitude and the multiplication cross is chosen.

With SCI or ENG, a minimum of 3 decimals can be shown $(15 + 2 \times (4 \times 16 + 8 + 15 + 16 + 4 \times 13)) + 44 + 1 = 370$ px, but another digit would need 2×16 px at least):

~~$$-4.234 \times 10^{-925} + i \times 4.234 \times 10^{-925}$$~~

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

~~$$-4.234\ 5 \cdot 10^{-925} + i \cdot 4.234\ 5 \cdot 10^{-925}$$~~

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

~~$$-6.234\ 5 \times 10^{-925} + i \times 6.234\ 5 \times 10^{-925}$$~~

~~$$-6.234\ 56 \cdot 10^{-925} + i \cdot 6.234\ 56 \cdot 10^{-925}$$~~

Complex numbers in **polar notation** need $4 + 16 + 4 = 24$ px for \angle plus 16 px for the angular unit in addition to the space for two signed reals. Both magnitude and angle may require a 15 px sign. 7 decimals in FIX occupy $40 + 2 \times (15 + 8 \times 16 + 3 \times 8) = 374$ px, so we can display them this way:

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

With SCI or ENG, the minimum number of decimals depends on the angular display mode since output is confined to the interval -180° to $+180^\circ$ or its equivalents, e.g. $-\pi$ to $+\pi$ in *radians* or -200^g to $+200^g$ in *gon* (see Sect. 2 of the OM). Hence, the angular parts can be displayed without exponents always. This allows for a minimum of 4 decimals for *degrees* and *gon*:

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

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

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

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 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 294 digits. *Long integers* $\geq 10^{294}$ shall be trailed by an exponent again

taking $9 + 13 + 3 \times 8 = 46$ px in worst case; thus, display precision may be reduced to 288 digits minimum then.

For unsigned ***short integers***, up to 21 *bits* may be shown in large digits in binary representation:

0 1100 0010 1101 0110 0000₂.

Base 3 (with narrow blanks every three digits) allows for displaying 20 digits and a sign:

-22 211 200 201 120 001 212₃.

In base 4 (with narrow blanks every two digits), 19 digits representing 38 *bits* are displayable:

3 21 23 30 22 11 21 20 32 12₄.

Also bases 5, 6, and 7 allow for showing 20 digits and a sign like base 3, base 8 for 19 digits like base 4 (but representing 57 *bits* in base 8).

Using the narrow digits provided, up to 25 *bits* are displayable in binary representation:

0 1110 1100 0010 1101 0110 0000₂.

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 0000₂.

41 digits and a sign can be displayed for base 3 being already sufficient for 64 *bits*, as well as the 39 digits theoretically displayable for base 4.

For showing the maximum of 64 *bits* in base 2, two special 5 px wide characters were created:

1111 1100 0010 1101 0110 1110 1100 0010 1101 0110 1110 1100 0010 1101 0110 0000₂.

Summing up, for given base and word size, the following fonts will do for *short integers*:

| Base ▼ | Allowable size of digits for display | | | |
|-----------|--------------------------------------|---------|---------|---------|
| | large | narrow | small | special |
| 2 | 21 bits | 25 bits | 44 bits | 64 bits |
| 3 | 31 bits | 38 bits | | |
| 4 | 38 bits | 44 bits | | |
| 5 | 46 bits | 55 bits | | |
| 6 | 51 bits | 62 bits | | 64 bits |
| 7 | 56 bits | | | |
| 8 | 57 bits | | 64 bits | |
| > 8 | 64 bits | | | |

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

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

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

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

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

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

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

Vertically, each such matrix row requires 20 px as other small font strings do. Within the space of 3 standard numeric output rows, $3 \times 32 + 2 \times 5 = 106$ px are available, allowing for 5 matrix rows ($5 \times 20 + 4$). Thus, a 5×4 real matrix can be displayed entirely always, using SCI 3 in worst case.

In consequence, any chosen 3×3 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 3×2 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 3×3 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 RL₄π /3 546f 64:u⁰ 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 17th will close input) for a 7-character command indirectly addressing a 7-character variable entered in *A/M*. This can be done in either font.

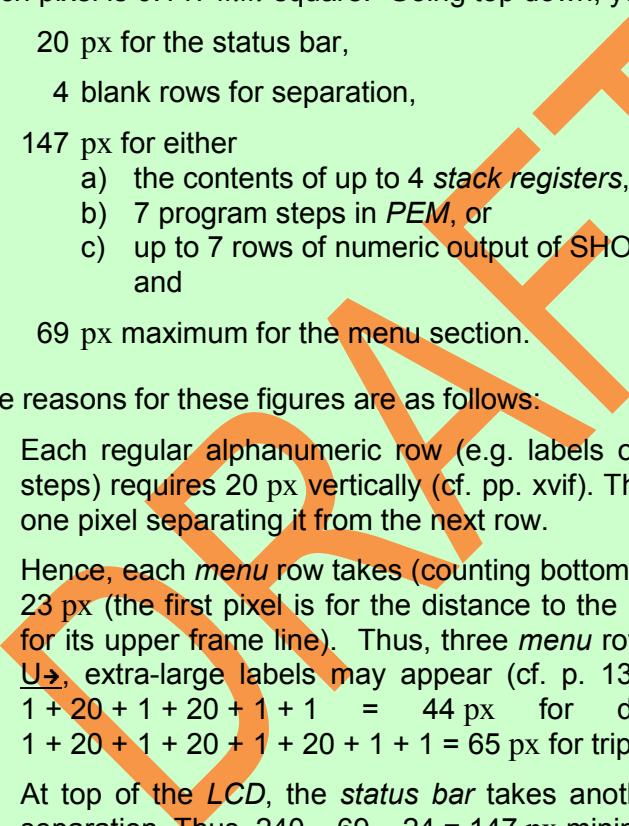
Command and variable *names* in menus are discussed in the last paragraph of next chapter. Although seven characters are allowed for such *names*, six may well fill the screen space available there already.

Thus, it is recommended to keep such *names* as short as possible, though meaningful.

Display Segmentation

The *LCD* of your *WP 43S* is full dot matrix: 400 px wide and 240 high. Each pixel is 0.147 mm square. Going top down, you will find

- 20 px for the status bar,
- 4 blank rows for separation,
- 147 px for either
 - a) the contents of up to 4 *stack registers*, or
 - b) 7 program steps in *PEM*, or
 - c) up to 7 rows of numeric output of *SHOW*, and
- 69 px maximum for the *menu* section.



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

The reasons for these figures are as follows:

- Each regular alphanumeric row (e.g. labels or status or program steps) requires 20 px vertically (cf. pp. xvif). There shall be at least one pixel separating it from the next row.
- Hence, each *menu* row takes (counting bottom-up) $1 + 20 + 1 + 1 = 23$ px (the first pixel is for the distance to the black frame, the last for its upper frame line). Thus, three *menu* rows require 69 px. In U₂, extra-large labels may appear (cf. p. 131): they will require $1 + 20 + 1 + 20 + 1 + 1 = 44$ px for double height or $1 + 20 + 1 + 20 + 1 + 20 + 1 + 1 = 65$ px for triple height then.
- At top of the *LCD*, the *status bar* takes another 20 px plus 4 for separation. Thus, $240 - 69 - 24 = 147$ px minimum remain.
- Each regular numeric output requires 32 px vertically (cf. pp. xvif) plus 5 px separating it from the next such row. Thus, for 4 rows we need $4 \times 32 + 3 \times 5 = 143$ px. We put the remaining 4 px below this output block.

- If there is a short alpha string in any stack *register*, its ground line is positioned where the ground line of the respective numeric output would have been.
- With an alpha string needing two rows, $20 + 1 + 20 + 5 = 46$ px are required vertically where 37 px are available for one numeric row. So a second numeric row has to go here – up to three stack *registers* can be displayed only now.

Two subsequent alpha strings of this kind, e.g. after **ENTER↑**, require 92 px. Three regular numeric rows cover 111 px, so here is no further loss. The ground line of the lowest alpha string is positioned where the ground line of the respective numeric output would have been. The other string is positioned in the center of the free space remaining.

- An alpha string needing three rows requires 67 px which are still covered by two regular numeric rows. Two such strings, however, push any other stack register out of the screen. Then string *y* shall have its ground line where the second numeric row would have it.
- In *PEM*, on the other hand, $147 = 7 \times 21$ corresponds to a block of 7 alphanumeric program rows.
- If there will be more space left, we will put it below the numeric block. This is for clear separation from the *menu section* and avoiding vertical output jitter. (gibt's diesen Fall überhaupt noch?)
- With *SHOW*, also pure numeric output may require more than one row – the small font will be used there as well. Cf. pp. 71 and xxi.

In the *menu section*, we also have a horizontal structure for the six *softkeys*. We start one pixel off the black frame at left display edge. On the right edge, the characters themselves contain at least one blank column. A minimum of 2 px separate *softkey* labels from each other (one black and one blank). This way we lose a total of $1 + 5 \times 2$ px. The remaining 389 px mean a width of 65 available for 6 *softkey* labels, corresponding to six standard width letters (though letters may extend from 4 to 14 px in small font) which should be centered as good as possible. Note that labels in *menu views* may be not fully displayed if they are wider than 64 px, so labels deviating only in their very last characters may become visually indistinguishable.

Equations

Equations are entered in **EQN** as written (i.e. following algebraic notation and rules). While editing them, punctuation spaces are automatically inserted after each constant or variable (you know a variable *name* ends when the next operator is entered) as well as after **=** and each operator like **+**, **-**, *****, **/**, **!**, except **^**; a standard space is inserted after **:**. There is no implicit multiplication.

Other functions like absolute values, roots, or trigs shall be written using the parentheses softkey, e.g. pressing **[fx] ()**, 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]**.

Closing the *Equation Editor*, numeric exponents are automatically converted from e.g. **xy ^23** to **xy²³**. For easier handling, this will be reverted when editing such an equation again.

Menus

Menu size corresponds to keystroke efficiency; optimum is a *menu* encompassing three views containing up to 54 functions in total: the top view, one view going up via **[▲]**, and one going down via **[▼]**. Larger *menus* lack efficiency, smaller *menus* lack functions. Besides function visibility, an operation presented in the unshifted row of top *menu* view is more efficient than a shifted function presented on the keyboard – if used more than just once.

Generally, I separated status setting from “acting” operations in different views or rows at least.

Number Range

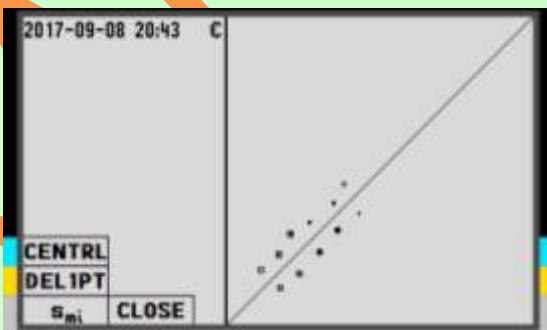
A number range up to 10^{99} is sufficient for almost all real-world problems – else common scientific calculators would feature a larger numeric range generally. So we can conclude that the *SP* number range (see p. 164) is sufficient by far for solving what has to be solved. For sake of consistency, maximum numbers of different *data types* should match. I.e. the maximum absolute value allowed for a long

integer should be approximately equal to the respective values for a real and a complex number. *DP* numbers are implemented for extended precision, not for extended range.

Plotting?

It is mentioned elsewhere we are not out for creating a graphing calculator. There is, however, a very useful application where a basic scatter plot of measured data points would support decision making significantly (see the third industrial statistics application example in *Section 2* of the OM). This would require the statistical data (e.g. max. 100 data points, i.e. 100 pairs of x and y values) to be stored point by point in a matrix, not just summed up as in earlier *RPN* calculators.

Plotting could be called by a command *PLOT* stored in *STAT* displaying the data points collected in a quadratic diagram. Both axes shall reach from minimum value measured to maximum value measured (plus a little extension which can be calculated based on the data points). Axis scales are not required for analysis so I omitted them. Drawing area has to be quadratic (240×240 px for data, 242×240 px incl. the vertical axis). Hence *softkeys* can be positioned on one side of the diagram (max. 3×2 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 is modified for clearing just the screen section required for the diagram.

Four characters are provided in small font for ‘drawing’ the vertical axis and the 45° line:



But both the axis and the line can be created using AGRAPH and PIXEL as well.

Data points can then be plotted using POINT (containing 3×3 px) – positioning them properly in the diagram, however, will require some background calculations best performed by a program. For POINT, also some of the control modes of *HP-42S* shall be implemented in analogy (the picture below is copied from the *HP-42S OM*, p. 137; settings 1 and 3 should do for our plotting):

| 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.

Softkey functions could be ...

- CENTRL for fitting the center line to the data points and plotting it for checking deviations from the 45° line (some background calculations in L.R. using ORTHOF for orthogonal regression are required for the plot, setting 1 in the picture above will do while plotting); (DEL1PT turned obsolete;)
- s_{mi} for calculating the minimum experimental standard deviation of the measuring instrument (some background calculations required again); and
- CLOSE for closing the plot screen, returning to normal display.

It may be beneficial to define a general origin for graphics at a location deviating from 0, 0 (i.e. the bottom left corner of the *LCD*) – the point 158, 0 may be a useful origin. This would allow for creating also other graphics than just the correlation diagrams mentioned above, while reserving a ‘protected screen space’ for up to six softkeys. Any user may do his own in this almost quadratic drawing area then, using the

commands AGRAPH, CENTRL, CLLCD, CLOSE, PIXEL, PLOT, POINT, and s_{mi} .

Precision and Accuracy

As mentioned above more than once, there are inevitable errors in each calculation step, frequently caused by rounding to the internal finite precision the calculator features. Already a simple fraction like $1/3$ stored as an SP real number deviates from the truth by more than 3×10^{-17} . During calculations, such errors accumulate as elaborated e.g. in footnote 59.

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° SP, you can nevertheless get 10 digits precision in the result since the input of 9° is exact (but note you lose one digit precision with each trigonometric function calculated here).

Internally, for instance, the *WP 34S* computes with 39 digits and rounds the results to 34 or 16 digits, respectively (seems Free42 works alike since the standard test results match). Following these, this is implemented for the *WP 43S* as well. SLVQ is calculated using 72 digits internally.

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

Prefixes

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

Sorting in Detail

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

Note that sorting is a two-step procedure: step 1 sorts the alphanumeric strings under consideration just according to column 1 of this table, comparing them; if two strings are rated equal in this aspect, step 2 takes the columns following into account:⁷⁹

| | | | | | | |
|---------|---------|--------|--------|--------|--------|--------|
| „ 0020 | 2003 | 2004 | ... | 2007 | 2008 | 200a |
| 0 0030 | „ 220e | ¤ 00b0 | ¤ 2070 | 0 2080 | | |
| 1 0031 | 1 2027 | ½ 00bd | ¼ 00bc | 1 00b9 | 1 2071 | 1 2081 |
| | | | | | | 1 2460 |
| 2 0032 | 2 00b2 | 2 2082 | 2 2461 | | | |
| 3 0033 | 3 00b3 | 3 2083 | 3 2462 | 3 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 | | | | | | |

⁷⁹ Applying this algorithm, a section of CATALOG'FCNS looks like e.g. **s**, **SAVE**, **SB**, **SCI**, **SCIOVR**, **scw→kg**, ..., **SLVQ**, **s_m**, **SMODE?**, **s_{mw}**, **SOLVE**, ...

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

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

| | | | | | | |
|---------------|---------------|---------------|---------------|---------------|---------------|--------|
| 13 | 246c | | | | | |
| 14 | 246d | | | | | |
| 15 | 246e | | | | | |
| 16 | 246f | | | | | |
| A 0041 | a 0061 | ä 00aa | A 24b6 | ä 2090 | a 249c | |
| | À 00c0 | à 00e0 | Á 00c1 | á 00e1 | Â 00c2 | ã 00e2 |
| | Ã 00c3 | ã 00e3 | Ä 00c4 | ä 00e4 | Å 00c5 | å 00e5 |
| | Æ 00c6 | æ 00e6 | Ā 0100 | ā 0101 | Ā 0102 | ă 0103 |
| | | | | | À 0104 | ą 0105 |
| | | | | | | |
| B 0042 | b 0062 | B 24b7 | b 249d | | | |
| C 0043 | c 0063 | c 24b8 | c 249e | ç 00c7 | ç 00e7 | |
| | Ć 0106 | ć 0107 | ć 010c | č 010d | Ć 2102 | ć 2201 |
| D 0044 | d 0064 | d 24b9 | d 249f | đ 00d0 | đ 00f0 | |
| | | | đ 010e | đ' 010f | đ 0110 | đ 0111 |
| E 0045 | e 0065 | E 24ba | e 2091 | e 24a0 | ě 00c8 | ě 00e8 |
| | É 00c9 | é 00e9 | Ě 00ca | ě 00ea | Ě 00cb | ě 00eb |
| | Ē 0112 | ē 0113 | Ě 0114 | ě 0115 | Ě 0116 | ě 0117 |
| | Ę 0118 | ę 0119 | Ě 011a | ě 011b | Ę 2073 | |
| F 0046 | f 0066 | f 24a1 | f 24bb | | | |
| G 0047 | g 0067 | g 24a2 | g 24bc | ğ 011e | ğ 011f | |
| H 0048 | h 0068 | h 210e | h 24a3 | ḥ 24bd | ḥ 2095 | |
| | | | | | ḥ 0127 | ḥ 210f |
| I 0049 | i 0069 | I 24be | i 24a4 | ǐ 00cc | ǐ 00ec | |
| | Í 00cd | í 00ed | Ǐ 00ce | ǐ 00ee | Ǐ 00cf | ǐ 00ef |
| | Ǐ 012a | í 012b | Ǐ 012c | ǐ 012d | Ǐ 012e | ǐ 012f |
| | | | | | ǐ 0130 | ǐ 0131 |
| J 004a | j 006a | J 24bf | j 24a5 | | | |
| K 004b | k 006b | k 24c0 | k 24a6 | k 2096 | | |

| | | | | | | |
|--------|--------|--------|--------|--------|--------|--------|
| L 004c | l 006c | L 24c1 | l 24a7 | l 2097 | Ľ 0139 | í 013a |
| | | | Ľ 013d | ľ 013e | ť 0141 | ť 0142 |
| M 004d | m 006d | M 24c2 | m 24a8 | m 2098 | | |
| N 004e | n 006e | N 24c3 | n 24a9 | n 2099 | Ň 00d1 | ň 00f1 |
| | Ń 0143 | ń 0144 | Ń 0147 | ň 0148 | N 2115 | |
| O 004f | o 006f | o 00ba | ö 00a9 | o 24c4 | o 24aa | o 2092 |
| | ò 00d2 | ò 00f2 | Ó 00d3 | ó 00f3 | ò 00d4 | ô 00f4 |
| | ő 00d5 | ő 00f5 | Ö 00d6 | ö 00f6 | ø 00d8 | ø 00f8 |
| | ō 014c | ō 014d | Ő 014e | ő 014f | Œ 0152 | œ 0153 |
| P 0050 | p 0070 | P 24c5 | p 24ab | p 209a | | |
| Q 0051 | q 0071 | Q 24c6 | q 24ac | Q 211a | | |
| R 0052 | r 0072 | r 24ad | R 24c7 | Ŕ 0154 | ř 0155 | Ŕ 0158 |
| | | | | | ř 0159 | Ŕ 211d |
| S 0053 | s 0073 | s 24c8 | s 24ae | s 209b | Ś 015a | ś 015b |
| | ſ 015e | ſ 015f | ſ 0160 | ſ 0161 | þ 00df | |
| T 0054 | t 0074 | T 24af | T 22a4 | T 24c9 | t 209c | |
| | | | T 0162 | ť 0163 | Ť 0164 | ť 0165 |
| U 0055 | u 0075 | u 24ca | u 24b0 | u 1d64 | Ù 00d9 | ù 00f9 |
| | ú 00da | ú 00fa | ú 00db | ú 00fb | Ü 00dc | ü 00fc |
| | ő 0168 | ő 0169 | ő 016a | ő 016b | ű 016c | ű 016d |
| | | | Ő 016e | ő 016f | Ų 0172 | ų 0173 |
| V 0056 | v 0076 | v 24cb | v 24b1 | | | |
| W 0057 | w 0077 | w 24cc | w 24b2 | ŵ 0174 | ŵ 0175 | |
| X 0058 | x 0078 | x 1d61 | x 24cd | x 24b3 | x 2093 | |
| | | | ŷ 0379 | ŷ 0378 | ŷ 037f | ŷ 221c |
| Y 0059 | y 0079 | ȝ 24ce | ȝ 24b4 | Ý 00dd | ý 00fd | |
| | ÿ 0176 | ÿ 0177 | ÿ 0178 | ÿ 00ff | ÿ 0233 | ÿ 0232 |
| Z 005a | z 007a | z 24cf | z 24b5 | Ž 0179 | ž 017a | ž 017b |
| | | | ž 017c | ž 017d | ž 017e | ž 2124 |

| | | | | | | | | | | | | |
|----------|------|----------|------|----------|------|----------|------|----------|------|----------|------|--|
| A | 0391 | α | 03b1 | α | 2065 | ά | 03ac | | | | | |
| B | 0392 | β | 03b2 | | | | | | | | | |
| Γ | 0393 | γ | 03b3 | | | | | | | | | |
| Δ | 0394 | δ | 03b4 | δ | 2066 | | | | | | | |
| Ε | 0395 | ε | 03b5 | έ | 03ad | | | | | | | |
| Ζ | 0396 | ζ | 03b6 | | | | | | | | | |
| Η | 0397 | η | 03b7 | ή | 03ae | | | | | | | |
| Θ | 0398 | θ | 03b8 | | | | | | | | | |
| Ι | 0399 | ι | 03b9 | ί | 03af | ϊ | 03aa | ϊ | 03ca | ΐ | 0390 | |
| Κ | 039a | κ | 03ba | | | | | | | | | |
| Λ | 039b | λ | 03bb | | | | | | | | | |
| Μ | 039c | μ | 03bc | μ | 00b5 | μ | 2067 | | | | | |
| Ν | 039d | ν | 03bd | | | | | | | | | |
| Ξ | 039e | ξ | 03be | | | | | | | | | |
| Ο | 039f | ο | 03bf | ό | 03cc | | | | | | | |
| Π | 03a0 | π | 220f | π | 03c0 | | | | | | | |
| Ρ | 03a1 | ρ | 03c1 | | | | | | | | | |
| Σ | 03a3 | σ | 03c3 | ς | 03c2 | | | | | | | |
| Τ | 03a4 | τ | 03c4 | | | | | | | | | |
| Υ | 03a5 | υ | 03c5 | ύ | 03cd | ΰ | 03ab | ΰ | 03cb | ΰ | 03b0 | |
| Φ | 03a6 | φ | 03c6 | | | | | | | | | |
| Χ | 03a7 | χ | 03c7 | | | | | | | | | |
| Ψ | 03a8 | ψ | 03c8 | | | | | | | | | |
| Ω | 03a9 | ω | 03c9 | ώ | 03ce | | | | | | | |
| (| 0028 |) | 0029 | | | | | | | | | |
| [| 005b | Γ | 23a1 | | 23a2 | | 23a3 | | | | | |
| | |] 005d | | | 23a4 | | 23a5 | | 23a6 | | | |
| { | 007b | } | 007d | | | | | | | | | |

| | | | | | | | | | | | | | |
|--------|--------|----------|---------|--------|--------|--------|--|--|--|--|--|--|--|
| + 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 | | | | | | | | | |
| " 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 | | | | | | | | | | | | | |
| ▲ 2227 | ▼ 2228 | ▼ 22bb | ▲ 22bc | ▼ 22bd | | | | | | | | | |
| & 0026 | | | | | | | | | | | | | |
| 007c | 2223 | 2224 | 2225 | 2226 | | | | | | | | | |

| | | | | | | |
|----------------------------|---------------------------|---------------------------|-----------------------------|----------------------------|--------------------------------|---------------------------------|
| <code><< 226a</code> | <code>< 003c</code> | <code>≤ 2264</code> | <code>≡ 2261</code> | <code>:= 2254</code> | <code>= 003d</code> | <code>≈ 2243</code> |
| | <code>≈ 2248</code> | <code>≡ 2258</code> | <code>△ 2259</code> | <code>≠ 2260</code> | <code>≥ 2265</code> | <code>> 003e</code> |
| | | | | | | <code>» 226b</code> |
| <code>% 0025</code> | <code>\$ 0024</code> | <code>€ 20ac</code> | <code>¢ 00a2</code> | <code>£ 00a3</code> | <code>¥ 00a5</code> | <code>₪ 00a7</code> |
| <code>✓ 221a</code> | <code>✗ 221d</code> | | | | | |
| <code>∞ 221e</code> | <code>∞ 209e</code> | <code>∞ 209f</code> | | | | |
| <code>∫ 222b</code> | <code>∬ 222c</code> | <code>∫ 222e</code> | <code>∬ 222f</code> | | | |
| <code>◎ 2299</code> | <code>◎ 229a</code> | <code>◎ 2068</code> | | | | |
| <code>⊕ 2295</code> | <code>⊕ 2069</code> | | | | | |
| <code>⊤ 221f</code> | <code>⊥ 22a5</code> | | | | | |
| <code>∠ 2220</code> | <code>∄ 2221</code> | | | | | |
| <code>⌈ 2308</code> | <code>⌋ 2309</code> | | | | | |
| <code>⌊ 230a</code> | <code>⌋ 230b</code> | | | | | |
| <code>⌚ 2399</code> | <code>⌚ 231b</code> | <code>⌚ 231a</code> | <code>⌚ 242a</code> | <code>⌚ 242c</code> | <code>⌚ 242f</code> | |
| <code># 0023</code> | | | | | | |
| <code>UK 242d</code> | <code>US 242e</code> | | | | | |
| <code>forall 2200</code> | <code>exists 2202</code> | <code>exists 2203</code> | <code>notexists 2204</code> | <code>emptyset 2205</code> | <code>triangleleft 2206</code> | <code>triangleright 2207</code> |
| | <code>epsilon 2208</code> | <code>epsilon 2209</code> | <code>epsilon 220b</code> | <code>epsilon 220c</code> | <code>nabla 2229</code> | <code>u 222a</code> |
| <code>lrcorner 2422</code> | <code>/ 2423</code> | <code>/ 2425</code> | <code>/ 2426</code> | | | |
| <code>✓ 2713</code> | | | | | | |

Stack Size

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

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.

After all, we decided sticking to *RPN* as implemented on the *WP 34S* and *WP 31S*. It covers everything needed most easily. For special action support, the commands STOS and RCLS are provided.

Stack Lift Disabling Functions

Also these functions were subject of discussion. For sake of backward compatibility, we decided to keep them as they were on the vintage *HP RPN* pocket calculators up to the *HP-42S* (and *WP 34S* and *WP 31S*):

Only ENTER↑, CLX, Σ+, and Σ- disable *automatic stack lift*, all other functions enable it. But compare INPUT on p. 41.

Structured Programming

In 2013, I suggested the following control structures:

- IF – THEN – ELSE – END,
- FOR – FROM – TO – END,
- REPEAT – UNTIL,
- WHILE – END.

Traditional END would need to be called ENDPGM then.

Later, we discussed some *PASCAL*-like structures:

- IF – THEN BEGIN – END ELSE BEGIN – END;
- FOR – DO BEGIN – END;
- WHILE – DO BEGIN – END;

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

UNDO

In 2013, UNDO was planned as it works in *HP-48*, recalling the stack as it was before executing last command. The *WP 31S*, on the other hand, features an UNDO recalling the entire calculator status as it was. It turned out that such a complete UNDO was viable here, too, so we implemented it.

DRAFT