HyperCalc

Originally created by Robert P. Munafo.  
Ported to JavaScript by Kenny TM~

Go ahead – just *try* to make me overflow!
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Chapter 1

Introducing HyperCalc

Which is bigger: $27^{86}$ or $(27^{86})!$? Most calculators can’t even give the value of $27^{86}$ or of $86!$.

With HyperCalc you can see that $27^{86}$ is $1.25107 \ldots \times 10^{123}$, and $86!$ is $2.422709 \ldots \times 10^{130}$. Some calculators can handle that – the current record-holder is AlCalc for the Pilot, which goes as high as $10^{27767}$ and can handle $9274!$ (9274 factorial).

But no other calculator can tell you that

$$(27^{86})! = 10^{1.534607 \ldots \times 10^{125}}$$

or that

$$27^{86} = 10^{3.467778 \ldots \times 10^{130}}$$

(in other words, the first has over $10^{125}$ digits and the second, with over $10^{130}$ digits is “just a little bit” larger.)

1.1 So what is HyperCalc?

HyperCalc is an open-source interpreted calculator program designed to calculate extremely large numbers (such as your phone number raised to the power of the factorial of the Federal budget deficit) without overflowing.

It does this by using a modified form of the level-index number system with a radix of $10^{300}$. 
### Table 1.1: Performance statistics for other calculators

<table>
<thead>
<tr>
<th>Year</th>
<th>Model</th>
<th>Overflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>TI SR-50</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>1980</td>
<td>Sharp EL-5100</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>1989</td>
<td>Casio fx-7500G</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>?</td>
<td>Casio fx-115D</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>1995</td>
<td>Casio CFX-9800G</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>1997</td>
<td>Pilot AlCalc</td>
<td>$10^{2788}$</td>
</tr>
<tr>
<td>1998</td>
<td>Casio fx-260</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>1998</td>
<td>Sharp EL-531L</td>
<td>$10^{100}$</td>
</tr>
<tr>
<td>1998</td>
<td>TI-85</td>
<td>$10^{1000}$</td>
</tr>
<tr>
<td>1998</td>
<td>TI-92</td>
<td>$10^{1000}$</td>
</tr>
<tr>
<td>1999</td>
<td>TI-89</td>
<td>$10^{1000}$</td>
</tr>
<tr>
<td>2003</td>
<td>Mathematica 5 for Windows</td>
<td>$1.92022 \times 10^{46456887}$</td>
</tr>
<tr>
<td>1998</td>
<td>HyperCalc PalmPilot (for Palm)</td>
<td>32768°(300)</td>
</tr>
<tr>
<td>1999</td>
<td>HyperCalc Perl (for UNIX)</td>
<td>$10^{10000}(300)$</td>
</tr>
<tr>
<td>2004</td>
<td>HyperCalc JavaScript (for WWW)</td>
<td>$(1.79769 \times 10^{308})^\sim(300)$</td>
</tr>
</tbody>
</table>

#### 1.2 Representing Numbers in HyperCalc

The overflow value for HyperCalc is so large it can’t be represented in the standard way. If we use HyperCalc’s internal “PT” (Power Tower) format it’s easy.

HyperCalc handles numbers with absolute value greater than the range supported by the floating point library by storing the numbers in many different formats. When the numbers are within normal floating-point range (less than $10^{300}$) they are stored in the normal floating-point format. Between $10^{300}$ and $10^{1000}$ they are stored as (common) logarithms, and Logarithmic Number System (LNS) algorithms are used. When the logarithm gets too big to store as a floating point number, the logarithm is taken again, and so on. An integer field is used to keep track of how many times the logarithm has been taken. Table 1.2 shows some examples:

Each time we transition from the top of one PT range to the bottom of the next, about 2.5 digits of precision are lost as the information formerly stored in the exponent has to be absorbed by the mantissa. Then, as we proceed up the range digits are gradually gained back until we reach the top of the range and we once again have a 2.5 digit exponent. So, for example at the top of the PT = 0 range the values are things like $1.23456789012345 \times 10^{299}$, and there are 53 binary digits of precision in the mantissa, or almost 16 decimal digits. Then we cross over into the PT-1 range and store the logarithm instead, which becomes a value like $301.456789012345$ – we still have 15 or more digits to work
Table 1.2: Examples of PT-Notation

<table>
<thead>
<tr>
<th>PT-Notation</th>
<th>PT</th>
<th>Value</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0**(1.0)</td>
<td>0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>0**(3.45 × 10**10)</td>
<td>0</td>
<td>3.45 × 10**10</td>
<td>3.45 × 10**10</td>
</tr>
<tr>
<td>0**(1.0 × 10**299)</td>
<td>0</td>
<td>1.0 × 10**299</td>
<td>1.0 × 10**299</td>
</tr>
<tr>
<td>0**(9.9 × 10**299)</td>
<td>0</td>
<td>9.9 × 10**299</td>
<td>9.9 × 10**299</td>
</tr>
<tr>
<td>1**(300)</td>
<td>1</td>
<td>300</td>
<td>10**300</td>
</tr>
<tr>
<td>1**(300.301)</td>
<td>1</td>
<td>300.301</td>
<td>2 × 10**301</td>
</tr>
<tr>
<td>1**(301)</td>
<td>1</td>
<td>301</td>
<td>10**301</td>
</tr>
<tr>
<td>1**(834.173)</td>
<td>1</td>
<td>834.173</td>
<td>1.489 × 10**834</td>
</tr>
<tr>
<td>2**(79)</td>
<td>2</td>
<td>79</td>
<td>10**79</td>
</tr>
<tr>
<td>3**(34)</td>
<td>3</td>
<td>34</td>
<td>10**34</td>
</tr>
<tr>
<td>254**(10**10)</td>
<td>254</td>
<td>10**10</td>
<td>(\frac{10^{10}}{254} = 3.906 \times 10^{7})</td>
</tr>
<tr>
<td>32767**(10**300)</td>
<td>32767</td>
<td>10**300</td>
<td>(\frac{10^{300}}{32767} = 3.048 \times 10^{286}) tens</td>
</tr>
</tbody>
</table>

(To read about even larger numbers, go to www.mrob.com and click on “Large Numbers”.)

with, but the first three correspond to the exponent of the number and there are only 12 or 13 digits left for expressing the mantissa. Of course as we keep going up we get to values like 123456.789012345 (which represents 6.15 × 10**123456) we lose even more mantissa digits to exponent, but eventually we’ll get to values like 123456789012345000000 = 1.2345… × 10**20, which represents 10**1.2345…×10**20 and as we go on up to even bigger numbers we see that since the exponent needs to be printed it once again holds information equivalent to 2.5 digits.

This entire issue of variable number of digits and the associated problems it causes with non-intuitive round-off performance would be avoided if one used a “natural” PT storage format, where e (base of natural logarithm) is the base and the representation is such that the floating point value is always in the interval [1, e]. So, for example, the number 143 would be represented as 2**((1.601979…), because e^{1.601979…} is 143. Such a format would be unwieldy for normal calculations, however, because you’d have to keep doing e^x and ln x all over the place when doing simple calculations like 25 + 2.
Chapter 2

History of HyperCalc

Notice that HyperCalc PalmPilot and HyperCalc Perl are created by Mr. Munafu, while HyperCalc JavaScript is written by Kenny TM~.

2.1 Revision history of HyperCalc PalmPilot

Oct 1?th, 1998 Start project from “SampleCalc” example.

Oct 18th, 1998 Fairly complete scientific calculator, except trigonometric functions.

Oct 21st, 1998 Start implementing PT functions, get \texttt{pt\_exp} and \texttt{pt\_mul} working.

Oct 22nd, 1998 Implement addition, subtract, power, common logarithm (base 10), common antilogarithm, and gamma function.

Oct 24th, 1998 Pretty much complete on the PT functions; they even handle infinity. Also, add a “tiny” font to print exponents when using the \texttt{stdFont}.

Oct 25th, 1998 Refine the formatting code for PT-1’s and higher so it computes exactly how many digits of mantissa can be shown. Add some more buttons, but most not implemented yet. Implement rounding (incredibly complex!). Add inverse trigonometric function, hyperbolic function, variable definition, and reciprocal keys. (but only reciprocal is implemented).

Oct 26th, 1998 Add the same formatting refinements to PT-0’s, so it can print contents of memories (which have fewer pixels available). Implement variable definition.
Oct 28th, 1998  Add hyperbolic functions and inverse trigonometric functions (but not inverse hyperbolic functions).


2.2 Revision history of HyperCalc Perl

Jun 10th, 1999  Start writing a simple Perl calculator program using a new concept: expression evaluation via regular expressions (I got the idea while writing the top100 movie statistics program). Right now it just does addition and multiplication.

Jul 1st, 1999  Break the addition operator into a separate subroutine \(\text{add1}\) (eventually all operators will be done this way).

Jul 20th, 1999  Add all the code from the HyperCalc PalmPilot, to eventually merge and translate into Perl.

Jul 21st, 1999  Parsing routine is fairly complete and now includes nested loop to handle parentheses. Subroutines for all four operators (+, −, ×, ÷). “\(e\)” and “\(\%\)” in an expression represent 2.71828 . . . and previous result, respectively.

Jul 25th, 1999  Add \(\text{split}\) and start writing first operator that handles PT types: \(\text{p_add}\), \(\text{pt_add}\), \(\text{pt_addpos}\).

Jul 27th, 1999

21:25  Do lots of porting work: put all routines in “proper” (Pascal) order; lots of global replaces to change things like \(x.pt\) to \(\$x_pt\); replace Taylor and Newton algorithms with builtin functions where available; minimum work to get \(\text{pt_addpos}\) working. It now properly adds \(10^{300} + 10^{300}\) (and gets \(1^{17}(300.3010299 . .\)).

21:54  \(\text{pt_add}\) fully works; \(\text{pt_div}\) works.

22:35  \(\text{pt_sub}\) and \(\text{pt_mul}\) work now. Output formatting handles some of the special cases to print values like \(1^{17}(2345.6789)\) as \(4.77 \times 10^{2345}\) rather than as “1 PT 2345.6789”.

27:22  \(\text{pt_ln}\) works; parser handles \(\ln()\) and \(\log()\).

Jul 28th, 1999

13:33  It now handles \(\text{exp()}\) and \(\text{pow()}\), so I can compute really big values without lots of repetitious keystrokes.
eva12() now stores all operator results into an array, and stores the array index into the expression string. This is to avoid numbers getting converted from strings into floating point and back again, and that dramatically reduces roundoff error.

Jul 29th, 1999 Start editing all the f_ routines so the primitive floating-point type can be changed easily later. This involves implementing a minimal set of “primitives” like f_int, f_le, f_neg, f_mul, etc. and making all the other f_ routines do all their operations by calling these primitives. Also, inline constants like “10” are replaced with globals.

Aug 1st, 1999 pt_root and pt_log_n work. All of the f_ routines are “primitivized”, but pt_ routines still need some work. Also added “debug” command. Put most of f_ primitives inside $f64_prim so they can be defined and redefined via exec. Create $g_pt_inf to distinguish uses of infinity in PT field from its uses in VAL field. A few other changes to support switching VAL primitive precision. Make it auto-promote inlines like “23E+456”.

Aug 2nd, 1999 Pretty much finished making the pt_ routines call f_.

Aug ??th, 1999 Use open2() to launch bc. Write bce.

Aug 5th, 1999 Write fbc_fix2sci, fbc_split, f_cmp, comparison primitives, f_neg, me_megcompare, m_truncround, me_addpos, f_add and f_sub. fbc_encode renamed to fbc_sci2fix. Redirect stderr when launching bc.

Aug ??th, 1999 Write me_subpos.

Aug 11th, 1999 Add HC_LOG debug log, lots of calls to dbg1. Fix lots of bugs. Write bc version of f_mul and f_div.

Oct 15th, 1999 Fix bug that caused small PT-1’s to be printed as e.g. 10301.30103. Make dbg1flag a bitmask to allow debugging functions, expression parsing, or both routines explicitly.

Oct 17th, 1999 Add variables (currently limited to all-alphabetic starting with “v”).

Oct 18th, 1999 Change single-letter function abbreviations and special letters like “e”, “p” etc. to uppercase, to clear the lowercase namespace for use by user variables.

Oct 19th, 1999 Fix some bugs relating to infinity handling and conversion in fbc routines. Four basic functions almost work (subtraction still seems to have problems).

Nov 17th, 1999 Variables no longer need to start with “v”. Add square root function.
Nov 24th, 1999  Combine parsing of $e$, $\pi$, $\phi$ with the variable and function parsing; add error-check for undefined variables.

Jan 20th, 2000  Write fbc versions of $f_{\ln}$ and $f_{\exp}$; fix bugs in $\text{fix2sci}$ and $\text{sci2fix}$; it now correctly computes $2^{100}$ in scale 30. Fix bugs in switching back and forth between $f64$ and $fbc$.

Feb 6th, 2000  Fix bug that prevented $\sqrt{1+2}$ from working.

Mar 4th, 2000  Square root now goes through $f_{\sqrt{}}$. Fix bugs that made $\text{bc hi_init}$ not compute $g_{\_pi}$ properly.

Jul 28th, 2000  Remove dependency on “rpmlib.pl”.

Jan 2nd, 2001  Add ERASE_BS test.

Jan 3rd, 2001  Clean up internals of $\text{eval\_2}$. Fix “right-to-left precedence bug”: $4 - 3 - 2$ used to give 3, and $4/3/2$ used to give 2.66667 ... I am deliberately leaving exponents that way: 4°3°2 still gives 262144.

Jan 7th, 2001  Fix bugs: $2+2/(1+1)$ gave 2; $7^-1$ didn’t parse; scale 50, $27^{27}$ printed in scientific notation. Write $\text{pt\_roundup}$. Fix $\text{prt1}$ handling of high PT-1’s. $fbc$-based PT calculation is actually usable now!

Jan 8th, 2001  Add history array and $\text{define\_hist}$. Conversion across scale changes works, at least in the cases I checked. Fix bug in $\text{eval\_2}$: Square root and other functions had become broken as a result of yesterday’s fixes. Clean up fbc version of $f_{\gamma}$ a little, but it still suffers from a fundamental limit of the Stirling formula method, which basically requires that the number being factorized must be at least as big as the 15th root of $10^{\text{currscale}}$. Combined with the current limit of $10^{300}$ for the $fbc$ float data type, that means we can’t get more than 33 digits of accuracy out of the $f_{\gamma}$ function. Increasing the exponent limit would fix it, but that poses another problem with the scaling loop – for 50 digits of accuracy, the scaling loop has to loop 2154 times (because $2154 = 10^{50}$). Finish implementing $\text{format}$ command.

Jan 9th, 2001  Fix bug that made history list usable only for first 9 items.

Jan 15th, 2001  Write $\text{init\_pi\_2}$, which calculates $\pi$ much more quickly. Decrease $\text{gammalim}$.

Jan 16th, 2001  Add input history.

Jan 17th, 2001  Change letters I/H for input and output history to C/R (commands and results).

Feb 10th, 2001  Fix “c2” in case where c2 is a variable assignment, and add “;” symbol to separate commands.

Feb 16th, 2001  Add ability to take 1E9 as input (used to require 1.E9).
May 21st, 2001  Make $x$ a synonym for *$. This works pretty well, in fact you can even define a variable $x$, and the expressions $2 \times 4$, $2 \times x$ and $x \times x$ all do the right thing! But, that’s not recommended. Also, change default output format to format 1, and make it print multiplication as $x$ because it looks better. Also, mapped [] in input to () . This almost solves the problem of having output and input formats match – the one missing piece is allowing the user to type “PT”, such as $3 \ PT \ 1.2 \times 10^{-45}$.

May 30th, 2001  Almost fix the ambiguity of “!!”: You can now type $4!!$ and it will give you $(4!)$, rather than “4” followed by the previous typed line.

Jun 1st, 2001  When “;” is present in input, print each of the commands with its C# = label as they’re being added to input history.

Jun 10th, 2001  Detect presence of UNIX and doesn’t try to run bc if not on UNIX.

Jun 13th, 2001  Fix some of the bugs in handling of “−”. Add pt_negate.

Oct 26th, 2001  Fix some bugs in command history expansion.

Nov 4th, 2001  Add autodetect of “H” and call stty erase if they type it (UNIX only)

Jan 29th, 2002  Move automatic stty erase fix to subroutine fixerase.

Mar 1st, 2002  Read first expression from command line.

Mar 5th, 2002  Fix some bugs in rounding and prnt2 – but it still has the problem that scale=15 prints the same number of digits as the default scale=14.

Mar 6th, 2002  Now can put multiple commands including scale= and quit on command line.

Jul 11th, 2002  Convert tabs to spaces in input.

2.3  Revision history of HyperCalc JavaScript

Oct 18th, 2004  Started to convert HyperCalc Perl into Visual Basic.

Oct 21st, 2004  Convert into JavaScript instead, since the language of VB does not really match that of Perl but JS. Moreover, JS has built-in support of Regular Expressions while VB not.

Nov 5th, 2004  Now the program displays $9^{99}$ as $4.2812 \ldots \times 10^{369693099.631\ldots}$ (i.e., will use scientific notation as much as possible.)


5**(5) now displays $10^{369693099.631\ldots}$ instead of $10^{369693099}$ (i.e., try to collapse PT level as much as possible. The current routine is not perfect yet, however). Implemented input history. Fixed a bug that causes functions not working.

Jan 11th, 2005  Now the program outputs $10^{-8}$ instead of $1e-8$. Improved the input-review system that it won’t wait too long when calling several $\$\$ repeatedly.

Jan 16th, 2005  Fixed a bug that calculates $\frac{e^{10^{10}}}{2}$ wrong (resulting a PT-0). Added the ? command.

HyperCalc

Figure 2.1: A typical screen of HyperCalc JavaScript
Chapter 3

Using HyperCalc

Big notice to HyperCalc Perl users: I've basically changed the interface of HyperCalc JavaScript from the original versions because I haven't copied those functions after eval_1(). So if you use the input like HyperCalc Perl you'll probably get a wrong answer or error.

3.1 Evaluating Simple Expressions

It is easy to use HyperCalc. After HyperCalc is loaded, you should be able to see a large blank in the middle, a text field under the blank and a button called “Calculate!” on the right of the field. The large blank is the output screen of HyperCalc that all results will be displayed there. The text field is for entering expression, and the button is to evaluate the expression you entered.

You can just enter your expressions like the ones displayed in textbook. For example, to calculate 1 + 2, you enter

\[ 1 + 2 \]

in the textfield and press the “Calculate!” or hit enter. The followings will be shown in the output screen:

\[
\begin{align*}
\text{In}[1] & := 1 + 2 \\
\text{Out}[1] & = 3
\end{align*}
\]

The following lists all available operations in HyperCalc:
<table>
<thead>
<tr>
<th>Operator</th>
<th>Purpose</th>
<th>Example</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Addition</td>
<td>1 + 2</td>
<td>3</td>
</tr>
<tr>
<td>-</td>
<td>Subtraction</td>
<td>6 - 7</td>
<td>−1</td>
</tr>
<tr>
<td>*</td>
<td>Multiplication</td>
<td>4 * 2</td>
<td>8</td>
</tr>
<tr>
<td>/</td>
<td>Division</td>
<td>3 / 5</td>
<td>0.6</td>
</tr>
<tr>
<td>^</td>
<td>Raising power</td>
<td>2 ^ 10</td>
<td>1024</td>
</tr>
<tr>
<td>e</td>
<td>Base of natural logarithm (e = 2.71828...)</td>
<td>e ^ 5</td>
<td>148.413...</td>
</tr>
<tr>
<td>pi</td>
<td>Pi (π = 3.14159...)</td>
<td>pi / 2</td>
<td>1.57079...</td>
</tr>
<tr>
<td>phi</td>
<td>Golden ratio (φ = √5/2)</td>
<td>1 / phi</td>
<td>0.618033...</td>
</tr>
<tr>
<td>eulerGamma</td>
<td>Euler’s gamma constant (γ = 0.577215...)</td>
<td>-eulerGamma</td>
<td>−0.577215...</td>
</tr>
<tr>
<td>!</td>
<td>Factorial</td>
<td>8!</td>
<td>40320</td>
</tr>
<tr>
<td>inf</td>
<td>Infinity</td>
<td>1 / inf</td>
<td>0</td>
</tr>
<tr>
<td>(...)</td>
<td>Parenthesis (Grouping)</td>
<td>5*(1-6)</td>
<td>−25</td>
</tr>
<tr>
<td>exp</td>
<td>Natural anti-logarithm (e^x)</td>
<td>exp(5)</td>
<td>148.413...</td>
</tr>
<tr>
<td>ln</td>
<td>Natural logarithm</td>
<td>ln(10)</td>
<td>2.32585...</td>
</tr>
<tr>
<td>log</td>
<td>Common logarithm</td>
<td>log(e)</td>
<td>0.434294...</td>
</tr>
<tr>
<td>logb</td>
<td>Logarithm of specific base</td>
<td>logb(2,64)</td>
<td>6</td>
</tr>
<tr>
<td>sqrt</td>
<td>Square root</td>
<td>sqrt(3)</td>
<td>1.73205...</td>
</tr>
<tr>
<td>root</td>
<td>Taking root</td>
<td>root(3, 8)</td>
<td>2</td>
</tr>
<tr>
<td>sin, cos, tan</td>
<td>Trigonometric functions</td>
<td>sin(pi/3)</td>
<td>0.866025...</td>
</tr>
<tr>
<td>asin, acos, atan</td>
<td>Inverse trigonometric functions</td>
<td>atan(inf)</td>
<td>1.57079...</td>
</tr>
<tr>
<td>gamma</td>
<td>Gamma function</td>
<td>gamma(0.5)^2</td>
<td>3.14159...</td>
</tr>
<tr>
<td>deg</td>
<td>Degree sign (° = π/180)</td>
<td>sin(60deg)</td>
<td>0.866025...</td>
</tr>
</tbody>
</table>

In HyperCalc, multiplication signs can be omitted. For instance, the expressions 3 * tan(30 * deg), 3 tan(30 deg) and 3tan(30deg) all result in √3. You can even type 7 4 for 7 x 4. However, the parenthesis around arguments of functions cannot be omitted, i.e., log(5) must be typed as is, and log 5 will be interpreted as “log x 5” and result in NaN.

HyperCalc follows the precedence like normal algebraic calculation. To explain explicitly, the functions and parenthesis, are handled first, then factorial, then negation (e.g., -123), then power raising, then multiplication and division and finally addition and subtraction. When operators of the same precedence go together, they are handled from left to right except power raising, which is handled from right to left.
HyperCalc is case-insensitive, that means `gamma`, `Gamma`, `GAMMA` and `gAmMA` are all the same. Also, many functions in HyperCalc possesses alias that do the same job as the original. The following lists all aliases available:

<table>
<thead>
<tr>
<th>Function</th>
<th>Alias</th>
</tr>
</thead>
<tbody>
<tr>
<td>(</td>
<td>[</td>
</tr>
<tr>
<td>)</td>
<td>]</td>
</tr>
<tr>
<td>inf</td>
<td>infin, infty, infinity</td>
</tr>
<tr>
<td>phi</td>
<td>goldenRatio</td>
</tr>
<tr>
<td>ln</td>
<td>loge</td>
</tr>
<tr>
<td>log</td>
<td>log10</td>
</tr>
<tr>
<td>logb</td>
<td>logn</td>
</tr>
<tr>
<td>asin</td>
<td>asn, arcsin</td>
</tr>
<tr>
<td>acos</td>
<td>acs, arccos</td>
</tr>
<tr>
<td>atan</td>
<td>atn, arctan</td>
</tr>
<tr>
<td>sqrt</td>
<td>sqr</td>
</tr>
<tr>
<td>root</td>
<td>rt</td>
</tr>
</tbody>
</table>

### 3.2 Big Numbers in HyperCalc

#### 3.2.1 Entering Big Numbers

Since HyperCalc is designed for calculation with really big numbers. To enter a big number, the most common method is using scientific form:

- **mantissaExponent**

Here “mantissa” and “exponent” are two real number. This represents \( m \times 10^e \). For example, \( 5E+16 \) means \( 5 \times 10^{16} \). The value of “exponent” is not limited as for many other calculators. You can set it as high as you want — there is no problem in handling \( 1E+1234567890 \).

However, the scientific form cannot be used to enter *really* big numbers, say, \( 10^{1234567890} \) would require you to enter \( 1E+10000\ldots0000 \). This is clearly impossible. However, we can use the PT notation to indicate these kinds of numbers. (See section 1.2 for details of PT notation.) To enter a PT number, use

- **ptPValue**
which represents

\[
10^{10^{10^{10^{10^{10}}}}} \approx 10^{10^{10^{10^{10}}}}
\]

So for \(10^{10^{234657890}}\) we can just input \(2\, P\, 1\, 2\, 3\, 4\, 5\, 6\, 7\, 8\, 9\, 0\). Note that the “value” must be positive.

The alias of \(E\) is \(^*\) and \(P\) is PT and \(^\wedge\).

### 3.2.2 Displaying Big Numbers

HyperCalc will display numbers as natural as possible. But sometimes the number will be too “big” to display in radix form, and it will be “collapsed” into a single PT notation. To be clear, try evaluate \(6\, P\, 1\) and \(7\, P\, 1\). The former will result in \(10^{10^{10^{10^{10^{10^{10^{10}}}}}}}\), but the latter will become \(6\, ^\wedge\, (10)\). This is because the latter is too “big” and using PT notation would be better. By default HyperCalc will only display values in radix form up to PT-5.

### 3.3 I/O History

The I/O history is the list of input/output results on the output screen. You can use I/O history retrieval commands to get those values.

#### 3.3.1 Output History

The last output can be obtained by entering \(%\). For example:

- \(\pi\, ^\wedge\, \pi\)
- \(\%\, ^2 - 2\% + \sin(\%)\)

will evaluate \(36.4621596072079\) and then \(1255.6199743011982\). If you want to refer to one specific output at line \(n\), use

- \(\%n\)
3.3.2 Input History

The last input can be re-evaluated by entering $. For example:

- 3
- 3 ^%
- $

will evaluate 3, 27 and 7625597484987. If you want to refer to one specific input at line n, use

- $n

3.4 Variables and Functions

The internal variables and functions are never enough for practical use. Because of this, you can define your own variables and functions in HyperCalc.

3.4.1 Custom Variables

To define a custom variable, enter

- name = def

Here, “name” is the name of the variable and “def” is its definition. To use the variable, just type its name. For example,

- $c = 299792458$
- $m = 9.10938188E-31$
- $massEnergyOfElectron = m \times c^2$

will define three variables: $c$, $m$ and $massEnergyOfElectron$ and are assigned to be 299792458, $9.10938 \times 10^{-31}$ and $mc^2 = 8.18710 \times 10^{-14}$ respectively.

Notice that the internal variables ($e$, $\pi$, $\phi$, $\gamma$ and $\infty$) will never be overridden. If you call $pi = 22/7$ then use $pi$ in later evaluations you will still get 3.14159… but not 3.142857…. .
3.4.2 Custom Functions

To define a custom variable, enter

• \textit{name} := \textit{def}

Here, “name” is the name of the function and “\textit{def}” is its definition. You can use any numbers of arguments, and use \#n to substitute them (the \textit{n} corresponds to the \textit{n}th argument). \#1 can be entered as just \#. To use the function, type its name then followed by the list of arguments enclosed inside the parenthesis. For example,

• \texttt{cosineLawS} := \texttt{sqrt(#1^2 + #2^2 - 2#1#2cos(#3))}
• \texttt{cosineLawA} := \texttt{acos((#1^2 + #2^2 - #3^2)/(2#1#2))}
• \texttt{cosineLawA(5, 6, 7)/deg}

will define two functions: \texttt{cosineLawS} and \texttt{cosineLawA} that both take three arguments. Their definitions are:

\[
\text{cosineLawS}(x_1, x_2, x_3) = \sqrt{x_1^2 + x_2^2 - 2x_1x_2\cos x_3}
\]

and

\[
\text{cosineLawA}(x_1, x_2, x_3) = \frac{x_1^2 + x_2^2 - x_3^2}{2x_1x_2}
\]

The last statement evaluates the \texttt{cosineLawA} function and set the arguments \((x_1, x_2, x_3)\) to be \((5, 6, 7)\). The result of this function would be 1.36943… and the final result would be \(78.46304096718451\).

A function can take no arguments as well. For example,

• \texttt{f} := \texttt{%^%}

To call these kinds of functions, you do not need to place a pair of parenthesis after them, i.e.,

• \texttt{12}
• \texttt{5 + f}

works and results \texttt{8916100448261}.

As with variables, the internal functions cannot be overridden either.
3.4.3 Variables vs. Functions

At a first glance, a function with no arguments seems to have the same meaning as variable. This is totally wrong. To major difference of variables and functions is that variables are evaluated once they are assigned while functions are evaluated only when they are called. Compare the followings:

- 5
- myVar = 4 + %
- myFunc := 4 + %
- 18

If you call myVar after “18”, you get 9 because when it is defined to be the result of 4 + % in the second line, which is 9. But if you call myFunc you will get 22 because when it is defined to be the pattern 4 + %.

3.4.4 Reviewing Custom Variables and Functions

To know what custom variables have been defined, enter

- !=

Similarly, to know definitions of all custom functions, enter

- !:=

3.4.5 Removing Custom Variables and Functions

To remove a variable or function, enter

- name =.

To remove all variables, enter

- !!=

or
• \(!=\).

To remove all functions, enter

• \(!!:=\)

or

• \(!:=\).

### 3.5 Miscellaneous

To clear the output screen, enter

• \(!!\)

To clear the I/O history, enter

• \(!!\%\)

or

• \(!!\$

To view all commands preset in HyperCalc, enter

• \(?\)
Chapter 4

Troubleshooting

4.1 Non-Intuitive Results when Working with Huge Numbers

If you spend a while exploring the ranges of huge numbers HyperCalc can handle, you will probably start noticing some paradoxical results and might even start to think the calculator is giving wrong answers.

For example, try calculating 27 to the power of googolplex (a googolplex is $10^{100}$ and a googol is $10^{100}$). Key in:

• $27^{10^{10^{100}}}$

and it prints $10^{10^{10^{100}}}$. So the calculator thinks that:

$$27^{10^{10^{100}}} = 10^{10^{10^{100}}}$$

This is clearly wrong — and it doesn’t even seem to be a good approximation. What’s going on?

Let’s try calculating the correct answer ourselves. We need to express the answer as 10 to the power of 10 to the power of something, because that’s the standard format the calculator is using, and we’re going to see how much of an error it made. So, we want to compute $27^{10^{10^{100}}}$ as a tower of powers of 10. The first step is express the power of 27 as a power of 10 with a product in the exponent, using the formula $x^y = 10^{y \log_{10} x}$:

$$27^{10^{10^{100}}} = 10^{\log_{10} 27 \times 10^{10^{100}}}$$
log 27 is about 1.43, so we have

\[ 27^{10^{100}} = 10^{1.43 \times 10^{100}} \]

Now we have a base of 10 but the exponent still needs work. The next step is to express the product as a sum in the next-higher exponent; this time the formula we use is \( x^y = 10^{\log x \times \log y} \):

\[ 10^{1.43 \times 10^{100}} = 10^{10^{\log 1.43 \times \log 100}} \]

log 1.43 is about 0.155, and if we add this to 10^{100} we get

\[ 
\begin{align*}
10^{10^{0.155 \times 10^{100}}} &= 10^{10^{1000.155}} \\
&= 10^{10^{1000.000155 \times 10^{100}}} 
\end{align*}
\]

where there are 94 more 0's in place of each of the “...”. So our final answer is:

\[ 27^{10^{100}} = 10^{10^{1000.000155 \times 10^{100}}} \]

Now that we’ve expressed the value of 27 googolplex precisely enough to see the calculator’s error — look how small the error is! The calculator would need to have at least 104 digits of precision to be able to handle the value “1.000...000155” accurately — but it only has 16 digits of accuracy. Those 16 digits are taken up by the 1 and the first 15 0’s — so when the calculator gets to the step where we’re adding 0.155 to 1.0 × 10^{100}, it just rounds off the answer to 1.0 × 10^{100} — and produces the answer we saw when we performed the calculation:

\[ 10^{10^{100}} \]

Even if it did have the precision, it wouldn’t have room to print the whole 104 digits on the screen, so the answer you see would look the same. And no matter how many digits of accuracy we try to give the calculator, there’s always another even bigger number it wouldn’t be able to handle. For example, the calculator would need slightly over a million digits of accuracy to distinguish

\[ 27^{10^{10^{100}}} \quad \text{from} \quad 10^{10^{10^{100}}} \]

and if we just add one more 10 to that tower of exponents, all hope of avoiding roundoff is lost.

### 4.2 FAQ

#### 4.2.1 Why I can’t use x as the multiplication sign?

If you were switched from HyperCalc Perl, you will notice that x can no longer be a substitution of multiplication sign, and you will get an “Undefined variable
or function” error. The reason is that HyperCalc JavaScript no longer supports
this because of the introduction of implicit multiplication sign (spaces). For
instance, if x is used as the multiplication sign, then it would be ambiguous for
what $x \times x \times x$ means: does it mean $x \cdot x$ or $x \cdot x \cdot x$? Of course, the implicit mulpi-
lication sign feature can be removed, but this is a bigger trade-off. Even without
the implicit multiplication sign, this feature is still a dirty implementation (at
least in my opinion) and should not be used.

4.2.2 Why I can’t use c or r as input/output history recall?

They are mapped to the characters $ and % respectively.

4.2.3 I entered !! for re-evaluating the last statement but the
screen was blanked.

You should enter $ instead. !! is for clearing the output screen.

4.2.4 Why $7 / 100 * 100$ does not give 7?

This is because of how JavaScript handles a number. In JavaScript, a number
is in IEEE 1394 Double format, and all key information about a number is in
binary format. Precision is lost because of this. Hence the result will be erred
by a little — about $8.88 \times 10^{-16}$ in this case. In order to improve the accuracy,
we have started to consider using arbitrary-precision float numbers, but this is
hard to implement. Hence you should expect waiting for a long period.

4.2.5 Can I store my custom variables/functions in a file?

Generally, you can’t.
Technically, you can do it by changing the source code (hint: changes line 86
and 87 in the source).

4.2.6 Can I redistribute/modify HyperCalc?

Yes. You can redistribute/modify HyperCalc under the terms of the GNU
General Public License (See chapter 5).
4.2.7 What if I still have questions?

Email it to casio_fifty@yahoo.com.hk.
Chapter 5

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