

Pari-GP reference card

(PARI-GP version 2.17.1)

Note: optional arguments are surrounded by braces {}.

To start the calculator, type its name in the terminal: **gp**

To exit **gp**, type **quit**, **\q**, or **<C-D>** at prompt.

Help

describe function	?function
extended description	??keyword
list of relevant help topics	???pattern
name of GP-1.39 function <i>f</i> in GP-2.*	whatnow(<i>f</i>)

Input/Output

previous result, the result before	%, %`, %``. etc.
<i>n</i> -th result since startup	% <i>n</i>
separate multiple statements on line	;
extend statement on additional lines	\
extend statements on several lines	{ <i>seq</i> ₁ ; <i>seq</i> ₂ ;}
comment	/* ... */
one-line comment, rest of line ignored	\\ ...

Metacommands & Defaults

set default <i>d</i> to <i>val</i>	default({ <i>d</i> },{ <i>val</i> })
toggle timer on/off	#
print time for last result	##
print defaults	\d
set debug level to <i>n</i>	\g <i>n</i>
set memory debug level to <i>n</i>	\gm <i>n</i>
set <i>n</i> significant digits / bits	\p <i>n</i> , \pb <i>n</i>
set <i>n</i> terms in series	\ps <i>n</i>
quit GP	\q
print the list of PARI types	\t
print the list of user-defined functions	\u
read file into GP	\r <i>filename</i>
set debuglevel for domain <i>D</i> to <i>n</i>	setdebug(<i>D</i> , <i>n</i>)

Debugger / break loop

get out of break loop	break or <C-D>
go up/down <i>n</i> frames	dbg_up({ <i>n</i> }), dbg_down
set break point	breakpoint()
examine object <i>o</i>	dbg_x(<i>o</i>)
current error data	dbg_err()
number of objects on heap and their size	getheap()
total size of objects on PARI stack	getstack()

PARI Types & Input Formats

t_INT. Integers; hex, binary	±31; ±0x1F, ±0b101
t_REAL. Reals	±3.14, 6.022 E23
t_INTMOD. Integers modulo <i>m</i>	Mod(<i>n</i> , <i>m</i>)
t_FRAC. Rational Numbers	<i>n</i> / <i>m</i>
t_FFELT. Elt in finite field F _{<i>q</i>}	ffgen(<i>q</i> , 't)
t_COMPLEX. Complex Numbers	<i>x</i> + <i>y</i> * I
t_PADIC. <i>p</i> -adic Numbers	<i>x</i> + 0(<i>p</i> ^ <i>k</i>)
t_QUAD. Quadratic Numbers	<i>x</i> + <i>y</i> * quadgen(<i>D</i> ,{'w'})
t_POLMOD. Polynomials modulo <i>g</i>	Mod(<i>f</i> , <i>g</i>)
t_POL. Polynomials	<i>a</i> * <i>x</i> ^ <i>n</i> + ... + <i>b</i>
t_SER. Power Series	<i>f</i> + 0(<i>x</i> ^ <i>k</i>)
t_RFRAC. Rational Functions	<i>f</i> / <i>g</i>
t_QFB. Binary quadratic form	Qfb(<i>a</i> , <i>b</i> , <i>c</i>)
t_VEC/t_COL. Row/Column Vectors	[<i>x</i> , <i>y</i> , <i>z</i>], [<i>x</i> , <i>y</i> , <i>z</i>]~
t_VEC integer range	[1..10]

t_VECSMALL. Vector of small ints	Vecsmall([<i>x</i> , <i>y</i> , <i>z</i>])
t_MAT. Matrices	[<i>a</i> , <i>b</i> ; <i>c</i> , <i>d</i>]
t_LIST. Lists	List([<i>x</i> , <i>y</i> , <i>z</i>])
t_STR. Strings	"abc"
t_INFINITY. ±∞	+oo, -oo

Reserved Variable Names

$\pi \approx 3.14$, $\gamma \approx 0.57$, $C \approx 0.91$, $I = \sqrt{-1}$	Pi, Euler, Catalan, I
Landau's big-oh notation	O

Information about an Object, Precision

PARI type of object <i>x</i>	type(<i>x</i>)
length of <i>x</i> / size of <i>x</i> in memory	# <i>x</i> , sizebyte(<i>x</i>)
real precision / bit precision of <i>x</i>	precision(<i>x</i>), bitprecision(<i>x</i>)
<i>p</i> -adic, series prec. of <i>x</i>	padicprec(<i>x</i> , <i>p</i>), serprec(<i>x</i> , <i>v</i>)
current dynamic precision	getlocalprec, getlocalbitprec

Operators

basic operations	+, −, *, /, ^, sqr
i←i+1, i←i-1, i←i*j, ...	i++, i--, i*=j,...
Euclidean quotient, remainder	<i>x</i> \/ <i>y</i> , <i>x</i> % <i>y</i> , divrem(<i>x</i> , <i>y</i>)
shift <i>x</i> left or right <i>n</i> bits	<i>x</i> << <i>n</i> , <i>x</i> >> <i>n</i> or shift(<i>x</i> ,± <i>n</i>)
multiply by 2 ^{<i>n</i>}	shiftmul(<i>x</i> , <i>n</i>)
comparison operators	<=, <, >=, >, ==, !=, ==, lex, cmp
boolean operators (or, and, not)	, &&, !
bit operations	bitand, bitneg, bitor, bitxor, bitnegimply
maximum/minimum of <i>x</i> and <i>y</i>	max(<i>x</i> , <i>y</i>), min(<i>x</i> , <i>y</i>)
sign of <i>x</i> (gives −1, 0, 1)	sign(<i>x</i>)
binary exponent of <i>x</i>	exponent(<i>x</i>)
derivative of <i>f</i> , 2nd derivative, etc.	<i>f</i> ' , <i>f</i> '' , ...
differential operator	diffop(<i>f</i> , <i>v</i> , <i>d</i> , { <i>n</i> = 1})
quote operator (formal variable)	'x
assignment	x = <i>value</i>
simultaneous assignment <i>x</i> ← <i>v</i> [1], <i>y</i> ← <i>v</i> [2]	[x,y] = v

Select Components

<i>Caveat</i> : components start at index <i>n</i> = 1.	
<i>n</i> -th component of <i>x</i>	component(<i>x</i> , <i>n</i>)
<i>n</i> -th component of vector/list <i>x</i>	<i>x</i> [<i>n</i>]
components <i>a</i> , <i>a</i> + 1, ..., <i>b</i> of vector <i>x</i>	<i>x</i> [<i>a</i> .. <i>b</i>]
(<i>m</i> , <i>n</i>)-th component of matrix <i>x</i>	<i>x</i> [<i>m</i> , <i>n</i>]
row <i>m</i> or column <i>n</i> of matrix <i>x</i>	<i>x</i> [<i>m</i> ,], <i>x</i> [, <i>n</i>]
numerator/denominator of <i>x</i>	numerator(<i>x</i>), denominator(<i>x</i>)

Random Numbers

random integer/prime in [0, <i>N</i> [random(<i>N</i>), randomprime(<i>N</i>)
get/set random seed	getrand, setrand(<i>s</i>)

Conversions

to vector, matrix, vec. of small ints	Col/Vec, Mat, Vecsmall
to list, set, map, string	List, Set, Map, Str
create (<i>x</i> mod <i>y</i>)	Mod(<i>x</i> , <i>y</i>)
make <i>x</i> a polynomial of <i>v</i>	Pol(<i>x</i> , { <i>v</i> })
variants of Pol <i>et al.</i> , in reverse order	Polrev, Vecrev, Colrev
make <i>x</i> a power series of <i>v</i>	Ser(<i>x</i> , { <i>v</i> })
convert <i>x</i> to simplest possible type	simplify(<i>x</i>)
object <i>x</i> with real precision <i>n</i>	precision(<i>x</i> , <i>n</i>)
object <i>x</i> with bit precision <i>n</i>	bitprecision(<i>x</i> , <i>n</i>)
set precision to <i>p</i> digits in dynamic scope	localprec(<i>p</i>)
set precision to <i>p</i> bits in dynamic scope	localbitprec(<i>p</i>)

Character strings

convert to TeX representation	strtex(<i>x</i>)
string from bytes / from format+args	strchr, sprintf
split string / join strings	strsplit, strjoin
convert time <i>t</i> ms. to h, m, s, ms format	strtime(<i>t</i>)
Conjugates and Lifts	
conjugate of a number <i>x</i>	conj(<i>x</i>)
norm of <i>x</i> , product with conjugate	norm(<i>x</i>)
<i>L</i> ^{<i>p</i>} norm of <i>x</i> (<i>L</i> [∞] if no <i>p</i>)	normlp(<i>x</i> , { <i>p</i> })
square of <i>L</i> ² norm of <i>x</i>	norml2(<i>x</i>)
lift of <i>x</i> from Mods and <i>p</i> -adics	lift, centerlift(<i>x</i>)
recursive lift	liftall
lift all t_INT and t_PADIC (→t_INT)	liftint
lift all t_POLMOD (→t_POL)	liftpol

Lists, Sets & Maps

Sets (= row vector with strictly increasing entries w.r.t. cmp)	
intersection of sets <i>x</i> and <i>y</i>	setintersect(<i>x</i> , <i>y</i>)
set of elements in <i>x</i> not belonging to <i>y</i>	setminus(<i>x</i> , <i>y</i>)
symmetric difference <i>x</i> Δ <i>y</i>	setdelta(<i>x</i> , <i>y</i>)
union of sets <i>x</i> and <i>y</i>	setunion(<i>x</i> , <i>y</i>)
does <i>y</i> belong to the set <i>x</i>	setsearch(<i>x</i> , <i>y</i> , { <i>flag</i> })
set of all <i>f</i> (<i>x</i> , <i>y</i>), <i>x</i> ∈ <i>X</i> , <i>y</i> ∈ <i>Y</i>	setbinop(<i>f</i> , <i>X</i> , <i>Y</i>)
is <i>x</i> a set ?	setisset(<i>x</i>)

Lists. create empty list: <i>L</i> = List()	
append <i>x</i> to list <i>L</i>	listput(<i>L</i> , <i>x</i> , { <i>i</i> })
remove <i>i</i> -th component from list <i>L</i>	listpop(<i>L</i> , { <i>i</i> })
insert <i>x</i> in list <i>L</i> at position <i>i</i>	listinsert(<i>L</i> , <i>x</i> , <i>i</i>)
sort the list <i>L</i> in place	listsort(<i>L</i> , { <i>flag</i> })
Maps. create empty dictionary: <i>M</i> = Map()	
attach value <i>v</i> to key <i>k</i>	mapput(<i>M</i> , <i>k</i> , <i>v</i>)
recover value attach to key <i>k</i> or error	mapget(<i>M</i> , <i>k</i>)
is key <i>k</i> in the dict? (set <i>v</i> to <i>M</i> (<i>k</i>))	mapisdefined(<i>M</i> , <i>k</i> , {& <i>v</i> })
evaluate <i>f</i> at <i>M</i> (<i>k</i>)	mapapply(<i>M</i> , <i>k</i> , <i>f</i>)
remove <i>k</i> from map domain	mapdelete(<i>M</i> , <i>k</i>)

GP Programming

User functions and closures

x, *y* are formal parameters; *y* defaults to Pi if parameter omitted;
z, *t* are local variables (lexical scope), *z* initialized to 1.

fun(x, y=Pi) = my(z=1, t); seq	
fun = (x, y=Pi) -> my(z=1, t); seq	
attach help message <i>h</i> to <i>s</i>	addhelp(<i>s</i> , <i>h</i>)
undefine symbol <i>s</i> (also kills help)	kill(<i>s</i>)
Control Statements (<i>X</i> : formal parameter in expression <i>seq</i>)	
if <i>a</i> ≠ 0, evaluate <i>seq</i> ₁ , else <i>seq</i> ₂	if(<i>a</i> , { <i>seq</i> ₁ }, { <i>seq</i> ₂ })
eval. <i>seq</i> for <i>a</i> ≤ <i>X</i> ≤ <i>b</i>	for(<i>X</i> = <i>a</i> , <i>b</i> , <i>seq</i>)
...for <i>X</i> ∈ <i>v</i>	foreach(<i>v</i> , <i>X</i> , <i>seq</i>)
...for primes <i>a</i> ≤ <i>X</i> ≤ <i>b</i>	forprime(<i>X</i> = <i>a</i> , <i>b</i> , <i>seq</i>)
...for primes ≡ <i>a</i> (mod <i>q</i>)	forprimestep(<i>X</i> = <i>a</i> , <i>b</i> , <i>q</i> , <i>seq</i>)
...for composites <i>a</i> ≤ <i>X</i> ≤ <i>b</i>	forcomposite(<i>X</i> = <i>a</i> , <i>b</i> , <i>seq</i>)
...for <i>a</i> ≤ <i>X</i> ≤ <i>b</i> stepping <i>s</i>	forstep(<i>X</i> = <i>a</i> , <i>b</i> , <i>s</i> , <i>seq</i>)
...for <i>X</i> dividing <i>n</i>	fordiv(<i>n</i> , <i>X</i> , <i>seq</i>)
... <i>X</i> = [<i>n</i> , factor(<i>n</i>)], <i>a</i> ≤ <i>n</i> ≤ <i>b</i>	forfactored(<i>X</i> = <i>a</i> , <i>b</i> , <i>seq</i>)
...as above, <i>n</i> squarefree	forsquarefree(<i>X</i> = <i>a</i> , <i>b</i> , <i>seq</i>)
... <i>X</i> = [<i>d</i> , factor(<i>d</i>)], <i>d</i> <i>n</i>	fordivfactored(<i>n</i> , <i>X</i> , <i>seq</i>)
multivariable for, lex ordering	forvec(<i>X</i> = <i>v</i> , <i>seq</i>)

loop over partitions of n
... permutations of S
... subsets of $\{1, \dots, n\}$
... k -subsets of $\{1, \dots, n\}$
... vectors $v, q(v) \leq B; q > 0$
... $H < G$ finite abelian group
evaluate seq until $a \neq 0$
while $a \neq 0$, evaluate seq
exit n innermost enclosing loops
start new iteration of n -th enclosing loop
return x from current subroutine

Exceptions, warnings
raise an exception / warning
type of error message E
try seq_1 , evaluate seq_2 on error

Functions with closure arguments / results
number of arguments of f
select from v according to f
apply f to all entries in v
evaluate $f(a_1, \dots, a_n)$
evaluate $f(\dots f(f(a_1, a_2), a_3) \dots, a_n)$
calling function as closure

Sums & Products
sum $X = a$ to $X = b$, initialized at x
sum entries of vector v
product of all vector entries
sum $expr$ over divisors of n
... assuming $expr$ multiplicative
product $a \leq X \leq b$, initialized at x
product over primes $a \leq X \leq b$

Sorting
sort x by k -th component
min. m of x ($m = x[i]$), max.
does y belong to x , sorted wrt. f
 $\prod g^x \rightarrow$ factorization (\Rightarrow sorted, unique g)

Input/Output
print with/without $\backslash n$, TeX format
pretty print matrix
print fields with separator
formatted printing
write $args$ to file
write x in binary format
read file into GP
... return as vector of lines
... return as vector of strings
read a string from keyboard

Files and file descriptors
File descriptors allow efficient small consecutive reads or writes from or to a given file. The argument n below is always a descriptor, attached to a file in **r**(ead), **w**(rite) or **a**(ppend) mode.
get descriptor n for file $path$ in given $mode$
... from shell cmd output (pipe)

close descriptor
commit pending write operations
read logical line from file
... raw line from file
write $s \backslash n$ to file
... write s to file

forpart($p = n, seq$)
forperm(S, p, seq)
forsubset(n, p, seq)
forsubset($[n, k], p, seq$)
forqfvec(v, q, b, seq)
forsubgroup($H = G$)
until(a, seq)
while(a, seq)
break($\{n\}$)
next($\{n\}$)
return($\{x\}$)

error(), warning()
errname(E)
iferr(seq_1, E, seq_2)

arity(f)
select(f, v)
apply(f, v)
call(f, a)
fold(f, a)
self()

sum($X = a, b, expr, \{x\}$)
vecsum(v)
vecprod(v)
sumdiv($n, X, expr$)
sumdivmult($n, X, expr$)
prod($X = a, b, expr, \{x\}$)
prodeuler($X = a, b, expr$)

vecsort($x, \{k\}, \{fl = 0\}$)
vecmin($x, \{&i\}$), vecmax
vecsearch($x, y, \{f\}$)
matreduce(m)

print, print1, printtex
printp
printsep(sep, \dots), printsep1
printf()

write, write1, writetex($file, args$)
writebin($file, x$)
read($\{file\}$)
readvec($\{file\}$)
readstr($\{file\}$)
input()

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(PARI-GP version 2.17.1)

Timers
CPU time in ms and reset timer
CPU time in ms since gp startup
time in ms since UNIX Epoch
timeout command after s seconds

Interface with system
allocates a new stack of s bytes
alias old to new
install function from library
execute system command a
... and feed result to GP
... returning GP string
get \$VAR from environment
expand env. variable in string

Parallel evaluation
These functions evaluate their arguments in parallel (pthreads or MPI); args. must not access global variables (use **export** for this) and must be free of side effects. Enabled if threading engine is not *single* in gp header.
evaluate f on $x[1], \dots, x[n]$
evaluate closures $f[1], \dots, f[n]$
as **select**
as **sum**
as **vector**
eval f for $i = a, \dots, b$
... for each element x in v
... for p prime in $[a, b]$
... for $p = a \bmod q$
... for $i = a, a + s, \dots, b$
... multivariate
export x to parallel world
... all dynamic variables
frees exported value x
... all exported values

gettime()
getabstime()
getwalltime()
alarm($s, expr$)

allocatemem($\{s\}$)
alias(new, old)
install($f, code, \{gpf\}, \{lib\}$)
system(a)
extern(a)
externstr(a)
getenv("VAR")
strexpend(x)

parapply(f, x)
pareval(f)
parselect($f, A, \{flag\}$)
parsum($i = a, b, expr$)
parvector($n, i, \{expr\}$)
parfor($i = a, \{b\}, f, \{r\}, \{f_2\}$)
parforeach($v, x, f, \{r\}, \{f_2\}$)
parforprime($p = a, \{b\}, f, \{r\}, \{f_2\}$)
parforprimestep($p = a, \{b\}, q, f, \{r\}, \{f_2\}$)
parforstep($i = a, \{b\}, s, f, \{r\}, \{f_2\}$)
parforvec($X = v, f, \{r\}, \{f_2\}, \{flag\}$)

export(x)
exportall()
unexport(x)
unexportall()

Linear Algebra
dimensions of matrix x
multiply two matrices
... assuming result is diagonal
concatenation of x and y
extract components of x
transpose of vector or matrix x
adjoint of the matrix x
eigenvectors/values of matrix x
characteristic/minimal polynomial of x
trace/determinant of matrix x
permanent of matrix x
Frobenius form of x
QR decomposition
apply **matqr**'s transform to v

Constructors & Special Matrices
 $\{g(x): x \in v \text{ s.t. } f(x)\}$
 $\{x: x \in v \text{ s.t. } f(x)\}$
 $\{g(x): x \in v\}$
row vec. of $expr$ eval'd at $1 \leq i \leq n$
col. vec. of $expr$ eval'd at $1 \leq i \leq n$
vector of small ints

matsize(x)
 $x * y$
matmultodiagonal(x, y)
concat($x, \{y\}$)
vecextract($x, y, \{z\}$)
 $x \sim$, mattranspose(x)
matadjoin(x)
mateigen(x)
charpoly(x), minpoly(x)
trace(x), matdet(x)
matpermanent(x)
matfrobenius(x)
matqr(x)
mathouseholder(Q, v)

[g(x) | x <- v, f(x)]
[x | x <- v, f(x)]
[g(x) | x <- v]
vector($n, \{i\}, \{expr\}$)
vectorv($n, \{i\}, \{expr\}$)
vectorsmall($n, \{i\}, \{expr\}$)

$[c, c \cdot x, \dots, c \cdot x^n]$
 $[1, 2^x, \dots, n^x]$
matrix $1 \leq i \leq m, 1 \leq j \leq n$
define matrix by blocks
diagonal matrix with diagonal x
is x diagonal?
 $x \cdot \text{matdiagonal}(d)$
 $n \times n$ identity matrix
Hessenberg form of square matrix x
 $n \times n$ Hilbert matrix $H_{ij} = (i + j - 1)^{-1}$
 $n \times n$ Pascal triangle
companion matrix to polynomial x
Sylvester matrix of x and y

powers($x, n, \{c = 1\}$)
dirpowers(n, x)
matrix($m, n, \{i\}, \{j\}, \{expr\}$)
matconcat(B)
matdiagonal(x)
matisdiagonal(x)
matmuldiagonal(x, d)
matid(n)
mathess(x)
mathilbert(n)
matpascal($n - 1$)
matcompanion(x)
polsylvestermatrix(x, y)

Gaussian elimination
kernel of matrix x
intersection of column spaces of x and y
solve $MX = B$ (M invertible)
one sol of $M * X = B$
basis for image of matrix x
columns of x *not* in **matimage**
supplement columns of x to get basis
rows, cols to extract invertible matrix
rank of the matrix x
solve $MX = B \bmod D$
image mod D
kernel mod D
inverse mod D
determinant mod D

Lattices & Quadratic Forms
Quadratic forms
evaluate ${}^t x Q y$
evaluate ${}^t x Q x$
signature of quad form ${}^t y * x * y$
decomp into squares of ${}^t y * x * y$
eigenvalues/vectors for real symmetric x
Cholesky decomposition of x

qfeval($\{Q = id\}, x, y$)
qfeval($\{Q = id\}, x$)
qfsign(x)
qfgaussred(x)
qfjacobi(x)
qfcholesky(x)

HNF and SNF
upper triangular Hermite Normal Form
HNF of x where d is a multiple of $\det(x)$
multiple of $\det(x)$
HNF of $(x \mid \text{diagonal}(D))$
elementary divisors of x
 q -rank from elementary divisors
elementary divisors of $\mathbf{Z}[a]/(f'(a))$
integer kernel of x
Z-module \leftrightarrow **Q**-vector space

Lattices
LLL-algorithm applied to columns of x
... for Gram matrix of lattice
find up to m sols of $qfeval(x, y) \leq b$
... up to m closest vectors to t
 $v, v[i] :=$ number of y s.t. $qfeval(x, y) = i$
perfection rank of x
find isomorphism between q and Q

mathnf(x)
mathnfmod(x, d)
matdetint(x)
mathnfmodid(x, D)
matsnf(x)
snfrank(v, q)
poldiscreduced(f)
matkerint(x)
matrixqz(x, p)

qflll($x, \{flag\}$)
qflllgram($x, \{flag\}$)
qfminim(x, b, m)
qfcvp(x, t, m)
qfrep($x, B, \{flag\}$)
qfperfection(x)
qfisom(q, Q)

Based on an earlier version by Joseph H. Silverman
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precompute for isomorphism test with q	<code>qfisominit(q)</code>
automorphism group of q	<code>qfauto(q)</code>
convert <code>qfauto</code> for GAP/Magma	<code>qfautoexport($G, \{flag\}$)</code>
orbits of V under $G \subset \mathrm{GL}(V)$	<code>qforbits(G, V)</code>
Polynomials & Rational Functions	
all defined polynomial variables	<code>variables()</code>
get var. of highest priority (higher than v)	<code>varhigher($name, \{v\}$)</code>
... of lowest priority (lower than v)	<code>varlower($name, \{v\}$)</code>
Coefficients, variables and basic operators	
degree of f	<code>poldegree(f)</code>
coef. of degree n of f , leading coef.	<code>polcoef(f, n), pollead</code>
main variable / all variables in f	<code>variable(f), variables(f)</code>
replace x by y in f	<code>subst(f, x, y)</code>
evaluate f replacing vars by their value	<code>eval(f)</code>
replace polynomial expr. $T(x)$ by y in f	<code>substpol(f, T, y)</code>
replace x_1, \dots, x_n by y_1, \dots, y_n in f	<code>substvec(f, x, y)</code>
$f \in A[x]$; reciprocal polynomial $x^{\deg f} f\left(\frac{1}{x}\right)$	<code>polrecip(f)</code>
gcd of coefficients of f	<code>content(f)</code>
derivative of f w.r.t. x	<code>deriv($f, \{x\}$)</code>
... n -th derivative of f	<code>derivn($f, n, \{x\}$)</code>
formal integral of f w.r.t. x	<code>intformal($f, \{x\}$)</code>
formal sum of f w.r.t. x	<code>sumformal($f, \{x\}$)</code>
Constructors & Special Polynomials	
interpolation polynomial at $(x[1], y[1]), \dots, (x[n], y[n])$, evaluated at t , with error estimate e	<code>polinterpolate($x, \{y\}, \{t\}, \{&e\}$)</code>
monic polynomial from roots r	<code>polfromroots(r)</code>
$T_n/U_n, H_n$	<code>polchebyshev(n), polhermite(n)</code>
$P_n, L_n^{(\alpha)}$	<code>pollegendre(n), pollaguerre(n, a)</code>
n -th cyclotomic polynomial Φ_n	<code>polcyclo(n)</code>
return n if $f = \Phi_n$, else 0	<code>poliscyclo(f)</code>
is f a product of cyclotomic polynomials?	<code>poliscycloprod(f)</code>
Zagier's polynomial of index (n, m)	<code>polzagier(n, m)</code>
Resultant, elimination	
discriminant of polynomial f	<code>poldisc(f)</code>
find factors of <code>poldisc(f)</code>	<code>poldiscfactors(f)</code>
resultant $R = \mathrm{Res}_v(f, g)$	<code>polresultant($f, g, \{v\}$)</code>
$[u, v, R], xu + yv = \mathrm{Res}_v(f, g)$	<code>polresultantext($x, y, \{v\}$)</code>
solve Thue equation $f(x, y) = a$	<code>thue($t, a, \{sol\}$)</code>
initialize t for Thue equation solver	<code>thueinit(f)</code>
Roots and Factorization (Complex/Real)	
complex roots of f	<code>polroots(f)</code>
bound complex roots of f	<code>polrootsbound(f)</code>
number of real roots of f (in $[a, b]$)	<code>polsturm($f, \{[a, b]\}$)</code>
real roots of f (in $[a, b]$)	<code>polrootsreal($f, \{[a, b]\}$)</code>
complex embeddings of <code>t.POLMOD z</code>	<code>conjvec(z)</code>
Roots and Factorization (Finite fields)	
factor f mod p , roots	<code>factormod(f, p), polrootsmod</code>
factor f over $\mathbf{F}_p[x]/(T)$, roots	<code>factormod($f, [T, p]$), polrootsmod</code>
squarefree factorization of f in $\mathbf{F}_q[x]$	<code>factormodSQF($f, \{D\}$)</code>
distinct degree factorization of f in $\mathbf{F}_q[x]$	<code>factormodDDF($f, \{D\}$)</code>
factor n -th cyclotomic pol. Φ_n mod p	<code>factormodcyclo(n, p)</code>
Roots and Factorization (p-adic fields)	
factor f over \mathbf{Q}_p , roots	<code>factorpadic(f, p, r), polrootspadic</code>
p -adic root of f congruent to a mod p	<code>padicappr(f, a)</code>
Newton polygon of f for prime p	<code>newtonpoly(f, p)</code>
Hensel lift $A/lc(A) = \prod_i B[i] \bmod p^e$	<code>polhensellift(A, B, p, e)</code>

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$T = \prod (x - z_i) \mapsto \prod (x - \omega(z_i)) \in \mathbf{Z}_p[x]$	<code>polteichmuller(T, p, e)</code>
extensions of \mathbf{Q}_p of degree N	<code>padicfields(p, N)</code>
Roots and Factorization (Miscellaneous)	
symmetric powers of roots of f up to n	<code>polsym(f, n)</code>
Graeffe transform of $f, g(x^2) = f(x)f(-x)$	<code>polgraeffe(f)</code>
factor f over coefficient field	<code>factor(f)</code>
cyclotomic factors of $f \in \mathbf{Q}[X]$	<code>polcyclofactors(f)</code>
Finite Fields	
A finite field is encoded by any element (<code>t_FFELT</code>).	
find irreducible $T \in \mathbf{F}_p[x]$, $\deg T = n$	<code>ffinit($p, n, \{x\}$)</code>
Create t in $\mathbf{F}_q \simeq \mathbf{F}_p[t]/(T)$	<code>t = ffgen($T, 't$)</code>
... indirectly, with implicit T	<code>t = ffgen($q, 't$); T = t.mod</code>
map m from $\mathbf{F}_q \ni a$ to $\mathbf{F}_{q^k} \ni b$	<code>m = ffbend(a, b)</code>
build $K = \mathbf{F}_q[x]/(P)$ extending $\mathbf{F}_q \ni a$,	<code>ffextend(a, P)</code>
evaluate map m on x	<code>ffmap(m, x)</code>
inverse map of m	<code>ffinvmap(m)</code>
compose maps $m \circ n$	<code>ffcompomap(m, n)</code>
x as polmod over codomain of map m	<code>ffmaprel(m, x)</code>
F^n over $\mathbf{F}_q \ni a$	<code>fffrobenius(a, n)</code>
$\#\{\text{monic irred. } T \in \mathbf{F}_q[x], \deg T = n\}$	<code>ffnbirred(q, n)</code>
Formal & p-adic Series	
truncate power series or p -adic number	<code>truncate(x)</code>
valuation of x at p	<code>valuation(x, p)</code>
Dirichlet and Power Series	
Taylor expansion around 0 of f w.r.t. x	<code>taylor(f, x)</code>
Laurent series of closure F up to x^k	<code>laurentseries(f, k)</code>
$\sum a_k b_k t^k$ from $\sum a_k t^k$ and $\sum b_k t^k$	<code>serconvol(a, b)</code>
$f = \sum a_k t^k$ from $\sum (a_k/k!) t^k$	<code>serlaplace(f)</code>
reverse power series F so $F(f(x)) = x$	<code>serreverse(f)</code>
remove terms of degree $< n$ in f	<code>serchop(f, n)</code>
Dirichlet series multiplication / division	<code>dirmul, dirdiv(x, y)</code>
Dirichlet Euler product (b terms)	<code>direuler($p = a, b, expr$)</code>
Transcendental and p-adic Functions	
real, imaginary part of x	<code>real(x), imag(x)</code>
absolute value, argument of x	<code>abs(x), arg(x)</code>
square/ n th root of x	<code>sqrt(x), sqrtsn($x, n, \{&z\}$)</code>
all n -th roots of 1	<code>rootsof1(n)</code>
FFT of $[f_0, \dots, f_{n-1}]$	<code>w = fftinit(n), fft/fftinw(w, f)</code>
trig functions	<code>sin, cos, tan, cotan, sinc</code>
inverse trig functions	<code>asin, acos, atan</code>
hyperbolic functions	<code>sinh, cosh, tanh, cotanh</code>
inverse hyperbolic functions	<code>asinh, acosh, atanh</code>
$\log(x)$, $\log(1+x)$, e^x , $e^x - 1$	<code>log, loglp, exp, expm1</code>
Euler Γ function, $\log \Gamma$, Γ'/Γ	<code>gamma, lngamma, psi</code>
half-integer gamma function $\Gamma(n+1/2)$	<code>gammah(n)</code>
Riemann's zeta $\zeta(s) = \sum n^{-s}$	<code>zeta(s)</code>
$\sum_{1 \leq n \leq N} n^s$	<code>dirpowerssum(N, s)</code>
Hurwitz's $\zeta(s, x) = \sum (n+x)^{-s}$	<code>zetahurwitz(s, x)</code>
Lerch $\Phi(z, s, x) = \sum z^n (n+x)^{-s}$	<code>lerchphi(z, s, x)</code>
Lerch $L(s, x, t) = \Phi(e^{2i\pi t}, s, x)$	<code>lerchzeta(s, x, t)</code>
multiple zeta value (MZV), $\zeta(s_1, \dots, s_k)$	<code>zetamult($s, \{T\}$)</code>
all MZVs for weight $\sum s_i = n$	<code>zetamultall(n)</code>
convert MZV id to $[s_1, \dots, s_k]$	<code>zetamultconvert($f, \{flag\}$)</code>
MZV dual sequence	<code>zetamultdual(s)</code>
multiple polylog $Li_{s_1, \dots, s_k}(z_1, \dots, z_k)$	<code>polylogmult(s, z)</code>

incomplete Γ function ($y = \Gamma(s)$)	<code>incgam($s, x, \{y\}$)</code>
complementary incomplete Γ	<code>incgamc(s, x)</code>
$\int_x^\infty e^{-t} dt/t$, $(2/\sqrt{\pi}) \int_x^\infty e^{-t^2} dt$	<code>eint1, erfc</code>
elliptic integral of 1st and 2nd kind	<code>ellK(k), ellE(k)</code>
dilogarithm of x	<code>dilog(x)</code>
m -th polylogarithm of x	<code>polylog($m, x, \{flag\}$)</code>
U -confluent hypergeometric function	<code>hyperu(a, b, u)</code>
Hypergeometric ${}_pF_q(A, B; z)$	<code>hypergeom(A, B, z)</code>
Bessel $J_n(x)$, $J_{n+1/2}(x)$	<code>besselj(n, x), besseljh(n, x)</code>
Bessel $I_\nu, K_\nu, H_\nu^1, H_\nu^2, Y_\nu$	<code>(bessel)i, k, h1, h2, y</code>
k -th zero of $J_\nu(x)$	<code>besseljzero($nu, \{k = 1\}$)</code>
k -th zero of $Y_\nu(x)$	<code>besselyzero($nu, \{k = 1\}$)</code>
Airy functions $A_i(x)$, $B_i(x)$	<code>airy(x)</code>
Lambert W : x s.t. $xe^x = y$	<code>lambertw(y)</code>
Teichmuller character of p -adic x	<code>teichmuller(x)</code>

Iterations, Sums & Products

Numerical integration for meromorphic functions	
Behaviour at endpoint for Double Exponential (DE) methods: either a scalar ($a \in \mathbf{C}$, regular) or $\pm\infty$ (decreasing at least as x^{-2}) or	
$(x-a)^{-\alpha}$ singularity	<code>[a, α]</code>
exponential decrease $e^{-\alpha x }$	<code>[$\pm\infty, \alpha$], $\alpha > 0$</code>
slow decrease $ x ^\alpha$	<code>... $\alpha < -1$</code>
oscillating as $\cos(kx)$	<code>$\alpha = k\mathbf{I}$, $k > 0$</code>
oscillating as $\sin(kx)$	<code>$\alpha = -k\mathbf{I}$, $k > 0$</code>
numerical integration	<code>intnum($x = a, b, f, \{T\}$)</code>
weights T for intnum	<code>intnuminit($a, b, \{m\}$)</code>
weights T incl. kernel K	<code>intfuncinit($t = a, b, K, \{m\}$)</code>
integrate $(2i\pi)^{-1} f$ on circle $ z-a = R$	<code>intcirc($x = a, R, f, \{T\}$)</code>
Other integration methods	
n -point Gauss-Legendre	<code>intnumgauss($x = a, b, f, \{n\}$)</code>
weights for n -point Gauss-Legendre	<code>intnumgaussinit($\{n\}$)</code>
quasi-periodic function, period $2H$	<code>intnumosc($x = a, f, H$)</code>
Romberg (low accuracy)	<code>intnumromb($x = a, b, f, \{flag\}$)</code>
Numerical summation	
sum of series $f(n)$, $n \geq a$ (low accuracy)	<code>suminf($n = a, expr$)</code>
sum of alternating/positive series	<code>sumalt, sumpos</code>
sum of series using Euler-Maclaurin	<code>sumnum($n = a, f, \{T\}$)</code>
... Sidi summation	<code>sumnumsidi($n = a, f$)</code>
$\sum_{n \geq a} F(n)$, F rational function	<code>sumnumrat(F, a)</code>
$\dots \sum_{p \geq a} F(p^s)$	<code>sumeulerrat($F, \{s = 1\}, \{a = 2\}$)</code>
weights for sumnum, a as in DE	<code>sumnuminit($\{\infty, a\}$)</code>
sum of series by Monien summation	<code>sumnummonien($n = a, f, \{T\}$)</code>
weights for sumnummonien	<code>sumnummonieninit($\{\infty, a\}$)</code>
sum of series using Abel-Plana	<code>sumnumap($n = a, f, \{T\}$)</code>
weights for sumnumap, a as in DE	<code>sumnumapinit($\{\infty, a\}$)</code>
sum of series using Lagrange	<code>sumnumlagrange($n = a, f, \{T\}$)</code>
weights for sumnumlagrange	<code>sumnumlagrangeinit</code>
Products	
product $a \leq X \leq b$, initialized at x	<code>prod($X = a, b, expr, \{x\}$)</code>
product over primes $a \leq X \leq b$	<code>prodeuler($X = a, b, expr$)</code>
infinite product $a \leq X \leq \infty$	<code>prodinf($X = a, expr$)</code>
$\prod_{n \geq a} F(n)$, F rational function	<code>prodnumrat(F, a)</code>
$\prod_{p \geq a} F(p^s)$	<code>prodeulerrat($F, \{s = 1\}, \{a = 2\}$)</code>

Other numerical methods

real root of f in $[a, b]$; bracketed root	<code>solve($X = a, b, f$)</code>
...interval splitting, step s	<code>solvestep($X = a, b, s, f, \{flag = 0\}$)</code>
limit of $f(t)$, $t \rightarrow \infty$	<code>limitnum($f, \{\alpha\}$)</code>
asymptotic expansion of f (rational)	<code>asypnum($f, \{\alpha\}$)</code>
... $N + 1$ terms as floats	<code>asypnumraw($f, N, \{\alpha\}$)</code>
numerical derivation w.r.t x : $f'(a)$	<code>derivnum($x = a, f$)</code>
evaluate continued fraction F at t	<code>contfraceval($F, t, \{L\}$)</code>
power series to cont. fraction (L terms)	<code>contfracinit($S, \{L\}$)</code>
Padé approximant (deg. denom. $\leq B$)	<code>bestapprPade($S, \{B\}$)</code>

Elementary Arithmetic Functions

vector of binary digits of $ x $	<code>binary(x)</code>
bit number n of integer x	<code>bittest(x, n)</code>
Hamming weight of integer x	<code>hammingweight(x)</code>
digits of integer x in base B	<code>digits($x, \{B = 10\}$)</code>
sum of digits of integer x in base B	<code>sumdigits($x, \{B = 10\}$)</code>
integer from digits	<code>fromdigits($v, \{B = 10\}$)</code>
ceiling/floor/fractional part	<code>ceil, floor, frac</code>
round x to nearest integer	<code>round($x, \{\&e\}$)</code>
truncate x	<code>truncate($x, \{\&e\}$)</code>
gcd/LCM of x and y	<code>gcd(x, y), lcm(x, y)</code>
gcd of entries of a vector/matrix	<code>content(x)</code>

Primes and Factorization

extra prime table	<code>addprimes()</code>
add primes in v to prime table	<code>addprimes(v)</code>
remove primes from prime table	<code>removeprimes(v)</code>
Chebyshev $\pi(x)$, n -th prime p_n	<code>primepi(x), prime(n)</code>
vector of first n primes	<code>primes(n)</code>
smallest prime $\geq x$	<code>nextprime(x)</code>
largest prime $\leq x$	<code>precprime(x)</code>
factorization of x	<code>factor($x, \{lim\}$)</code>
...selecting specific algorithms	<code>factorint($x, \{flag = 0\}$)</code>
$n = df^2$, d squarefree/fundamental	<code>core($n, \{fl\}$), coredisc</code>
certificate for (prime) N	<code>primecert(N)</code>
verifies a certificate c	<code>primecertisvalid(c)</code>
convert certificate to Magma/PRIMO	<code>primecertexport</code>
recover x from its factorization	<code>factorback($f, \{e\}$)</code>
$x \in \mathbf{Z}$, $ x \leq X$, $\gcd(N, P(x)) \geq N$	<code>zncoppersmith($P, N, X, \{B\}$)</code>
divisors of N in residue class r mod s	<code>divisorslensstra(N, r, s)</code>

Divisors and multiplicative functions

number of prime divisors $\omega(n)$ / $\Omega(n)$	<code>omega(n), bigomega</code>
divisors of n / number of divisors $\tau(n)$	<code>divisors(n), numdiv</code>
sum of (k -th powers of) divisors of n	<code>sigma($n, \{k\}$)</code>
Möbius μ -function	<code>moebius(x)</code>
Ramanujan's τ -function	<code>ramanujantau(x)</code>

Combinatorics

factorial of x	<code>x!</code> or <code>factorial(x)</code>
binomial coefficient $\binom{x}{k}$	<code>binomial($x, \{k\}$)</code>
Bernoulli number B_n as real/rational	<code>bernreal(n), bernfrac</code>
$[B_0, B_2, \dots B_{2k}]$	<code>bernvec(k)</code>
Bernoulli polynomial $B_n(x)$	<code>bernpol($n, \{x\}$)</code>
Euler numbers	<code>eulerfrac, eulerreal, eulervec</code>
Euler polynomial $E_n(x)$	<code>eulerpol($n, \{x\}$)</code>
Eulerian polynomial $A_n(x)$	<code>eulerianpol</code>
Fibonacci number F_n	<code>fibonacci(n)</code>
Harmonic number $H_{n,r} = 1^{-r} + \dots + n^{-r}$	<code>harmonic(n, r)</code>
Stirling numbers $s(n, k)$ and $S(n, k)$	<code>stirling($n, k, \{flag\}$)</code>

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number of partitions of n	<code>numbpart(n)</code>
k -th permutation on n letters	<code>numtoperm(n, k)</code>
...index k of permutation v	<code>permtotnum(v)</code>
order of permutation p	<code>permorder(p)</code>
signature of permutation p	<code>permsign(p)</code>
cyclic decomposition of permutation p	<code>permcycles(p)</code>

Multiplicative groups $(\mathbf{Z}/N\mathbf{Z})^*$, \mathbf{F}_q^*

Euler ϕ -function	<code>eulerphi(x)</code>
multiplicative order of x (divides ϕ)	<code>znorder($x, \{o\}$), fforder</code>
primitive root mod q / x .mod	<code>znprimroot(q), fprimroot(x)</code>
structure of $(\mathbf{Z}/n\mathbf{Z})^*$	<code>znstar(n)</code>
discrete logarithm of x in base g	<code>znlog($x, g, \{o\}$), fflag</code>
Kronecker-Legendre symbol $(\frac{x}{y})$	<code>kronecker(x, y)</code>
quadratic Hilbert symbol (at p)	<code>hilbert($x, y, \{p\}$)</code>

Euclidean algorithm, continued fractions

CRT: solve $z \equiv x$ and $z \equiv y$	<code>chinese(x, y)</code>
minimal u, v so $xu + yv = \gcd(x, y)$	<code>gcdext(x, y)</code>
half-gcd algorithm	<code>halfgcd(x, y)</code>
continued fraction of x	<code>confrac($x, \{b\}, \{lmax\}$)</code>
last convergent of continued fraction x	<code>confracpnqn(x)</code>
rational approximation to x (den. $\leq B$)	<code>bestappr($x, \{B\}$)</code>
recognize $x \in \mathbf{C}$ as polmod mod $T \in \mathbf{Z}[X]$	<code>bestapprnf(x, T)</code>

Miscellaneous

integer square / n -th root of x	<code>sqrtnint(x, n)</code>
largest integer e s.t. $b^e \leq x$, $e = \lfloor \log_b(x) \rfloor$	<code>logint($x, b, \{\&z\}$)</code>

Characters

Let $\chi = [d_1, \dots, d_k]$ represent an abelian group $G = \oplus (\mathbf{Z}/d_j\mathbf{Z}) \cdot g_j$ or any structure G affording a `.cyc` method; e.g. `znstar($q, 1$)` for Dirichlet characters. A character χ is coded by $[c_1, \dots, c_k]$ such that $\chi(g_j) = e(n_j/d_j)$.
 $\chi \cdot \psi$; χ^{-1} ; $\chi \cdot \psi^{-1}$; χ^k `charmul, charconj, chardiv, charpow`
order of χ `charorder(cyc, χ)`
kernel of χ `charker(cyc, χ)`
 $\chi(x)$, G a GP group structure `chareval($G, \chi, x, \{z\}$)`
Galois orbits of characters `chargalois(G)`

Dirichlet Characters

initialize $G = (\mathbf{Z}/q\mathbf{Z})^*$	<code>G = znstar($q, 1$)</code>
convert datum D to $[G, \chi]$	<code>znchar(D)</code>
is χ odd?	<code>zncharisodd(G, χ)</code>
real $\chi \rightarrow$ Kronecker symbol (D/\cdot)	<code>znchartokronecker(G, χ)</code>
conductor of χ	<code>zncharconductor(G, χ)</code>
$[G_0, \chi_0]$ primitive attached to χ	<code>znchartoprimitive(G, χ)</code>
induce $\chi \in \hat{G}$ to $\mathbf{Z}/N\mathbf{Z}$	<code>zncharinduce(G, χ, N)</code>
χp	<code>znchardecompose(G, χ, p)</code>
$\prod_p (Q, N) \chi p$	<code>znchardecompose(G, χ, Q)</code>
complex Gauss sum $G_a(\chi)$	<code>znchargauss(G, χ)</code>

Conrey labelling

Conrey label $m \in (\mathbf{Z}/q\mathbf{Z})^* \rightarrow$ character	<code>znconreychar(G, m)</code>
character \rightarrow Conrey label	<code>znconreyexp(G, χ)</code>
log on Conrey generators	<code>znconreylog(G, m)</code>
conductor of χ (χ_0 primitive)	<code>znconreyconductor($G, \chi, \{\chi_0\}$)</code>

True-False Tests

is x the disc. of a quadratic field?	<code>isfundamental(x)</code>
is x a prime?	<code>isprime(x)</code>
is x a strong pseudo-prime?	<code>ispseudoprime(x)</code>
is x square-free?	<code>issquarefree(x)</code>
is x a square?	<code>issquare($x, \{\&n\}$)</code>
is x a perfect power?	<code>ispower($x, \{k\}, \{\&n\}$)</code>
is x a perfect power of a prime? ($x = p^n$)	<code>isprimepower($x, \&n$)</code>
... of a pseudoprime?	<code>ispseudoprimepower($x, \&n$)</code>
is x powerful?	<code>ispowerful(x)</code>
is x a totient? ($x = \varphi(n)$)	<code>istotient($x, \{\&n\}$)</code>
is x a polygonal number? ($x = P(s, n)$)	<code>ispolygonal($x, s, \{\&n\}$)</code>
is pol irreducible?	<code>polisirreducible(pol)</code>

Graphic Functions

crude graph of $expr$ between a and b	<code>plot($X = a, b, expr$)</code>
High-resolution plot (immediate plot)	
plot $expr$ between a and b	<code>plotoh($X = a, b, expr, \{flag\}, \{n\}$)</code>
plot points given by lists lx, ly	<code>plotthraw($lx, ly, \{flag\}$)</code>
terminal dimensions	<code>plotsizes()</code>

Rectwindow functions

init window w , with size x, y	<code>plotinit(w, x, y)</code>
erase window w	<code>plotkill(w)</code>
copy w to w_2 with offset (dx, dy)	<code>plotcopy(w, w_2, dx, dy)</code>
scale contents of w	<code>plotclip(w)</code>
scale coordinates in w	<code>plotscale(w, x_1, x_2, y_1, y_2)</code>
plotoh in w	<code>plotrecth($w, X = a, b, expr, \{flag\}, \{n\}$)</code>
plotthraw in w	<code>plotrectthraw($w, data, \{flag\}$)</code>
draw window w_1 at $(x_1, y_1), \dots$	<code>plotdraw($[[w_1, x_1, y_1], \dots]$)</code>

Low-level Rectwindow Functions

set current drawing color in w to c	<code>plotcolor(w, c)</code>
current position of cursor in w	<code>plotcursor(w)</code>
write s at cursor's position	<code>plotstring(w, s)</code>
move cursor to (x, y)	<code>plotmove(w, x, y)</code>
move cursor to $(x + dx, y + dy)$	<code>plotrmove(w, dx, dy)</code>
draw a box to (x_2, y_2)	<code>plotbox(w, x_2, y_2)</code>
draw a box to $(x + dx, y + dy)$	<code>plotrbox(w, dx, dy)</code>
draw polygon	<code>plotlines($w, lx, ly, \{flag\}$)</code>
draw points	<code>plotpoints(w, lx, ly)</code>
draw ellipse	<code>plotarc($w, lx, ly, \{flag\}$)</code>
draw line to $(x + dx, y + dy)$	<code>plotrline(w, dx, dy)</code>
draw point $(x + dx, y + dy)$	<code>plotrpoint(w, dx, dy)</code>

Convert to Postscript or Scalable Vector Graphics

The format f is either "ps" or "svg".	
as plotoh	<code>plotlexport($f, X = a, b, expr, \{flag\}, \{n\}$)</code>
as plotthraw	<code>plotthrawexport($f, lx, ly, \{flag\}$)</code>
as plotdraw	<code>plotexport($f, [[w_1, x_1, y_1], \dots]$)</code>