PARI-GP Reference Card

(PARI-GP version 2.3.0)

Note: optional arguments are surrounded by braces {}.

Starting & Stopping GP

to enter GP, just type its name:	`gp`
to exit GP, type	`\q` or `quit`

Help

describe function	`?`*function*
extended description	`??`*keyword*
list of relevant help topics	`???`*pattern*

Input/Output & Defaults

output previous line, the lines before	`%`, ``%` ``, ``%`` `` , etc.
output from line n	`%`n
separate multiple statements on line	`;`
extend statement on additional lines	`\`
extend statements on several lines	`{`seq_1`;` seq_2`;}`
comment	`/* ... */`
one-line comment, rest of line ignored	`\\ ...`
set default d to *val*	`default`$(\{d\},\{val\},flag)$
mimic behaviour of GP 1.39	`default(compatible,3)`

Metacommands

toggle timer on/off	`#`
print time for last result	`##`
print %n in raw format	`\a` n
print %n in pretty format	`\b` n
print defaults	`\d`
set debug level to n	`\g` n
set memory debug level to n	`\gm` n
enable/disable logfile	`\l` {*filename*}
print %n in pretty matrix format	`\m`
set output mode (raw, default, prettyprint)	`\o` n
set n significant digits	`\p` n
set n terms in series	`\ps` n
quit GP	`\q`
print the list of PARI types	`\t`
print the list of user-defined functions	`\u`
read file into GP	`\r` *filename*
write %n to file	`\w` n *filename*

GP Within Emacs

to enter GP from within Emacs:	`M-x gp`, `C-u M-x gp`
word completion	⟨TAB⟩
help menu window	`M-\c`
describe function	`M-?`
display TEX'd PARI manual	`M-x gpman`
set prompt string	`M-\p`
break line at column 100, insert \	`M-\\`
PARI metacommand *letter*	`M-\`*letter*

Reserved Variable Names

$\pi = 3.14159\cdots$	`Pi`
Euler's constant $= .57721\cdots$	`Euler`
square root of -1	`I`
big-oh notation	`O`

PARI Types & Input Formats

`t_INT`. Integers	$\pm n$
`t_REAL`. Real Numbers	$\pm n.ddd$
`t_INTMOD`. Integers modulo m	`Mod`(n,m)
`t_FRAC`. Rational Numbers	n/m
`t_COMPLEX`. Complex Numbers	$x + y *$ `I`
`t_PADIC`. p-adic Numbers	$x +$ `O`$(p$`^`$k)$
`t_QUAD`. Quadratic Numbers	$x + y *$ `quadgen`(D)
`t_POLMOD`. Polynomials modulo g	`Mod`(f,g)
`t_POL`. Polynomials	$a * x$`^`$n + \cdots + b$
`t_SER`. Power Series	$f +$ `O`$(x$`^`$k)$
`t_QFI`/`t_QFR`. Imag/Real bin. quad. forms	`Qfb`$(a,b,c,\{d\})$
`t_RFRAC`. Rational Functions	f/g
`t_VEC`/`t_COL`. Row/Column Vectors	`[`x,y,z`]`, `[`x,y,z`]~`
`t_MAT`. Matrices	`[`$x,y;z,t;u,v$`]`
`t_LIST`. Lists	`List([`x,y,z`])`
`t_STR`. Strings	`"aaa"`

Standard Operators

basic operations	`+`, `-` , `*`, `/`, `^`
`i=i+1`, `i=i-1`, `i=i*j`, ...	`i++`, `i--`, `i*=j`,...
euclidean quotient, remainder	x`\/`y, x`\`y, x`%`y, `divrem`(x,y)
shift x left or right n bits	x`<<`n, x`>>`n or `shift`(x,n)
comparison operators	`<=`, `<`, `>=`, `>`, `==`, `!=`
boolean operators (or, and, not)	`||`, `&&`, `!`
sign of $x = -1, 0, 1$	`sign`(x)
maximum/minimum of x and y	`max`, `min`(x,y)
integer or real factorial of x	x`!` or `factorial`(x)
derivative of f w.r.t. x	f`'`

Conversions

Change Objects

to vector, matrix, set, list, string	`Col`/`Vec`,`Mat`,`Set`,`List`,`Str`
create PARI object (x mod y)	`Mod`(x,y)
make x a polynomial of v	`Pol`$(x,\{v\})$
as above, starting with constant term	`Polrev`$(x,\{v\})$
make x a power series of v	`Ser`$(x,\{v\})$
PARI type of object x	`type`$(x,\{t\})$
object x with precision n	`prec`$(x,\{n\})$
evaluate f replacing vars by their value	`eval`(f)

Select Pieces of an Object

length of x	`#`x or `length`(x)
n-th component of x	`component`(x,n)
n-th component of vector/list x	x`[`n`]`
(m,n)-th component of matrix x	x`[`m,n`]`
row m or column n of matrix x	x`[`m`,]`, x`[,`n`]`
numerator of x	`numerator`(x)
lowest denominator of x	`denominator`(x)

Conjugates and Lifts

conjugate of a number x	`conj`(x)
conjugate vector of algebraic number x	`conjvec`(x)
norm of x, product with conjugate	`norm`(x)
square of L^2 norm of vector x	`norml2`(x)
lift of x from Mods	`lift`, `centerlift`(x)

Random Numbers

random integer between 0 and $N-1$	`random`$(\{N\})$
get random seed	`getrand()`
set random seed to s	`setrand`(s)

Lists, Sets & Sorting

sort x by kth component	`vecsort`$(x,\{k\},\{fl=0\})$

Sets (= row vector of strings with strictly increasing entries)

intersection of sets x and y	`setintersect`(x,y)
set of elements in x not belonging to y	`setminus`(x,y)
union of sets x and y	`setunion`(x,y)
look if y belongs to the set x	`setsearch`$(x,y,flag)$

Lists

create empty list of maximal length n	`listcreate`(n)
delete all components of list l	`listkill`(l)
append x to list l	`listput`$(l,x,\{i\})$
insert x in list l at position i	`listinsert`(l,x,i)
sort the list l	`listsort`$(l,flag)$

Programming & User Functions

Control Statements (X: formal parameter in expression *seq*)

eval. *seq* for $a \le X \le b$	`for`$(X = a,b,seq)$
eval. *seq* for X dividing n	`fordiv`(n,X,seq)
eval. *seq* for primes $a \le X \le b$	`forprime`$(X = a,b,seq)$
eval. *seq* for $a \le X \le b$ stepping s	`forstep`$(X = a,b,s,seq)$
multivariable `for`	`forvec`$(X = v,seq)$
if $a \ne 0$, evaluate seq_1, else seq_2	`if`$(a,\{seq_1\},\{seq_2\})$
evaluate *seq* until $a \ne 0$	`until`(a,seq)
while $a \ne 0$, evaluate *seq*	`while`(a,seq)
exit n innermost enclosing loops	`break`$(\{n\})$
start new iteration of nth enclosing loop	`next`$(\{n\})$
return x from current subroutine	`return`(x)
error recovery (try seq_1)	`trap`$(\{err\},\{seq_2\},\{seq_1\})$

Input/Output

prettyprint args with/without newline	`printp()`, `printp1()`
print args with/without newline	`print()`, `print1()`
read a string from keyboard	`input()`
reorder priority of variables x,y,z	`reorder`$(\{[x,y,z]\})$
output *args* in TEX format	`printtex`$(args)$
write *args* to file	`write`, `write1`, `writetex`$(file,args)$
read file into GP	`read`$(\{file\})$

Interface with User and System

allocates a new stack of s bytes	`allocatemem`$(\{s\})$
execute system command a	`system`(a)
as above, feed result to GP	`extern`(a)
install function from library	`install`$(f,code,\{gpf\},\{lib\})$
alias *old* to *new*	`alias`(new,old)
new name of function f in GP 2.0	`whatnow`(f)

User Defined Functions

`name(formal vars) = local(local vars);` *seq*

`struct.member =` *seq*

kill value of variable or function x	`kill`(x)
declare global variables	`global`$(x,\ldots)$

Iterations, Sums & Products

numerical integration	`intnum`$(X = a,b,expr,flag)$
sum *expr* over divisors of n	`sumdiv`$(n,X,expr)$
sum $X = a$ to $X = b$, initialized at x	`sum`$(X = a,b,expr,\{x\})$
sum of series *expr*	`suminf`$(X = a,expr)$
sum of alternating/positive series	`sumalt`, `sumpos`
product $a \le X \le b$, initialized at x	`prod`$(X = a,b,expr,\{x\})$
product over primes $a \le X \le b$	`prodeuler`$(X = a,b,expr)$
infinite product $a \le X \le \infty$	`prodinf`$(X = a,expr)$
real root of *expr* between a and b	`solve`$(X = a,b,expr)$

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Vectors & Matrices

dimensions of matrix x	matsize(x)
concatenation of x and y	concat($x, \{y\}$)
extract components of x	vecextract($x, y, \{z\}$)
transpose of vector or matrix x	mattranspose(x) or x~
adjoint of the matrix x	matadjoint(x)
eigenvectors of matrix x	mateigen(x)
characteristic polynomial of x	charpoly($x, \{v\}, flag$)
minimal polynomial of x	minpoly($x, \{v\}$)
trace of matrix x	trace(x)

Constructors & Special Matrices

row vec. of *expr* eval'ed at $1 \le i \le n$	vector($n, \{i\}, \{expr\}$)
col. vec. of *expr* eval'ed at $1 \le i \le n$	vectorv($n, \{i\}, \{expr\}$)
matrix $1 \le i \le m$, $1 \le j \le n$	matrix($m, n, \{i\}, \{j\}, \{expr\}$)
diagonal matrix whose diag. is x	matdiagonal(x)
$n \times n$ identity matrix	matid(n)
Hessenberg form of square matrix x	mathess(x)
$n \times n$ Hilbert matrix $H_{ij} = (i+j-1)^{-1}$	mathilbert(n)
$n \times n$ Pascal triangle $P_{ij} = \binom{i}{j}$	matpascal($n-1$)
companion matrix to polynomial x	matcompanion(x)

Gaussian elimination

determinant of matrix x	matdet($x, flag$)
kernel of matrix x	matker($x, flag$)
intersection of column spaces of x and y	matintersect(x, y)
solve $M * X = B$ (M invertible)	matsolve(M, B)
as solve, modulo D (col. vector)	matsolvemod(M, D, B)
one sol of $M * X = B$	matinverseimage(M, B)
basis for image of matrix x	matimage(x)
supplement columns of x to get basis	matsupplement(x)
rows, cols to extract invertible matrix	matindexrank(x)
rank of the matrix x	matrank(x)

Lattices & Quadratic Forms

upper triangular Hermite Normal Form	mathnf(x)
HNF of x where d is a multiple of $\det(x)$	mathnfmod(x, d)
elementary divisors of x	matsnf(x)
LLL-algorithm applied to columns of x	qflll($x, flag$)
like qflll, x is Gram matrix of lattice	qflllgram($x, flag$)
LLL-reduced basis for kernel of x	matkerint(x)
$\mathbf{Z}$-lattice $\longleftrightarrow$ $\mathbf{Q}$-vector space	matrixqz(x, p)
signature of quad form ${}^t y * x * y$	qfsign(x)
decomp into squares of ${}^t y * x * y$	qfgaussred(x)
find up to m sols of ${}^t y * x * y \le b$	qfminim(x, b, m)
v, $v[i]$:=number of sols of ${}^t y * x * y = i$	qfrep($x, B, flag$)
eigenvals/eigenvecs for real symmetric x	qfjacobi(x)

Formal & p-adic Series

truncate power series or p-adic number	truncate(x)
valuation of x at p	valuation(x, p)

Dirichlet and Power Series

Taylor expansion around 0 of f w.r.t. x	taylor(f, x)
$\sum a_k b_k t^k$ from $\sum a_k t^k$ and $\sum b_k t^k$	serconvol(x, y)
$f = \sum a_k * t^k$ from $\sum (a_k/k!) * t^k$	serlaplace(f)
reverse power series F so $F(f(x)) = x$	serreverse(f)
Dirichlet series multiplication / division	dirmul, dirdiv(x, y)
Dirichlet Euler product (b terms)	direuler($p = a, b, expr$)

p-adic Functions

Teichmuller character of x	teichmuller(x)
Newton polygon of f for prime p	newtonpoly(f, p)

Polynomials & Rational Functions

degree of f	poldegree(f)
coefficient of degree n of f	polcoeff(f, n)
round coeffs of f to nearest integer	round($f, \{\&e\}$)
gcd of coefficients of f	content(f)
replace x by y in f	subst(f, x, y)
discriminant of polynomial f	poldisc(f)
resultant of f and g	polresultant($f, g, flag$)
as above, give $[u, v, d]$, $xu + yv = d$	bezoutres(x, y)
derivative of f w.r.t. x	deriv(f, x)
formal integral of f w.r.t. x	intformal(f, x)
reciprocal poly $x^{\deg f} f(1/x)$	polrecip(f)
interpol. pol. eval. at a	polinterpolate($X, \{Y\}, \{a\}, \{\&e\}$)
initialize t for Thue equation solver	thueinit(f)
solve Thue equation $f(x, y) = a$	thue($t, a, \{sol\}$)

Roots and Factorization

number of real roots of f, $a < x \le b$	polsturm($f, \{a\}, \{b\}$)
complex roots of f	polroots(f)
symmetric powers of roots of f up to n	polsym(f, n)
roots of f mod p	polrootsmod($f, p, flag$)
factor f	factor($f, \{lim\}$)
factorization of f mod p	factormod($f, p, flag$)
factorization of f over $\mathbf{F}_{p^a}$	factorff(f, p, a)
p-adic fact. of f to prec. r	factorpadic($f, p, r, flag$)
p-adic roots of f to prec. r	polrootspadic(f, p, r)
p-adic root of f cong. to a mod p	padicappr(f, a)
Newton polygon of f for prime p	newtonpoly(f, p)

Special Polynomials

nth cyclotomic polynomial in var. v	polcyclo($n, \{v\}$)
d-th degree subfield of $\mathbf{Q}(\zeta_n)$	polsubcyclo($n, d, \{v\}$)
n-th Legendre polynomial	pollegendre(n)
n-th Tchebicheff polynomial	poltchebi(n)
Zagier's polynomial of index n,m	polzagier(n, m)

Transcendental Functions

real, imaginary part of x	real(x), imag(x)
absolute value, argument of x	abs(x), arg(x)
square/nth root of x	sqrt(x), sqrtn(x,n,&z)
trig functions	sin, cos, tan, cotan
inverse trig functions	asin, acos, atan
hyperbolic functions	sinh, cosh, tanh
inverse hyperbolic functions	asinh, acosh, atanh
exponential of x	exp(x)
natural log of x	ln(x) or log(x)
gamma function $\Gamma(x) = \int_0^\infty e^{-t} t^{x-1} dt$	gamma(x)
logarithm of gamma function	lngamma(x)
$\psi(x) = \Gamma'(x)/\Gamma(x)$	psi(x)
incomplete gamma function ($y = \Gamma(s)$)	incgam($s, x, \{y\}$)
exponential integral $\int_x^\infty e^{-t}/t\, dt$	eint1(x)
error function $2/\sqrt{\pi} \int_x^\infty e^{-t^2} dt$	erfc(x)
dilogarithm of x	dilog(x)
mth polylogarithm of x	polylog($m, x, flag$)
U-confluent hypergeometric function	hyperu(a, b, u)
J-Bessel function $J_{n+1/2}(x)$	besseljh(n, x)
K-Bessel function of index nu	besselk(nu, x)

Elementary Arithmetic Functions

vector of binary digits of $\|x\|$	binary(x)
give bit number n of integer x	bittest(x, n)
ceiling of x	ceil(x)
floor of x	floor(x)
fractional part of x	frac(x)
round x to nearest integer	round($x, \{\&e\}$)
truncate x	truncate($x, \{\&e\}$)
gcd/LCM of x and y	gcd(x, y), lcm(x, y)
gcd of entries of a vector/matrix	content(x)

Primes and Factorization

add primes in v to the prime table	addprimes(v)
the nth prime	prime(n)
vector of first n primes	primes(n)
smallest prime $\ge x$	nextprime(x)
largest prime $\le x$	precprime(x)
factorization of x	factor($x, \{lim\}$)
reconstruct x from its factorization	factorback($fa, \{nf\}$)

Divisors

number of distinct prime divisors	omega(x)
number of prime divisors with mult	bigomega(x)
number of divisors of x	numdiv(x)
row vector of divisors of x	divisors(x)
sum of (k-th powers of) divisors of x	sigma($x, \{k\}$)

Special Functions and Numbers

binomial coefficient $\binom{x}{y}$	binomial(x, y)
Bernoulli number B_n as real	bernreal(n)
Bernoulli vector $B_0, B_2, \ldots, B_{2n}$	bernvec(n)
nth Fibonacci number	fibonacci(n)
number of partitions of n	numbpart(n)
Euler ϕ-function	eulerphi(x)
Möbius μ-function	moebius(x)
Hilbert symbol of x and y (at p)	hilbert($x, y, \{p\}$)
Kronecker-Legendre symbol $(\frac{x}{y})$	kronecker(x, y)

Miscellaneous

integer or real factorial of x	$x!$ or fact(x)
integer square root of x	sqrtint(x)
solve $z \equiv x$ and $z \equiv y$	chinese(x, y)
minimal u, v so $xu + yv = \gcd(x, y)$	bezout(x, y)
multiplicative order of x (intmod) (¡=o)	znorder($x, \{o\}$)
primitive root mod prime power q	znprimroot(q)
structure of $(\mathbf{Z}/n\mathbf{Z})^*$	znstar(n)
continued fraction of x	contfrac($x, \{b\}, \{lmax\}$)
last convergent of continued fraction x	contfracpnqn(x)
best rational approximation to x	bestappr(x, k)

True-False Tests

is x the disc. of a quadratic field?	isfundamental(x)
is x a prime?	isprime(x)
is x a strong pseudo-prime?	ispseudoprime(x)
is x square-free?	issquarefree(x)
is x a square?	Z_issquare($x, \{\&n\}$)
is *pol* irreducible?	polisirreducible(pol)

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PARI-GP Reference Card (2)

(PARI-GP version 2.3.0)

Elliptic Curves

Elliptic curve initially given by 5-tuple $E = \texttt{[}a_1, a_2, a_3, a_4, a_6\texttt{]}$.
Points are `[x,y]`, the origin is `[0]`.

Initialize elliptic struct. *ell*, i.e create	$\texttt{ellinit}(E, \mathit{flag})$

$a_1, a_2, a_3, a_4, a_6, b_2, b_4, b_6, b_8, c_4, c_6, \mathit{disc}, j$. This data can be recovered by typing $\mathit{ell}\texttt{.a1}, \ldots, \mathit{ell}\texttt{.j}$. If *fl* omitted, also

E defined over $\mathbf{R}$	
x-coords. of points of order 2	$\mathit{ell}\texttt{.roots}$
real and complex periods	$\mathit{ell}\texttt{.omega}$
associated quasi-periods	$\mathit{ell}\texttt{.eta}$
volume of complex lattice	$\mathit{ell}\texttt{.area}$
E defined over $\mathbf{Q}_p$, $\lvert j\rvert_p > 1$	
x-coord. of unit 2 torsion point	$\mathit{ell}\texttt{.roots}$
Tate's $[u^2, u, q]$	$\mathit{ell}\texttt{.tate}$
Mestre's w	$\mathit{ell}\texttt{.w}$
change curve E using $v = \texttt{[}u, r, s, t\texttt{]}$	$\texttt{ellchangecurve}(\mathit{ell}, v)$
change point z using $v = \texttt{[}u, r, s, t\texttt{]}$	$\texttt{ellchangepoint}(z, v)$
cond, min mod, Tamagawa num $\texttt{[}N, v, c\texttt{]}$	$\texttt{ellglobalred}(\mathit{ell})$
Kodaira type of p fiber of E	$\texttt{elllocalred}(\mathit{ell}, p)$
add points $z_1 + z_2$	$\texttt{elladd}(\mathit{ell}, z_1, z_2)$
subtract points $z_1 - z_2$	$\texttt{ellsub}(\mathit{ell}, z_1, z_2)$
compute $n \cdot z$	$\texttt{ellpow}(\mathit{ell}, z, n)$
check if z is on E	$\texttt{ellisoncurve}(\mathit{ell}, z)$
order of torsion point z	$\texttt{ellorder}(\mathit{ell}, z)$
torsion subgroup with generators	$\texttt{elltors}(\mathit{ell})$
y-coordinates of point(s) for x	$\texttt{ellordinate}(\mathit{ell}, x)$
canonical bilinear form taken at z_1, z_2	$\texttt{ellbil}(\mathit{ell}, z_1, z_2)$
canonical height of z	$\texttt{ellheight}(\mathit{ell}, z, \mathit{flag})$
height regulator matrix for pts in x	$\texttt{ellheightmatrix}(\mathit{ell}, x)$
pth coeff a_p of L-function, p prime	$\texttt{ellap}(\mathit{ell}, p)$
kth coeff a_k of L-function	$\texttt{ellak}(\mathit{ell}, k)$
vector of first n a_k's in L-function	$\texttt{ellan}(\mathit{ell}, n)$
$L(E, s)$, set $A \approx 1$	$\texttt{elllseries}(\mathit{ell}, s, \{A\})$
root number for $L(E, .)$ at p	$\texttt{ellrootno}(\mathit{ell}, \{p\})$
modular parametrization of E	$\texttt{elltaniyama}(\mathit{ell})$
point $[\wp(z), \wp'(z)]$ corresp. to z	$\texttt{ellztopoint}(\mathit{ell}, z)$
complex z such that $p = [\wp(z), \wp'(z)]$	$\texttt{ellpointtoz}(\mathit{ell}, p)$

Elliptic & Modular Functions

arithmetic-geometric mean	$\texttt{agm}(x, y)$
elliptic j-function $1/q + 744 + \cdots$	$\texttt{ellj}(x)$
Weierstrass σ function	$\texttt{ellsigma}(\mathit{ell}, z, \mathit{flag})$
Weierstrass $\wp$ function	$\texttt{ellwp}(\mathit{ell}, \{z\}, \mathit{flag})$
Weierstrass ζ function	$\texttt{ellzeta}(\mathit{ell}, z)$
modified Dedekind η func. $\prod(1 - q^n)$	$\texttt{eta}(x, \mathit{flag})$
Jacobi sine theta function	$\texttt{theta}(q, z)$
k-th derivative at z=0 of $\texttt{theta}(q, z)$	$\texttt{thetanullk}(q, k)$
Weber's f functions	$\texttt{weber}(x, \mathit{flag})$
Riemann's zeta $\zeta(s) = \sum n^{-s}$	$\texttt{zeta}(s)$

Graphic Functions

crude graph of *expr* between a and b	$\texttt{plot}(X\texttt{=}a, b, \mathit{expr})$
High-resolution plot (immediate plot)	
plot *expr* between a and b	$\texttt{ploth}(X\texttt{=}a, b, \mathit{expr}, \mathit{flag}, \{n\})$
plot points given by lists lx, ly	$\texttt{plothraw}(lx, ly, \mathit{flag})$
terminal dimensions	$\texttt{plothsizes}()$
Rectwindow functions	
init window w, with size x,y	$\texttt{plotinit}(w, x, y)$
erase window w	$\texttt{plotkill}(w)$
copy w to w_2 with offset (dx, dy)	$\texttt{plotcopy}(w, w_2, dx, dy)$
scale coordinates in w	$\texttt{plotscale}(w, x_1, x_2, y_1, y_2)$
`ploth` in w	$\texttt{plotrecth}(w, X = a, b, \mathit{expr}, \mathit{flag}, \{n\})$
`plothraw` in w	$\texttt{plotrecthraw}(w, \mathit{data}, \mathit{flag})$
draw window w_1 at (x_1, y_1), …	$\texttt{plotdraw}(\texttt{[[}w_1, x_1, y_1\texttt{]}, \ldots\texttt{]})$
Low-level Rectwindow Functions	
set current drawing color in w to c	$\texttt{plotcolor}(w, c)$
current position of cursor in w	$\texttt{plotcursor}(w)$
write s at cursor's position	$\texttt{plotstring}(w, s)$
move cursor to (x, y)	$\texttt{plotmove}(w, x, y)$
move cursor to $(x + dx, y + dy)$	$\texttt{plotrmove}(w, dx, dy)$
draw a box to (x_2, y_2)	$\texttt{plotbox}(w, x_2, y_2)$
draw a box to $(x + dx, y + dy)$	$\texttt{plotrbox}(w, dx, dy)$
draw polygon	$\texttt{plotlines}(w, lx, ly, \mathit{flag})$
draw points	$\texttt{plotpoints}(w, lx, ly)$
draw line to $(x + dx, y + dy)$	$\texttt{plotrline}(w, dx, dy)$
draw point $(x + dx, y + dy)$	$\texttt{plotrpoint}(w, dx, dy)$
Postscript Functions	
as `ploth`	$\texttt{psploth}(X\texttt{=}a, b, \mathit{expr}, \mathit{flag}, \{n\})$
as `plothraw`	$\texttt{psplothraw}(lx, ly, \mathit{flag})$
as `plotdraw`	$\texttt{psdraw}(\texttt{[[}w_1, x_1, y_1\texttt{]}, \ldots\texttt{]})$

Binary Quadratic Forms

create $ax^2 + bxy + cy^2$ (distance d)	$\texttt{Qfb}(a, b, c, \{d\})$
reduce x ($s = \sqrt{D}$, $l = \lfloor s \rfloor$)	$\texttt{qfbred}(x, \mathit{flag}, \{D\}, \{l\}, \{s\})$
composition of forms	$x\texttt{*}y$ or $\texttt{qfbnucomp}(x, y, l)$
n-th power of form	$x\texttt{\^{}}n$ or $\texttt{qfbnupow}(x, n)$
composition without reduction	$\texttt{qfbcompraw}(x, y)$
n-th power without reduction	$\texttt{qfbpowraw}(x, n)$
prime form of disc. x above prime p	$\texttt{qfbprimeform}(x, p)$
class number of disc. x	$\texttt{qfbclassno}(x)$
Hurwitz class number of disc. x	$\texttt{qfbhclassno}(x)$

Quadratic Fields

quadratic number $\omega = \sqrt{x}$ or $(1 + \sqrt{x})/2$	$\texttt{quadgen}(x)$
minimal polynomial of ω	$\texttt{quadpoly}(x)$
discriminant of $\mathbf{Q}(\sqrt{D})$	$\texttt{quaddisc}(x)$
regulator of real quadratic field	$\texttt{quadregulator}(x)$
fundamental unit in real $\mathbf{Q}(x)$	$\texttt{quadunit}(x)$
class group of $\mathbf{Q}(\sqrt{D})$	$\texttt{quadclassunit}(D, \mathit{flag}, \{t\})$
Hilbert class field of $\mathbf{Q}(\sqrt{D})$	$\texttt{quadhilbert}(D, \mathit{flag})$
ray class field modulo f of $\mathbf{Q}(\sqrt{D})$	$\texttt{quadray}(D, f, \mathit{flag})$

General Number Fields: Initializations

A number field K is given by a monic irreducible $f \in \mathbf{Z}[X]$.

init number field structure *nf*	$\texttt{nfinit}(f, \mathit{flag})$
nf members:	
polynomial defining *nf*, $f(\theta) = 0$	$\mathit{nf}\texttt{.pol}$
number of real/complex places	$\mathit{nf}\texttt{.r1}$, $\mathit{nf}\texttt{.r2}$
discriminant of *nf*	$\mathit{nf}\texttt{.disc}$
T_2 matrix	$\mathit{nf}\texttt{.t2}$
vector of roots of f	$\mathit{nf}\texttt{.roots}$
integral basis of $\mathbf{Z}_K$ as powers of θ	$\mathit{nf}\texttt{.zk}$
different	$\mathit{nf}\texttt{.diff}$
codifferent	$\mathit{nf}\texttt{.codiff}$
recompute *nf* using current precision	$\texttt{nfnewprec}(\mathit{nf})$
init relative *rnf* given by $g = 0$ over K	$\texttt{rnfinit}(\mathit{nf}, g)$
init*bnf* structure	$\texttt{bnfinit}(f, \mathit{flag})$
bnf members: same as *nf*, plus	
underlying *nf*	$\mathit{bnf}\texttt{.nf}$
classgroup	$\mathit{bnf}\texttt{.clgp}$
regulator	$\mathit{bnf}\texttt{.reg}$
fundamental units	$\mathit{bnf}\texttt{.fu}$
torsion units	$\mathit{bnf}\texttt{.tu}$
$[tu, fu]$	$\mathit{bnf}\texttt{.tufu}$
compute a *bnf* from small *bnf*	$\texttt{bnfmake}(\mathit{sbnf})$
add S-class group and units, yield *bnf* s	$\texttt{bnfsunit}(\mathit{nf}, S)$
init class field structure *bnr*	$\texttt{bnrinit}(\mathit{bnf}, m, \mathit{flag})$
bnr members: same as *bnf*, plus	
underlying *bnf*	$\mathit{bnr}\texttt{.bnf}$
structure of $(\mathbf{Z}_K/m)^*$	$\mathit{bnr}\texttt{.zkst}$

Simple Arithmetic Invariants (nf)

Elements are rational numbers, polynomials, polmods, or column vectors (on integral basis *nf*`.zk`).

integral basis of field def. by $f = 0$	`nfbasis`(f)
field discriminant of field $f = 0$	`nfdisc`(f)
reverse polmod $a = A(X) \bmod T(X)$	`modreverse`(a)
Galois group of field $f = 0$, $\deg f \leq 11$	`polgalois`(f)
smallest poly defining $f = 0$	`polredabs`($f, flag$)
small polys defining subfields of $f = 0$	`polred`($f, flag, \{p\}$)
small polys defining suborders of $f = 0$	`polredord`(f)
poly of degree $\leq k$ with root $x \in \mathbf{C}$	`algdep`(x, k)
small linear rel. on coords of vector x	`lindep`(x)
are fields $f = 0$ and $g = 0$ isomorphic?	`nfisisom`(f, g)
is field $f = 0$ a subfield of $g = 0$?	`nfisincl`(f, g)
compositum of $f = 0$, $g = 0$	`polcompositum`($f, g, flag$)
basic element operations (prefix `nfelt`):	
(`nfelt`)`mul`, `pow`, `div`, `diveuc`, `mod`, `divrem`, `val`	
express x on integer basis	`nfalgtobasis`(nf, x)
express element x as a polmod	`nfbasistoalg`(nf, x)
quadratic Hilbert symbol (at p)	`nfhilbert`($nf, a, b, \{p\}$)
roots of g belonging to *nf*	`nfroots`($\{nf\}, g$)
factor g in *nf*	`nffactor`(nf, g)
factor g mod prime pr in *nf*	`nffactormod`(nf, g, pr)
number of roots of unity in *nf*	`nfrootsof1`(nf)
conjugates of a root θ of *nf*	`nfgaloisconj`($nf, flag$)
apply Galois automorphism s to x	`nfgaloisapply`(nf, s, x)
subfields (of degree d) of *nf*	`nfsubfields`($nf, \{d\}$)

Dedekind Zeta Function ζ_K

ζ_K as Dirichlet series, $N(I) < b$	`dirzetak`(nf, b)
init *nfz* for field $f = 0$	`zetakinit`(f)
compute $\zeta_K(s)$	`zetak`($nfz, s, flag$)
Artin root number of K	`bnrrootnumber`($bnr, chi, flag$)

Class Groups & Units (bnf, bnr)

$a_1, \{a_2\}, \{a_3\}$ usually $bnr, subgp$ or $bnf, module, \{subgp\}$

remove GRH assumption from *bnf*	`bnfcertify`(bnf)
expo. of ideal x on class gp	`bnfisprincipal`($bnf, x, flag$)
expo. of ideal x on ray class gp	`bnrisprincipal`($bnr, x, flag$)
expo. of x on fund. units	`bnfisunit`(bnf, x)
as above for S-units	`bnfissunit`($bnfs, x$)
fundamental units of *bnf*	`bnfunit`(bnf)
signs of real embeddings of *bnf*`.fu`	`bnfsignunit`(bnf)

Class Field Theory

ray class group structure for mod. m	`bnrclass`($bnf, m, flag$)
ray class number for mod. m	`bnrclassno`(bnf, m)
discriminant of class field ext	`bnrdisc`($a_1, \{a_2\}, \{a_3\}$)
ray class numbers, l list of mods	`bnrclassnolist`(bnf, l)
discriminants of class fields	`bnrdisclist`($bnf, l, \{arch\}, flag$)
decode output from `bnrdisclist`	`bnfdecodemodule`(nf, fa)
is modulus the conductor?	`bnrisconductor`($a_1, \{a_2\}, \{a_3\}$)
conductor of character *chi*	`bnrconductorofchar`(bnr, chi)
conductor of extension	`bnrconductor`($a_1, \{a_2\}, \{a_3\}, flag$)
conductor of extension def. by g	`rnfconductor`(bnf, g)
Artin group of ext. def'd by g	`rnfnormgroup`(bnr, g)
subgroups of *bnr*, index $<= b$	`subgrouplist`($bnr, b, flag$)
rel. eq. for class field def'd by *sub*	`rnfkummer`($bnr, sub, \{d\}$)
same, using Stark units (real field)	`bnrstark`($bnr, sub, flag$)

PARI-GP Reference Card (2)

(PARI-GP version 2.3.0)

Ideals

Ideals are elements, primes, or matrix of generators in HNF.

is *id* an ideal in *nf* ?	`nfisideal`(nf, id)
is x principal in *bnf* ?	`bnfisprincipal`(bnf, x)
principal ideal generated by x	`idealprincipal`(nf, x)
principal idele generated by x	`ideleprincipal`(nf, x)
give $[a, b]$, s.t. $a\mathbf{Z}_K + b\mathbf{Z}_K = x$	`idealtwoelt`($nf, x, \{a\}$)
put ideal a ($a\mathbf{Z}_K + b\mathbf{Z}_K$) in HNF form	`idealhnf`($nf, a, \{b\}$)
norm of ideal x	`idealnorm`(nf, x)
minimum of ideal x (direction v)	`idealmin`(nf, x, v)
LLL-reduce the ideal x (direction v)	`idealred`($nf, x, \{v\}$)

Ideal Operations

add ideals x and y	`idealadd`(nf, x, y)
multiply ideals x and y	`idealmul`($nf, x, y, flag$)
intersection of ideals x and y	`idealintersect`($nf, x, y, flag$)
n-th power of ideal x	`idealpow`($nf, x, n, flag$)
inverse of ideal x	`idealinv`(nf, x)
divide ideal x by y	`idealdiv`($nf, x, y, flag$)
Find $(a, b) \in x \times y$, $a + b = 1$	`idealaddtoone`($nf, x, \{y\}$)

Primes and Multiplicative Structure

factor ideal x in *nf*	`idealfactor`(nf, x)
recover x from its factorization in *nf*	`factorback`(x, nf)
decomposition of prime p in *nf*	`idealprimedec`(nf, p)
valuation of x at prime ideal pr	`idealval`(nf, x, pr)
weak approximation theorem in *nf*	`idealchinese`(nf, x, y)
give *bid* =structure of $(\mathbf{Z}_K/id)^*$	`idealstar`($nf, id, flag$)
discrete log of x in $(\mathbf{Z}_K/bid)^*$	`ideallog`(nf, x, bid)
`idealstar` of all ideals of norm $\leq b$	`ideallist`($nf, b, flag$)
add archimedean places	`ideallistarch`($nf, b, \{ar\}, flag$)
init `prmod` structure	`nfmodprinit`(nf, pr)
kernel of matrix M in $(\mathbf{Z}_K/pr)^*$	`nfkermodpr`($nf, M, prmod$)
solve $Mx = B$ in $(\mathbf{Z}_K/pr)^*$	`nfsolvemodpr`($nf, M, B, prmod$)

Galois theory over Q

initializes a Galois group structure	`galoisinit`($pol, \{den\}$)
action of p in nfgaloisconj form	`galoispermtopol`($G, \{p\}$)
identifies as abstract group	`galoisidentify`(G)
exports a group for GAP or MAGMA	`galoisexport`($G, flag$)
subgroups of the Galois group G	`galoissubgroups`(G)
subfields from subgroups of G	`galoissubfields`($G, flag, \{v\}$)
fixed field	`galoisfixedfield`($G, perm, flag, \{v\}$)
is G abelian?	`galoisisabelian`($G, flag$)
abelian number fields	`galoissubcyclo(N,H,`$flag$`,{v})`

Relative Number Fields (rnf)

Extension L/K is defined by $g \in K[x]$. We have *order* $\subset L$.

absolute equation of L	`rnfequation`($nf, g, flag$)
relative `nfalgtobasis`	`rnfalgtobasis`(rnf, x)
relative `nfbasistoalg`	`rnfbasistoalg`(rnf, x)
relative `idealhnf`	`rnfidealhnf`(rnf, x)
relative `idealmul`	`rnfidealmul`(rnf, x, y)
relative `idealtwoelt`	`rnfidealtwoelt`(rnf, x)

Lifts and Push-downs

absolute $\to$ relative repres. for x	`rnfeltabstorel`(rnf, x)
relative $\to$ absolute repres. for x	`rnfeltreltoabs`(rnf, x)
lift x to the relative field	`rnfeltup`(rnf, x)
push x down to the base field	`rnfeltdown`(rnf, x)
idem for x ideal: (`rnfideal`)`reltoabs`, `abstorel`, `up`, `down`	

Projective $\mathbf{Z}_K$-modules, maximal order

relative `polred`	`rnfpolred`(nf, g)
relative `polredabs`	`rnfpolredabs`(nf, g)
characteristic poly. of a mod g	`rnfcharpoly`($nf, g, a, \{v\}$)
relative Dedekind criterion, prime pr	`rnfdedekind`(nf, g, pr)
discriminant of relative extension	`rnfdisc`(nf, g)
pseudo-basis of $\mathbf{Z}_L$	`rnfpseudobasis`(nf, g)
relative HNF basis of *order*	`rnfhnfbasis`($bnf, order$)
reduced basis for *order*	`rnflllgram`($nf, g, order$)
determinant of pseudo-matrix A	`rnfdet`(nf, A)
Steinitz class of *order*	`rnfsteinitz`($nf, order$)
is *order* a free $\mathbf{Z}_K$-module?	`rnfisfree`($bnf, order$)
true basis of *order*, if it is free	`rnfbasis`($bnf, order$)

Norms

absolute norm of ideal x	`rnfidealnormabs`(rnf, x)
relative norm of ideal x	`rnfidealnormrel`(rnf, x)
solutions of $N_{K/\mathbf{Q}}(y) = x \in \mathbf{Z}$	`bnfisintnorm`(bnf, x)
is $x \in \mathbf{Q}$ a norm from K?	`bnfisnorm`($bnf, x, flag$)
initialize T for norm eq. solver	`rnfisnorminit`($K, pol, flag$)
is $a \in K$ a norm from L?	`rnfisnorm`($T, a, flag$)

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