

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

`{seq1; seq2};`

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

$\pi = 3.14159\dots$

`Pi`

Euler's constant $= .57721\dots$

`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

$x + y * \text{quadgen}(D)$

`t_POLMOD`. Polynomials modulo g

`Mod(f,g)`

`t_POL`. Polynomials

$a * x^n + \dots + b$

`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

$x \backslash y, x \backslash y, x \backslash y, \text{divrem}(x,y)$

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 ($x \bmod y$)

`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 k th 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 $a \leq X \leq b$ `for(X=a,b,seq)`

eval. seq for X dividing n `fordiv(n,X,seq)`

eval. seq for primes $a \leq X \leq b$ `forprime(X=a,b,seq)`

eval. seq for $a \leq X \leq b$ stepping s `forstep(X=a,b,s,seq)`

multivariable for `forvec(X=v,seq)`

if $a \neq 0$, evaluate seq_1 , else seq_2 `if(a,{seq1},{seq2})`

evaluate seq until $a \neq 0$ `until(a,seq)`

while $a \neq 0$, evaluate seq `while(a,seq)`

exit n innermost enclosing loops `break({n})`

start new iteration of n th enclosing loop `next({n})`

return x from current subroutine `return(x)`

error recovery (try seq_1) `trap({err},{seq2},{seq1})`

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,...)`

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 $a \leq X \leq b$, initialized at x `prod(X=a,b,expr,{x})`

product over primes $a \leq X \leq b$ `prodeuler(X=a,b,expr)`

infinite product $a \leq X \leq \infty$ `prodinf(X=a,expr)`

real root of $expr$ between a and b `solve(X=a,b,expr)`

Vectors & Matrices

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

Constructors & Special Matrices

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

Gaussian elimination

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

Lattices & Quadratic Forms

upper triangular Hermite Normal Form	<code>mathnf(x)</code>
HNF of x where d is a multiple of $\det(x)$	<code>mathnfmod(x, d)</code>
elementary divisors of x	<code>matsnf(x)</code>
LLL-algorithm applied to columns of x	<code>qflll($x, flag$)</code>
like <code>qflll</code> , x is Gram matrix of lattice	<code>qflllgram($x, flag$)</code>
LLL-reduced basis for kernel of x	<code>matkerint(x)</code>
Z -lattice $\longleftrightarrow$ Q -vector space	<code>matrixqz(x, p)</code>
signature of quad form $t^y * x * y$	<code>qfsign(x)</code>
decomp into squares of $t^y * x * y$	<code>qfgaussred(x)</code>
find up to m sols of $t^y * x * y \leq b$	<code>qfminim(x, b, m)</code>
$v, v[i] :=$ number of sols of $t^y * x * y = i$	<code>qfrep($x, B, flag$)</code>
eigenvals/eigenvecs for real symmetric x	<code>qfjacobi(x)</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>
$\sum a_k b_k t^k$ from $\sum a_k t^k$ and $\sum b_k t^k$	<code>serconvol(x, y)</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>
Dirichlet series multiplication / division	<code>dirmul, dirdiv(x, y)</code>
Dirichlet Euler product (b terms)	<code>direuler($p = a, b, expr$)</code>

p-adic Functions

Teichmuller character of x	<code>teichmuller(x)</code>
Newton polygon of f for prime p	<code>newtonpoly(f, p)</code>

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Polynomials & Rational Functions

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

Roots and Factorization

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

Special Polynomials

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

Transcendental 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>sqrtn($x, n, &z$)</code>
trig functions	<code>sin, cos, tan, cotan</code>
inverse trig functions	<code>asin, acos, atan</code>
hyperbolic functions	<code>sinh, cosh, tanh</code>
inverse hyperbolic functions	<code>asinh, acosh, atanh</code>
exponential of x	<code>exp(x)</code>
natural log of x	<code>ln(x)</code> or <code>log(x)</code>
gamma function $\Gamma(x) = \int_0^\infty e^{-t} t^{x-1} dt$	<code>gamma(x)</code>
logarithm of gamma function	<code>lngamma(x)</code>
$\psi(x) = \Gamma'(x) / \Gamma(x)$	<code>psi(x)</code>
incomplete gamma function ($y = \Gamma(s)$)	<code>incgam($s, x, \{y\}$)</code>
exponential integral $\int_x^\infty e^{-t} / t dt$	<code>eint1(x)</code>
error function $2 / \sqrt{\pi} \int_x^\infty e^{-t^2} dt$	<code>erfc(x)</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>
J -Bessel function $J_{n+1/2}(x)$	<code>besseljh(n, x)</code>
K -Bessel function of index nu	<code>besselk(nu, x)</code>

Elementary Arithmetic Functions

vector of binary digits of $ x $	<code>binary(x)</code>
give bit number n of integer x	<code>bittest(x, n)</code>
ceiling of x	<code>ceil(x)</code>
floor of x	<code>floor(x)</code>
fractional part of x	<code>frac(x)</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	
add primes in v to the prime table	<code>addprimes(v)</code>
the n th prime	<code>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>
reconstruct x from its factorization	<code>factorback($fa, \{nf\}$)</code>

Divisors

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

Special Functions and Numbers

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

Miscellaneous

integer or real factorial of x	<code>x!</code> or <code>fact(x)</code>
integer square root of x	<code>sqrntint(x)</code>
solve $z \equiv x$ and $z \equiv y$	<code>chinese(x, y)</code>
minimal u, v so $xu + yv = \gcd(x, y)$	<code>bezout(x, y)</code>
multiplicative order of x (intmod) (i=0)	<code>znorder($x, \{o\}$)</code>
primitive root mod prime power q	<code>znprimroot(q)</code>
structure of $(\mathbf{Z}/n\mathbf{Z})^*$	<code>znstar(n)</code>
continued fraction of x	<code>contfrac($x, \{b\}, \{lmax\}$)</code>
last convergent of continued fraction x	<code>contfracpnqn(x)</code>
best rational approximation to x	<code>bestappr(x, k)</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>Z_issquare($x, \{&n\}$)</code>
is pol irreducible?	<code>polisirreducible(pol)</code>

Based on an earlier version by Joseph H. Silverman
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PARI-GP Reference Card (2)

(PARI-GP version 2.3.0)

Elliptic Curves

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

Initialize elliptic struct. ell , i.e create `ellinit( $E, flag$ )`

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

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

Elliptic & Modular Functions

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

Graphic Functions

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

Rectwindow functions

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

Low-level Rectwindow Functions

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

Postscript Functions

as `plotth` `psplotth( $X = a, b, expr, flag, \{n\}$ )`
as `plotthraw` `psplotthraw( $lx, ly, flag$ )`
as `plotdraw` `psdraw([[ $w_1, x_1, y_1$ ], \dots])`

Binary Quadratic Forms

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

Quadratic Fields

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

General Number Fields: Initializations

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

init number field structure nf `nfinit( $f, flag$ )`

nf members:

polynomial defining nf , $f(\theta) = 0$	<code>nf.pol</code>
number of real/complex places	<code>nf.r1, nf.r2</code>
discriminant of nf	<code>nf.disc</code>
T_2 matrix	<code>nf.t2</code>
vector of roots of f	<code>nf.roots</code>
integral basis of $\mathbf{Z}_K$ as powers of θ	<code>nf.zk</code>
different	<code>nf.diff</code>
codifferent	<code>nf.codiff</code>
recompute nf using current precision	<code>nfnewprec(nf)</code>
init relative rmf given by $g = 0$ over K	<code>rnfininit(nf, g)</code>
init bnf structure	<code>bnfininit($f, flag$)</code>

bnf members: same as nf , plus

underlying nf	<code>bnf.nf</code>
classgroup	<code>bnf.clgp</code>
regulator	<code>bnf.reg</code>
fundamental units	<code>bnf.fu</code>
torsion units	<code>bnf.tu</code>
$[tu, fu]$	<code>bnf.tufu</code>
compute a bnf from small bnf	<code>bnfmake($sbnf$)</code>
add S -class group and units, yield bnf s	<code>bnfsunit(nf, S)</code>
init class field structure bnr	<code>bnrinit($bnf, m, flag$)</code>

bnr members: same as bnf , plus

underlying bnf	<code>bnr.bnf</code>
structure of $(\mathbf{Z}_K/m)^*$	<code>bnr.zkst</code>

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? **nfisom**(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 **nfactor**(nf, g)
 factor g mod prime pr in nf **nfactormod**(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 **bnrdisc**($bnf, l, \{arch\}, flag$)
 decode output from **bnrdisc** **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 $\leq b$ **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 **idealnrm**(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 $\mathbf{q}$

initializes a Galois group structure **galoisinit**($pol, \{den\}$)
 action of p in **nfgaloisconj** form **galoispermopol**($G, \{p\}$)
 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 $\rightarrow$ relative repres. for x **rnfeltabstorel**(rnf, x)
 relative $\rightarrow$ 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 $a \bmod g$ **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 $order$ **rnfstesinitz**($nf, order$)
 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 **rnfidealnrmabs**(rnf, x)
 relative norm of ideal x **rnfidealnrmrel**(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**($T, a, flag$)

Based on an earlier version by Joseph H. Silverman

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