

C

Index

- ** , 43
- + , 43, 58, 71, 160, 368
- .. , 46
- ; , 41
- = , 43
- == , 17, 44
- ? , 11, 43
- # , 41
- _ , 12
- \ , 42, 168
- ~ , 160

- AA , 103, 140, 275
- abs , 9, 96, 105
- absolute value , 9
- acceleration of convergence , 276
- _add_ , 96
- add , 63
- add_constraint , 391
- add_edge , 363
- add_edges , 363, 386
- add_vertex , 363
- adjacency matrix , 157, 364
- adjacency table , 364
- algebraic geometry , 201
- algebraic number , 38, 108, 111, 132, 137, 140, 144, 185
- algebraic structure , 99–101
- algebraic variety , 187
- AlgebraicField , 103
- AlgebraicRealField , 103
- algorithm
 - Dijkstra's , 374
 - Edmonds' , 375
 - fast multiplication , 153
 - Ford-Fulkerson , 375
 - QR , 293
- aliasing , 69
- aliquot sequence , 124
- all , 63, 345, 446
- AlternatingSignMatrices , 343
- and , 106
- animate , 76
- animation , 76
- antiderivative , 30
- any , 63, 345
- append , 66, 67, 274
- Arb , 249
- arithmetic
 - basic , 7
 - elementary , 104–105
 - interval , *see* interval arithmetic
 - modular , 115–117
 - of polynomials , 133, 183
- arithmetic operations , 7, 17, 97
 - finite fields , 117
 - matrices , 160
 - modulo n , 116
 - polynomials , 130, 182
- arithmetic-harmonic mean , 49, 53
- Arrangements , 330
- assert , 42, 264
- assignment , 43, 49, 69
- assume , 21, 225

- attrcall, 347
- augment, 156
- automatic completion, 11, 98
- automatic_names, 14
- automorphism_group, 377
- Axiom, 99, 128

- backslash, 42
- bar chart, 79, 91
- bar graph, 79, 91
- bar_chart, 79, 91
- base_extend, 156, 160
- base_ring, 116, 128, 156, 275
- basic type, 103
- basis, 156
- basis (vector space), 36, 156
- basis_is_groebner, 207
- berlekamp_massey, 146, 426
- Bézout relation, 135
- BinaryTree, 349
- binomial, 9, 336
- binomial coefficient, 9
- bisection, 266
- BLAS, 298
- block matrix, 158
- block_diagonal_matrix, 158
- block_matrix, 156, 158
- bool, 17, 103
- boolean, 11, 105
- breadth_first_search, 374
- break, 47
- bug, iii

- C++, 5
- canonical form, *see* normal form, 115
- canonicalize_radical, 20, 21
- cardinality, 343, 444
- cartesian product, 64, 100
- cartesian_product, 259, 350
- Cassini surface, 93
- catalan, 11
- Catalan constant, 11
- catastrophic cancellation, 240
- categories, 134
- category, 101, 134
- category, 101
- Cauchy interpolation, 147
- CBF, 253
- CC, 103, 258, 275
- CDF, 245, 255, 258, 275
- center, 374
- change of variables, 221
- change_ring, 131, 156, 160, 208
- character string, 58
- characteristic, 116
- characteristic polynomial, 37, 162, 170, 173
- characteristic value, 170
- characteristic_polynomial, 37, 162

- charpoly, 137, 162, 172
- Chinese remainder theorem, *see* theorem
- chromatic number, 366, 367
- chromatic_number, 366, 376
- CIF, 140, 253, 258, 275
- circle, 89, 91
- class, 95, 99
- class, 42
- clique, 376
- clique_maximum, 376
- Cliquer (program), 376
- closed-form expression, 186
- CoCalc, 4, 5
- CoCoA, 201
- coefficient
 - matrix, 158
 - polynomial, 131, 181
- coefficients, 131, 181
- coercion, 97
- collect, 19, 20, 130
- collections, 274
- coloring, 370, 376, 381
- colour, 75, 370
- column_space, 37, 412
- combine, 19
- comstruct, 334
- command history, 12
- command line, 5
- command prompt, 7
- comment, 41
- companion matrix, 176
- comparison, 44
 - of two expressions, 17
- complement, 372
- CompleteBipartiteGraph, 366
- CompleteGraph, 366
- complex floating-point number, 105
- complex_plot, 79, 91
- ComplexBallField, 253
- ComplexDoubleField, 258
- ComplexField, 103, 245, 255, 258
- ComplexIntervalField, 253, 258
- comprehension, 62, 343
- computation of π , 31, 32, 34
- computational domain, 101–112
- computer algebra, 3
 - and numerical computation, 10, 263
 - system, 110
- concatenation, 68
- conchoid, 78
- condition number, 279–282, 287, 288, 301
- conditional, 51
- conditional instruction, 51
- conjugate, 132, 160
- conjugate gradient, 301
- connected component, 375
- connected_components, 375
- connectivity, 375, 376, 378, 381

- constants, 246
- constants (predefined), 11
- content, 133
- continue, 47
- contrib_ode, 216
- conventions, 7
- convergence, 32, 50, 242, 243, 265, 276
 - acceleration of, 276
- conversion, 97, 100, 104, 132, 238
- copy, 69, 160, 293, 373
- cos, 21
- count, 66
- cover_ring, 137
- Cox, David A., 179
- Cramer's formula, 283
- cross product, 35
- cross_product, 35, 410
- crt, 120, 133
- cryptology, 117, 191
- CSV (*comma-separated values*), 80
- cut (graph), 377, 381
- Cyclic, 190
- cyclic vector, 171

- data sharing, 69
- decimal number, 104
- decimal point, 8
- decomposableObjects, 334
- decomposition
 - partial fraction, 143
 - square-free, 138
- decomposition, 174
- decorator, 55
- deepcopy, 70
- def, 42, 53
- degree, 131, 181
- del, 43, 67, 72
- delayed reduction, 117
- delete_edge, 364
- delete_vertex, 364
- denominator, 143, 335
- depth_first_search, 374
- deque, 274
- derivative
 - of a polynomial, 131, 181
 - of an expression, 30, 33, 65
 - partial, 33, 181, 216
- derivative, 33, 131, 181, 263
- Descartes' rule, 264
- desolve, 24, 216, 229
- desolve_laplace, 226, 229
- desolve_rk4, 84, 91
- desolve_system, 227
- det, 167
- determinant, 162, 167, 170
- diagonalisation, 37, 162
- diameter, 374
- diameter of a graph, 374

- Dickson lemma, 207
- dict, 72, 131
- dictionary, 181
- diff, 30, 33, 131, 229, 407
- differential equation, 84, 149, 215–228, 305, 318
 - Bernoulli, 217
 - Clairaut, 218
 - constant coefficient, 223
 - exact, 218
 - homogeneous, 217, 221, 222
 - Lagrange, 218
 - linear first-order, 217, 218
 - parametric, 223
 - plot, 220
 - Riccati, 218
 - separable, 217, 219, 221
 - systems, 226
- diffusion list, 4
- DiGraph, 372
- dimension
 - of a variety, 210
 - of an ideal, 184, 192, 198, 210
- dimension, 185, 192, 193
- discrete logarithm, 123–124
- discriminant, 139
- discriminant of a polynomial, 25, 141
- disjoint_union, 368, 369
- display
 - graphs, 369
- distance (in a graph), 374
- divides, 133, 184
- division, 8
 - by increasing powers, 135
 - integers, 9
 - of polynomials, 133, 136, 183, 204, 209
- divmod, 9
- documentation, 4
- domain
 - computation domain, 22
- dominating set, 376, 395
- dominating_set, 376
- Dormand-Prince method, 319
- dot_product, 35
- double exponential method, 309
- double-precision, 237, 245, 278
- drawing, 81

- e, 11
- eccentricity, 374
- eccentricity, 374
- echelon form, 37, 163
- echelon_form, 37, 162, 165, 166, 412
- echelonize, 162, 165
- edge (graph), 363
- edge_coloring, 376
- edge_connectivity, 375

- edge_cut, 375
- edge_disjoint_paths, 375
- Edmonds, Jack, 394
- eigenmatrix_left, 162, 176
- eigenmatrix_right, 162, 176
- eigenspace, 162, 170
- eigenspaces_left, 162, 175
- eigenspaces_right, 162, 175
- eigenvalue, 37, 162, 170, 174, 227
- eigenvalues, 37, 175
- eigenvector, 37, 162, 174
- eigenvectors_left, 162
- eigenvectors_right, 37, 162
- elementary function, 21
- elementary_divisors, 162, 167
- elementwise_product, 160
- elif, 52
- elimination
 - algebraic, 184, 192, 196, 211
- elimination_ideal, 193
- else, 51
- endomorphism reduction, 37
- envelope of a family of curves, 89, 195
- equality
 - left/right-hand side, 24
- equation, 10, 23–26
 - differential, *see* differential equation
 - linear, 23, 24
 - numerical solution, 25, 257–278
 - of a curve, 78, 79, 195
 - of a surface, 93
 - partial differential, *see* partial differential equation
 - polynomial, 139
 - solving, 24
 - system of equations, 24
- Euler’s method, 318
- euler_gamma, 11
- exec, 42
- exists, 346
- exp, 21
- expand, 18, 20
- expand_sum, 21
- expand_trig, 21
- exponent of a float, 235–237
- exponentiation
 - binary, 136
 - modular, 117, 122
- exporting a figure, 371
- Expression, 260
- expression tree, 17
- extend, 66
- extension, 38

- factor, 9, 20, 96, 97, 103, 138, 139, 184
- factor_list, 20
- factorial, 9
 - programming, 54
- factorial, 9, 21, 104
- factorisation
 - integer, 96, 123, 138
 - polynomial, 110, 120, 132, 137
- False, 11, 105
- fast multiplication, 153
- Fermat test, 120
- Fermat, Pierre de, 9
- Fibonacci sequence, 54–58
- FieldIdeal, 190
- Fields, 101
- figure export, 76
- filter, 62, 67, 69, 71
- finance, 80
- find_root, 24, 25, 277
- finite field, 103, 106, 115–118, 121
 - non-prime, 117
- FiniteEnumeratedSet, 442
- FiniteField, 103, 117
- fixed point, 150
- flatten, 64, 69
- float, 103
- floating-point number, 25, 104
- floor, 9
- flow, 375–377, 395
- flow, 375
- for, 42, 44, 62, 64, 340, 344
- forget, 22
- formal power series, 108, 143, 145, 147, 425
- formula
 - Bailey–Borwein–Plouffe, 34
 - Sherman–Morrison, 440
- Fourier series, 77
- fourier_series_partial_sum, 77
- Frac, 143
- Frobenius normal form, 170, 173
- frozenset, 399
- function, 19, 216, 229
- function graph, 91
- function_factory, 424
- functional equation, 149

- Galois group, 142
- galois_group, 139, 142
- GAP, 5, 6, 360
- Gauss–Jordan elimination, 164
- Gauss–Kronrod method, 306, 308
- Gauss–Legendre method, 308
- Gaussian elimination, 161–163
- gcd
 - integers, 116, 118, 119
 - polynomials, 133, 263
- gcd, 133, 184
- Gear’s method, 319
- gen, 129, 192
- generator, 117, 129, 271, 272
 - of a polynomial ring, 179
 - programming, 267

- vector space, 156
- genericity, 97
- gens, 156, 179
- genus, 193, 377
- genus, 193, 377
- geometry, 195, 197
- get_values, 391
- GF, 103, 117, 121
- gfun, 334
- Gibbs phenomenon, 77
- girth (graph), 366
- GL, 157
- global, 53
- GMP, 258
- GMRES, 301, 304
- GNU MPFR, 237, 298
- GNU/Linux, 4
- golden_ratio, 11
- Graph, 363, 364, 372, 376
- graph, 91
 - adjoint, *see* line graph
 - bipartite, 367, 378
 - chordal, 374, 378
 - circulant, 365, 367
 - complete, 367
 - Eulerian, 378
 - families of graphs, 366
 - interval, 378
 - graph
 - k -connected, 375
 - Kneser, 366
 - perfect, 378
 - Petersen, 365, 366
 - planar, 366
 - random, 367, 375, 381, 383
 - small graphs, 365
 - vertex-transitive, 366, 378
 - graph colouring, 376, 379, 387
 - graph isomorphism, 377
 - graph minor, 377
 - forbidden, 366
 - graph of a function, 75
 - differential equation solution, 84, 320
 - graph paths
 - edge-disjoint, 375
 - vertex-disjoint, 375
 - graph traversal, 373, 375
- Graphics, 84, 91
- graphics, 15, 75–94
- Gröbner basis, 189, 192, 202, 205–213
 - computation cost, 211
 - definition, 207
 - reduced, 210
- group, 101
 - linear GL_n , 156
- GSL, 84, 312, 313, 320, 321, 441
- guessing, 147
- Hamiltonian cycle, 376, 397
- hamiltonian_cycle, 376, 377
- harmonic function, 33
- harmonic number, 119, 243
- hash table, 71
- help, 4, 11, 98
- Hermite normal form, 165, 412
- hermite_form, 166
- Hilbert matrix, 281, 295, 296
- histogram, 79, 91
- homogenize, 181, 190
- i (imaginary unit), 11, 105
- ideal
 - polynomials, 183, 184, 187
 - polynomials with an infinite number of variables, 182
- ideal, 136, 137, 184, 190
- identifier, 42
- identity_matrix, 156, 157, 292
- IEEE-754 standard, 236
- if, 51, 62
- imag, 105
- image, *see* graphics
 - of a function, 73
 - of a linear transformation, 168
- image, 162, 168
- immutability, 160, 364, 391
- immutable, 70, 72
- implicit_plot, 79, 91
- implicit_plot3d, 93
- import, 13, 42
- in, 60, 71, 72
- indentation, 7, 45, 46
- independent set, 369, 376, 382, 386
- independent_set, 369, 376, 386
- index, 67
- induced subgraph, 368, 383
- inequality, 25, 389
 - polynomial system, 197
- inert function, 424
- infinite, 238
- InfinitePolynomialRing, 181, 182
- Infinity, 11, 28, 338
- initial conditions, 216
- inject_variables, 430
- insert, 66
- instance, 95
- instruction block, 45
- int, 103, 338
- Integer, 104, 258
- integer
 - modulo n , 106
 - number, 103
 - part, 9, 21
 - ring, 115–117
- integer_kernel, 162, 169
- IntegerListsLex, 352, 353

- IntegerModRing, 103, 106, 115, 121
- IntegerRing, 103
- Integers, 103, 115
- IntegerVectors, 343
- integral, 33
- integral curve, 84, 91
- integrate, 30, 33, 312
- integrate_numerical, 34
- integration
 - numerical, 34, 305–316
 - symbolic, 30, 33
- interreduced_basis, 210
- intersection, 190, 192
- interval arithmetic, 258
- introspection, 98
- invariant factor, 166, 174
- invariant subspace, 170
- inverse
 - compositional (of a series), 143
 - modular, 116
 - power, 292
- inverse_laplace, 226, 229
- IPython, 5
- irrelevant_ideal, 190
- is_bipartite, 378
- is_cartesian_transitive, 378
- is_chordal, 374, 378
- is_connected, 375
- is_constant, 131
- is_eulerian, 378
- is_exact, 275
- is_hamiltonian, 377
- is_integral_domain, 128
- is_interval, 378
- is_irreducible, 137, 139
- is_isomorphic, 368, 377
- is_monic, 131
- is_noetherian, 134
- is_perfect, 378
- is_prime, 121
- is_pseudoprime, 121
- is_regular, 366
- is_ring, 134
- is_squarefree, 184
- is_tree, 378
- is_vertex_transitive, 366, 378
- is_zero, 23, 263
- iter, 344
- iterable, 340, 344
- iterator, 45, 46, 267, 347, 374
- itertools, 347

- jacobi, 123
- Jacobi symbol, 123
- jacobian_ideal, 190
- Jmol, 91
- Jordan
 - block, 176
 - form, 37, 169, 176
 - matrix, 176
- jordan_block, 156, 157, 162, 177
- jordan_form, 37, 38, 177
- Jupyter, 4, 5, 14

- Kash, 98
- kernel, 36, 37, 162, 168
- kernel, 162, 169
- keyboard shortcut, 7
- keys, 73, 350
- knapsack (problem), 393
- knot, 93
- Krylov sequence, 170

- label (graph), 364, 369
- lagrange_polynomial, 133, 274, 307
- lambda, 42, 61, 67
- Lapack, 294, 298
- laplace, 229
- Laplace transform, 225
- L^AT_EX, 76
- LattE, 353
- LaurentSeriesRing, 143
- lazy computation, 150
- LazyPowerSeriesRing, 150, 332
- lc, 181
- lcm, 119, 133, 184
- leading coefficient, 181, 182, 203
- leading monomial, 181, 182, 203
- leading term, 181, 182, 203
- leading_coefficient, 131
- left_kernel, 36, 37, 162, 169
- left_solve, 24
- Legendre polynomial, 35, 308
- Leibniz formula, 65
- len, 59, 68, 71, 338
- lex_BFS, 374, 378
- lexicographic order, 65, 203
- lhs, 24, 223, 229
- lift, 116, 136, 137, 189, 190
- lim, 28
- limit, 30
 - numerical approximation, 49
- limit, 28, 30, 407
- limit point, 229
- line, 81, 84, 91
- line graph, 373
- line3d, 93
- linear algebra, 35–39, 155–178
 - numerical, 279–304
- linear equation, 168
- linear programming, 375, 376, 389–401
 - over the integers, 390
- linear system, 168
 - solving, 162, 168
- linearisation (trigonometrics), 21
- Linux, 4

- list, 59
- `list`, 131
- Little, John B., 179
- `lm`, 181
- `log`, 21, 124, 246
- logic, 105
- logistic map, 228
- loop
 - `while`, 45
 - early abort, 47
 - `for` (enumeration), 44
 - infinite, 65
- `lt`, 181

- Macaulay2, 201
- Machin's formula, 31
- Machin, John, 31
- MacOS, 4
- Magma, 98, 99, 128
- Magnus effect, 88
- manual, 4
- `map`, 61, 64, 69, 71
- `map_coefficients`, 181
- Maple, 13, 14, 128, 334
- Masser-Gramain constant, 124
- matching, 375, 376, 394
- `matching`, 386
- matrix, 36, 37, 107, 155, 178, 279–304, 389
 - column, 158
 - companion, 171
 - decomposition, *see* matrix factorisation
 - equivalence, 161, 164, 169
 - factorisation
 - Cholesky, 285, 286, 290
 - LU, 165, 283, 285, 286, 293
 - QR, 286–288, 293, 294
 - inverse, 160
 - norm, 280, 287–289
 - normal form, 161, 164–166, 173
 - rank, 286–288
 - row, 158
 - similarity, *see* similarity (matrix)
 - transpose, 160
 - unimodular, 165
- `matrix`, 36, 37, 107, 137, 157
- `matrix_block`, 37
- `MatrixGroup`, 156, 157
- `MatrixSpace`, 103, 107, 155, 156
- `max_cut`, 377
- `max_symbolic`, 315
- Maxima, 6, 13, 14, 128, 221, 262, 313, 321
- `maxspin`, 162, 172
- Mendès France, Michel, 82
- method
 - bisection, 266
 - Brent's, 277
 - false position, 269
 - Newton's, 270
 - Newton-Cotes, 307
 - programming, 96
 - secant, 272
 - separation of variables, 224
 - Steffensen's, 276
- Microsoft Windows, 4
- minimal polynomial, 37
 - algebraic number, 186
 - linear recurrence, 136
 - matrix, 38, 162, 171
 - vector, 171
- `minimal_polynomial`, 37, 162
- minor, 162
- `minor`, 377
- `minpoly`, 137, 162
- `MixedIntegerLinearProgram`, 390, 391
- `mod`, 116, 137, 183, 190
- modulus (complex number), 9, 105
- monomial order, 180, 182, 183, 203
 - change of order, 212
- MPFI, 249
- MPFR, *see* GNU MPFR
- `MPolynomial`, 181
- `mq`, 191
- `__mul__`, 96
- Muller, David E., 273
- Muller, Jean-Michel, 242
- `multicommodity_flow`, 377
- multiplicity, 188, 257, 262
- MuPAD, 99, 128
- MuPAD-Combinat, 334
- mutability, *see* immutability

- `n`, *see* `numerical_approx`
- n*-tuple, *see* tuple
- NaN (Not a Number), 238
- `new_variable`, 392, 395
- `next`, 344
- `next_prime`, 120
- `None`, 42, 53
- `norm`
 - of a matrix, *see* matrix norm
 - of a vector, 35
- `norm`, 35
- normal equations, 287, 288
- normal form
 - expression, 20, 22, 101, 112, 128
 - modulo an ideal, 189
- `normal_basis`, 193, 202
- `not`, 106
- notebook, 7
- `NotImplementedError`, 132
- `nth_root`, 21
- Nullstellensatz, 190
- number
 - Carmichael, 122
 - floating-point, 235

- integer modular, 115–117
 - prime, 120–121
- number field, 38, 111, 137
- `number_field`, 137
- `NumberField`, 38, 108, 137
- `numer`, 96
- `numerator`, 143
- numerical approximation, 8, 47, 125, 140, 246, 279
 - differential equation, 318–323
 - equation solving, 257
 - integral, 305–316
 - limits, 32
 - solutions of equations, 25–26, 140, 200, 241, 278
- numerical sequence, 49
 - uniformly distributed, 81
- `numerical_approx`, 8, 11, 22, 105
- `NumPy`, 86, 275, 298
- object, 95
- object-oriented programming, 95–98
- objective function, 391
- `ode_contrib`, 218
- `ode_solver`, 84, 319
- `odeint`, 84, 91, 416
- `one`, 156
- `oo`, 11
- optimisation, 389–401
- `or`, 106
- order
 - additive, 116
 - multiplicative, 116
- `order`, 363
- order of variables, 180
- `OrderedSetPartitions`, 343
- osculating circle, 90
- O’Shea, Donal, 179
- p*-adic number, 139
- Padé approximant, 145
- pairing, 386
- PALP, 353
- parametric curve, 78, 88, 91, 195
 - in 3D, 93
- parametric surface, 91
- `parametric_plot`, 78, 91
- parametrisation, 88, 195
- parent, 99, 101, 129, 134
- `parent`, 116
- PARI/GP, 5, 6, 98, 275, 311, 314, 315
- partial differential equation, 216
- partial fraction decomposition, 19, 226
- `partial_fraction`, 19, 20, 226
- `partial_fraction_decomposition`, 143
- `pass`, 42
- `periphery`, 374
- `Permutations`, 380
- π (Archimedes’ constant), 11
 - computation, *see* computation of π
- `piecewise`, 77
- `pivot_rows`, 162, 167
- `pivots`, 162, 167
- `plot`, 15, 30, 75, 91, 220, 259, 306, 372
- plot (differential equation), 220
- `plot3d`, 15, 91
- `plot_histogram`, 79, 91
- `plot_points`, 75
- `plot_vector_field`, 86
- `point`, 81
- point cloud, 81
- `points`, 81, 91
- polar coordinates, 36, 78
- `polar_plot`, 78, 91
- `polygen`, 128
- `polygon`, 91
- polymorphism, 97
- polynomial, 127–153, 179–213
 - Chebyshev, 135
- `polynomial`, 181, 182
- polynomial representation
 - dense, 152
 - recursive, 130, 181
 - sparse, 152
- polynomial ring, 128, 179, 275
 - with infinite number of variables, 182
- polynomial root, 257
- `polynomial_sequence`, 191
- `PolynomialRing`, 103, 128, 179, 181
- `pop`, 66, 72
- power, 8
- power method, 291–293, 302–304
- power series, 27, 30, 108
 - expansion, 30
- `PowerSeriesRing`, 108, 143
- `prec`, 148
- precision
 - arbitrary vs fixed, 237, 255
 - floating-point number, 235–238, 240, 241, 243
 - loss of, 240
 - numerical computation, 200
 - series, 148
- predator-prey model, 86
- primality, *see* number, prime
- primary normal form, 177
- `prime_range`, 122
- `print`, 42, 54, 58
- probability, 368
- procedure, 43, 52
- `prod`, 63
- product, 63
 - of graphs, 373, 378
- programming, 41–73, 343–349
 - method, 43
- projection, 194

- pseudo-division, 135
- pseudo-primality, 120
- pseudo_divrem, 133
- public server, 4–6
- Python
 - function, 43, 52
 - anonymous, 61
 - variable, 12–13
 - version 3, 41
- q -factorial, 446
- QQ, 103, 258, 275
- QQbar, 103, 140, 185, 275
- QUADPACK, 313
- quadratic residue, 123
- quadrature rule, 307
- quit, 42
- quo, 136, 137, 190
- quo_rem, 133, 183
- quotient
 - numerical, *see* arithmetic operations
 - polynomial ring, 188, 202
 - $\mathbb{Z}/n\mathbb{Z}$, 115
- quotient, 190, 192
- radical, 139, 190
- radical of an ideal, 190
- radius, 374
- radius of a graph, 374
- Ramanujan, Srinivasa, 32
- random, 81
- random walk, 81
- random_element, 131, 380
- random_matrix, 156, 157
- randrange, 79
- range, 46
- range, 46, 345
- rank, 162
 - matrix, 167, 170
 - profile, 162, 167
- rank, 167
- Rational, 95, 96
- rational
 - number, 104
- rational function, 19, 135, 142–143
- rational reconstruction, 118, 125, 143, 144
- rational_argument, 186
- rational_reconstruct, 143, 145
- rational_reconstruction, 118
- RationalField, 103
- raw_input, 59
- RBF, 248
- RDF, 132, 237, 255, 258, 275
- real, 105
- real_root_intervals, 139
- real_roots, 139, 275, 277
- RealBallField, 248
- RealField, 103, 237, 255, 258
- RealIntervalField, 247, 258
- Reals, 237, 258
- rectangle rule, 307
- recurrence, 45
- recurrence relation, 228–232
- recurrent sequence, 47–55, 136
 - drawing, 84
 - numerical stability, 241
- recurrent series, 147
- recursivity, 54
- reduce
 - list, 63
 - modulo, 136, 143, 189, 190
- reduce_trig, 21
- reduced echelon form, 164
 - transformation to, 164
- reduction of endomorphism, 162
- regular expression, 69
- remove, 67
- representation of polynomials
 - factored, 110
 - sparse, 181
- reset, 13, 43
- resolution
 - polynomial systems, 184
- resources, 4
- restore, 13
- resultant, 140, 196
- resultant, 139, 184, 193
- return, 42, 47, 53, 267, 347
- reverse, 65, 130, 131, 143
- rewriting, 205
- rhs, 24, 229
- RIF, 140, 247, 258, 275
- right_kernel, 36, 37, 162, 168, 411
- right_solve, 24
- root
 - n -th root, 9, 21
 - of a polynomial, 139, 240, 265
 - isolation, 264
- root_field, 259
- roots, 24, 25, 139, 198, 257, 262, 263, 277
- rounding, 236, 240, 245
- row_space, 37
- RR, 103, 258, 275
- RSA (crypto-system), 117
- rsolve, 231
- Runge’s phenomenon, 307
- Runge-Kutta
 - method, 319
- Sage developers, 6
- Sage history, 6
- sage-support, iii
- sage:, 7
- sagemath.org, 4
- SageMathCloud, *see* CoCalc, 4
- SageMathInc, 4

- save, 76
- scalar product, 35
- SciPy, 84, 85, 277, 278, 298, 300, 303, 304, 416
- sequence, *see* tuple
 - numerical, 28
 - Syracuse, 51
- series, 31, 243
 - alternating, 49
 - expansion, 150
- series, 30, 108
- Set, 71, 442
- set, 71
- set_binary, 392
- set_immutable, 160
- set_integer, 392
- set_max, 392
- set_min, 392
- set_objective, 391
- set_real, 392
- shortest path (graph), 374
- shortest_path, 374
- show, 76, 91, 369, 372
- significand, 235–244
- similarity (matrix), 169, 173, 178
- similarity invariant, 170, 172, 174
- simplification, 11, 21, 22, 110
- simplify, 11, 20, 109
- simplify_factorial, 21
- simplify_full, 21
- simplify_rational, 20, 21, 335
- simplify_rectform, 21
- simplify_trig, 20, 21, 23
- sin, 21, 246
- Singular, 5, 6, 181, 201
- singular value decomposition, 286, 288, 289
- size, 363
- SL, 157
- small_roots, 132
- Smith normal form, 166
- smith_form, 162
- solve, 23, 24, 88, 184, 222, 391, 392
- solve_left, 36, 37, 162, 168
- solve_right, 36, 37, 162, 168
- solving
 - linear programming, 391
 - linear systems, 35
 - numerical equations, 23–26, 257–278
- sort, 65
- sorted, 66
- sorting, 65
- split, 68
- spreadsheet, 80
- sqrt, 21, 22, 38
- squarefree_decomposition, 139
- SR, 103, 152, 260
- SR.var, *see* var
- srange, 46
- SSP (subset sum problem), 394
- stable (graph), *see* independent set
- stack, 156
- staircase, 205, 206
- StandardTableaux, 343
- Stein, William, 6
- steiner_tree, 377
- str, 68, 103
- study of a function, 21
- Sturm sequence, 264
- subgraph, 373
- subgraph_search, 368, 377, 379, 385
- submatrix, 159
- submatrix, 156
- SubMultiset, 429
- subs, 18, 131, 181, 183
- subset sum, 394
- Subsets, 429, 448
- substitute, 18
- substitute_function, 424
- sum, 27, 30, 63, 345
- summation
 - compensated, 244
 - programming, 48
 - symbolic, 27, 30
- SVD, *see* singular value decomposition
- swap_columns, 162
- swap_rows, 162
- sxrange, 46
- symbolic expression, 10–14, 17, 105, 108–109, 112, 128, 152
 - function, 19
 - test of zero, 22
- symbolic function, 19, 229, 405
- symbolic variable, 13–14
- SymPy, 231
- system of equations, 35, 179, 389
 - differential, 226
- tabulation, 11
- Tachyon, 91
- tangent (to a curve), 270
- taylor, 30, 145, 405
- Taylor expansion, 30, 108
- Tenenbaum, Gérard, 82
- test of zero, 22
- test_poly, 180
- text, 91
- theorem
 - Borsuk-Ulam, 367
 - Cayley-Hamilton, 173
 - Chinese remainder, 119
 - theorem
 - fundamental (of algebra), 259
 - Kuratowski's, 366
 - Menger's, 375
 - Pocklington's, 121
 - Schwarz', 33

- three.js, 91
- timeit, 117
- TimeSeries, 80
- trac.sagemath.org, iii
- trace, 280, 289
- trace, 137
- transformation matrix, 166
- transformed_basis, 187, 212
- transpose, 160, 285, 287, 290
- transposition matrix, 161
- transvection, 161, 162
- trapezoidal rule, 309
- traveling salesman problem, 376, 397
- traveling_salesman_problem, 377
- tree, 367, 378
 - Steiner, 377
- tree, 367
- triangular decomposition
 - of an ideal, 199
- triangular form, 37, 163
- triangular_decomposition, 187, 193, 199
- trig_expand, 406
- trig_simplify, 406
- trigonometric function, 9, 21, 246
- trigonometry, 211
- True, 11, 105
- truncate, 30
- truncation of a series, 143
- try, 42, 80
- tuple, 70

- ulp, 239
- ulp (*unit in the last place*), 239
- uniform distribution, 81
- union (of graphs), 368

- valuation, 133
- values, 73
- Vandermonde determinant, 110
- var, 13, 229

- variable
 - dependent, 216
 - independent, 216
 - Python, 43, 53
 - symbolic, 21
- variable_name, 131
- variable_names_recursive, 181
- variables, 131, 229
- variation of a function, 21
- variety, 185, 193, 198
- vector, 35
 - construction, 157
- vector, 35, 157
- vector space, 37
- vector_space_dimension, 193
- VectorSpace, 155
- Verhulst equation, 223
- vertex (graph), 363
- vertex_connectivity, 375
- vertex_cut, 375
- vertex_disjoint_paths, 375
- visualisation, 76, 369

- WeightedIntegerVectors, 339
- while, 42
- Windows, 4
- with, 42

- x (symbolic variable), 13
- xcgcd, 133
- xrange, 46, 345

- yield, 42, 267, 347

- Zariski closure, 192, 194
- zero, 156
- ζ (Riemann zeta function), 31, 51
- zip, 71
- ZZ, 103, 116, 258, 275