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# **Sage Reference Manual**

***Release 9.2***

**The Sage Development Team**

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Welcome to the Sage reference manual. Here you find documentation for all of Sage's features, illustrated with lots of examples. A thematic index follows.

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## USER INTERFACES

- Command Line Interface
- Jupyter Notebook Interface





## GRAPHICS

- 2D Graphics
- 3D Graphics



### 3.1 Parents and Categories

- Parents and Elements
- Coercion
- Categories

### 3.2 Basic Rings and Fields

- Integers and Rational Numbers
- Real and Complex Numbers
- Commutative Polynomials
- Power Series and Laurent Series
- Finite Rings and Fields
- $p$ -adic Numbers
- Noncommutative Polynomials
- Quaternion Algebras

### 3.3 Linear Algebra

- Matrices and Spaces of Matrices
- Vectors and Modules
- Tensors on Free Modules of Finite Rank

## 3.4 Calculus and Analysis

- Symbolic Calculus
- Mathematical Constants
- Elementary and Special Functions
- Asymptotic Expansions
- Numerical Optimization

## 3.5 Probability and Statistics

- Probability
- Statistics
- Quantitative Finance

## 3.6 Mathematical Structures

- Sets
- Monoids
- Groups
- Semirings
- Rings
- Algebras

## 3.7 Discrete Mathematics

- Combinatorics
- Graph Theory
- Quivers
- Matroid Theory
- Discrete Dynamics
- Coding Theory
- Cryptography
- Game Theory
- Symbolic Logic
- SAT solvers

## 3.8 Geometry and Topology

- Euclidean Spaces and Vector Calculus
- Combinatorial and Discrete Geometry
- Cell Complexes and their Homology
- Manifolds and Differential Geometry
- Hyperbolic Geometry
- Parametrized Surfaces
- Knot Theory

## 3.9 Number Fields, Function Fields, and Valuations

- Number Fields
- Function Fields
- Discrete Valuations

## 3.10 Number Theory

- Diophantine approximation
- Quadratic Forms
- $L$ -Functions
- Arithmetic Subgroups of  $SL_2(\mathbb{Z})$
- General Hecke Algebras and Hecke Modules
- Modular Symbols
- Modular Forms
- Modular Forms for Hecke Triangle Groups
- Modular Abelian Varieties
- Miscellaneous Modular-Form-Related Modules

## 3.11 Algebraic and Arithmetic Geometry

- Schemes
- Plane and Space Curves
- Elliptic and Hyperelliptic Curves

## 3.12 Miscellaneous

- Databases
- Games

## PROGRAMMING

### 4.1 Facilities

- Data Structures
- Utilities
- Test Framework
- Parallel Computing

### 4.2 Interfaces

- Interpreter Interfaces
- C/C++ Library Interfaces
- Python Technicalities





## GENERAL INFORMATION

- External Packages
- Bibliographic References
- History and License



## INDICES AND TABLES

- `genindex`
- `modindex`
- `search`