Sage Reference Manual

Release 9.5

The Sage Development Team

Jan 31, 2022
# CONTENTS

1 User Interfaces 3  
2 Graphics 5  
3 Mathematics 7  
   3.1 Parents and Categories 7  
   3.2 Basic Rings and Fields 7  
   3.3 Linear Algebra 7  
   3.4 Calculus and Analysis 8  
   3.5 Probability and Statistics 8  
   3.6 Mathematical Structures 8  
   3.7 Discrete Mathematics 8  
   3.8 Geometry and Topology 9  
   3.9 Number Fields, Function Fields, and Valuations 9  
   3.10 Number Theory 9  
   3.11 Algebraic and Arithmetic Geometry 9  
   3.12 Miscellaneous 10  
4 Programming 11  
   4.1 Facilities 11  
   4.2 Interfaces 11  
5 General Information 13  
6 Indices and Tables 15
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.

This documentation is licensed under the Creative Commons Attribution-Share Alike 3.0 License.
CHAPTER ONE

USER INTERFACES

• Command Line Interface
• Jupyter Notebook Interface
CHAPTER
TWO

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 $\text{SL}_2(\mathbb{Z})$
• General Hecke Algebras and Hecke Modules
• Modular Symbols
• Modular Forms
• Quasimodular 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
4.1 Facilities

- Data Structures
- Utilities
- Test Framework
- Parallel Computing

4.2 Interfaces

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

GENERAL INFORMATION

• External Packages
• Bibliographic References
• History and License
Chapter Six

Indices and Tables

- genindex
- modindex
- search