

Table of Contents

About the Author	xv
About the Technical Reviewers	xvii
Introduction	xxi
Chapter 1: Introduction to Computing with Python	1
Environments for Computing with Python	5
Python	6
Interpreter	7
IPython Console	8
Input and Output Caching	9
Autocompletion and Object Introspection	11
Documentation	11
Interaction with the System Shell	12
IPython Extensions	13
Jupyter	19
The Jupyter QtConsole	20
The Jupyter Notebook	21
Jupyter Lab	24
Cell Types	25
Editing Cells	26
Markdown Cells	28
Rich Output Display	30
nbconvert	34

Spyder: An Integrated Development Environment 37

 Source Code Editor 38

 Consoles in Spyder 40

 Object Inspector 40

Summary..... 41

Further Reading 41

References..... 41

Chapter 2: Vectors, Matrices, and Multidimensional Arrays 43

 Importing the Modules..... 44

 The NumPy Array Object 44

 Data Types 46

 Order of Array Data in Memory..... 49

 Creating Arrays 50

 Arrays Created from Lists and Other Array-Like Objects..... 52

 Arrays Filled with Constant Values 52

 Arrays Filled with Incremental Sequences 54

 Arrays Filled with Logarithmic Sequences 54

 Meshgrid Arrays 55

 Creating Uninitialized Arrays 56

 Creating Arrays with Properties of Other Arrays..... 56

 Creating Matrix Arrays..... 57

 Indexing and Slicing..... 58

 One-Dimensional Arrays 58

 Multidimensional Arrays 60

 Views 62

 Fancy Indexing and Boolean-Valued Indexing 63

 Reshaping and Resizing..... 66

 Vectorized Expressions 70

 Arithmetic Operations..... 72

 Elementwise Functions 76

 Aggregate Functions 79

 Boolean Arrays and Conditional Expressions 82

 Set Operations 85

 Operations on Arrays 87

Matrix and Vector Operations..... 88

Summary..... 95

Further Reading 95

References..... 96

Chapter 3: Symbolic Computing 97

 Importing SymPy..... 98

 Symbols 99

 Numbers 102

 Expressions..... 109

 Manipulating Expressions 110

 Simplification..... 111

 Expand..... 112

 Factor, Collect, and Combine 114

 Apart, Together, and Cancel 115

 Substitutions 115

 Numerical Evaluation 117

 Calculus 118

 Derivatives..... 119

 Integrals 121

 Series 123

 Limits..... 125

 Sums and Products 126

 Equations 127

 Linear Algebra 130

Summary..... 134

Further Reading 134

Reference..... 134

Chapter 4: Plotting and Visualization 135

 Importing Modules 136

 Getting Started 137

 Interactive and Noninteractive Modes..... 141

 Figure 143

 Axes 145

 Plot Types 146

 Line Properties 147

 Legends..... 152

 Text Formatting and Annotations..... 153

 Axis Properties 156

 Advanced Axes Layouts 168

 Insets..... 168

 Subplots 170

 Subplot2grid 172

 GridSpec..... 173

 Colormap Plots..... 174

 3 D Plots..... 177

 Summary..... 180

 Further Reading 180

 References..... 181

Chapter 5: Equation Solving 183

 Importing Modules 184

 Linear Equation Systems 185

 Square Systems 186

 Rectangular Systems..... 192

Eigenvalue Problems..... 196

Nonlinear Equations..... 198

 Univariate Equations..... 199

 Systems of Nonlinear Equations..... 207

Summary..... 212

Further Reading 212

References..... 212

Chapter 6: Optimization..... 213

 Importing Modules 214

 Classification of Optimization Problems 214

 Univariate Optimization..... 217

 Unconstrained Multivariate Optimization..... 221

 Nonlinear Least Square Problems..... 230

 Constrained Optimization..... 232

 Linear Programming..... 238

 Summary..... 241

 Further Reading 241

 References..... 242

Chapter 7: Interpolation..... 243

 Importing Modules 244

 Interpolation..... 244

 Polynomials..... 245

 Polynomial Interpolation 249

 Spline Interpolation..... 255

 Multivariate Interpolation..... 258

 Summary..... 265

 Further Reading 265

 References..... 265

Chapter 8: Integration..... 267

- Importing Modules 268
- Numerical Integration Methods..... 269
- Numerical Integration with SciPy..... 274
 - Tabulated Integrand..... 277
- Multiple Integration..... 280
- Symbolic and Arbitrary-Precision Integration 285
 - Line Integrals..... 288
- Integral Transforms 289
- Summary..... 292
- Further Reading 293
- References..... 293

Chapter 9: Ordinary Differential Equations..... 295

- Importing Modules 296
- Ordinary Differential Equations 296
- Symbolic Solution to ODEs..... 298
 - Direction Fields..... 304
 - Solving ODEs Using Laplace Transformations 309
- Numerical Methods for Solving ODEs 313
- Numerical Integration of ODEs Using SciPy 317
- Summary..... 332
- Further Reading 333
- References..... 333

Chapter 10: Sparse Matrices and Graphs..... 335

- Importing Modules 336
- Sparse Matrices in SciPy 336
 - Functions for Creating Sparse Matrices 342
 - Sparse Linear Algebra Functions..... 345

- Linear Equation Systems..... 345
- Graphs and Networks..... 352
- Summary..... 360
- Further Reading 361
- References..... 361

Chapter 11: Partial Differential Equations 363

- Importing Modules 364
- Partial Differential Equations 365
- Finite-Difference Methods 366
- Finite-Element Methods..... 373
 - Survey of FEM Libraries 377
- Solving PDEs Using FEniCS..... 378
- Summary..... 403
- Further Reading 403
- References..... 404

Chapter 12: Data Processing and Analysis..... 405

- Importing Modules 406
- Introduction to Pandas..... 407
 - Series 407
 - DataFrame..... 410
 - Time Series..... 422
- The Seaborn Graphics Library..... 434
- Summary..... 440
- Further Reading 440
- References..... 441

Chapter 13: Statistics 443

- Importing Modules..... 444
- Review of Statistics and Probability 444
- Random Numbers 446

Random Variables and Distributions	451
Hypothesis Testing	460
Nonparametric Methods	466
Summary.....	469
Further Reading	470
References	470
Chapter 14: Statistical Modeling	471
Importing Modules	472
Introduction to Statistical Modeling	473
Defining Statistical Models with Patsy.....	474
Linear Regression	485
Example Datasets.....	494
Discrete Regression	496
Logistic Regression	496
Poisson Model	502
Time Series	506
Summary.....	511
Further Reading	511
References.....	511
Chapter 15: Machine Learning	513
Importing Modules	514
Brief Review of Machine Learning	515
Regression	518
Classification.....	529
Clustering.....	535
Summary.....	540
Further Reading	540
References.....	541

Chapter 16: Bayesian Statistics.....	543
Importing Modules	544
Introduction to Bayesian Statistics	545
Model Definition.....	548
Sampling Posterior Distributions.....	553
Linear Regression.....	558
Summary.....	571
Further Reading	572
References.....	572
Chapter 17: Signal Processing	573
Importing Modules	574
Spectral Analysis.....	574
Fourier Transforms	575
Windowing.....	581
Spectrogram.....	585
Signal Filters	590
Convolution Filters.....	590
FIR and IIR Filters	593
Summary.....	598
Further Reading	599
References.....	599
Chapter 18: Data Input and Output	601
Importing Modules	602
Comma-Separated Values.....	603
HDF5	608
h5py.....	610
PyTables	623
Pandas HDFStore.....	629

TABLE OF CONTENTS

JSON	631
Serialization	636
Summary.....	639
Further Reading	639
Reference.....	640
Chapter 19: Code Optimization	641
Importing Modules	644
Numba.....	644
Cython.....	652
Summary.....	664
Further Reading	665
References	665
Appendix: Installation.....	667
Miniconda and Conda	668
A Complete Environment.....	676
Summary.....	680
Further Reading	680
Index.....	683