

Table of Contents

What Is <i>Mathematica</i>?	vii
Numerical Computation • Symbolic Computation • Graphics • The <i>Mathematica</i> Language • <i>Mathematica</i> Interfaces	
About This Book	xii
The Scope of This Book • The <i>Mathematica</i> System Described in This Book • The Parts of This Book • How to Read This Book • About the Examples in This Book • Suggestions about Learning <i>Mathematica</i> • What Else to Read • Changes since the First Edition • About the Production of This Book • Acknowledgments	

Tour of *Mathematica*

1. Numerical Calculations	2
2. Graphics	3
3. Algebra and Calculus	6
4. Solving Equations	7
5. Lists	8
6. Matrices	9
7. Transformation Rules and Definitions	10
8. Advanced Topic: Symbolic Computation	11
9. Programming	12
10. <i>Mathematica</i> Packages	14
11. Interfacing with <i>Mathematica</i>	16
12. Front Ends and Notebooks	17

<i>Mathematica</i> Graphics Gallery	18
--	-----------

Mathematica Graphics Gallery

Two-Dimensional Graphics	20
Three-Dimensional Graphics	22
Evolution towards Fractals.....	24
Minimal Surfaces.....	27
Conchoid Surfaces.....	29
Trinoids.....	31
Knots.....	33
Ideal Hyperbolic Polyhedra.....	34
Symmetric Quasitilings	36
Visualization of Fermat's Last Theorem.....	39
Color Models.....	40
Lighting and Reflection Models	41

Part 1. A Practical Introduction to *Mathematica*

1.0	Running <i>Mathematica</i>	44
	Text-Based Interfaces • Notebook Interfaces	
1.1	Numerical Calculations	47
	Arithmetic • Exact and Approximate Results • Some Mathematical Functions • Arbitrary-Precision Calculations • Complex Numbers • Getting Used to <i>Mathematica</i>	
1.2	Building Up Calculations	54
	Using Previous Results • Defining Variables • Making Lists of Objects • Manipulating Elements of Lists • The Four Kinds of Bracketing in <i>Mathematica</i> • Sequences of Operations	
1.3	Using the <i>Mathematica</i> System	60
	Interfaces to <i>Mathematica</i> • Entering Input • Special Topic: Notebooks • <i>Mathematica</i> Packages • Getting Information from <i>Mathematica</i> • Warnings and Messages • Interrupting Calculations	
1.4	Algebraic Calculations	72
	Symbolic Computation • Values for Symbols • Transforming Algebraic Expressions • Simplifying Algebraic Expressions • Advanced Topic: Putting Expressions into Different Forms • Picking Out Pieces of Algebraic Expressions • Controlling the Display of Large Expressions • The Limits of <i>Mathematica</i> • Using Symbols to Tag Objects	
1.5	Symbolic Mathematics	87
	Basic Operations • Differentiation • Integration • Sums and Products • Equations • Relational and Logical Operators • Solving Equations • Differential Equations • Power Series • Limits • Packages for Symbolic Mathematics	
1.6	Numerical Mathematics	105
	Basic Operations • Numerical Sums, Products and Integrals • Numerical Equation Solving • Numerical Differential Equations • Numerical Optimization • Manipulating Numerical Data • Statistics Packages	
1.7	Functions and Programs	113
	Defining Functions • Functions as Procedures • Repetitive Operations • Transformation Rules for Functions	
1.8	Lists	118
	Collecting Objects Together • Making Tables of Values • Vectors and Matrices • Getting Pieces of Lists • Testing and Searching List Elements • Adding, Removing and Modifying List Elements • Combining Lists • Advanced Topic: Lists as Sets • Rearranging Lists • Grouping Together Elements of Lists • Mathematical Operations on Lists • Advanced Topic: Rearranging Nested Lists • Advanced Topic: Combinatorial Operations	
1.9	Graphics and Sound	134
	Basic Plotting • Special Topic: How Graphics Are Output • Options • Redrawing and Combining Plots • Advanced Topic: Manipulating Options • Contour and Density Plots • Three-Dimensional Surface Plots • Converting between Types of Graphics • Plotting Lists of Data • Parametric Plots • Some Special Plots • Special Topic: Animated Graphics • Special Topic: Sound	
1.10	Files and External Operations	178
	Reading and Writing <i>Mathematica</i> Files • Advanced Topic: Finding and Manipulating Files • Reading Data Files • Generating C and Fortran Expressions • Generating T _E X Input • Splicing <i>Mathematica</i> Output into External Files • Running External Programs • <i>MathLink</i>	

Part 2. Principles of *Mathematica*

- 2.1 Expressions** 190
Everything Is an Expression • The Meaning of Expressions • Special Ways to Input Expressions • Parts of Expressions
• Manipulating Expressions Like Lists • Expressions as Trees • Advanced Topic: Levels in Expressions
- 2.2 Functional Operations** 200
Function Names as Expressions • Applying Functions Repeatedly • Applying Functions to Lists and Other Expressions
• Applying Functions to Parts of Expressions • Pure Functions • Building Lists from Functions • Selecting Parts of Ex-
pressions with Functions • Expressions with Heads That Are Not Symbols • Advanced Topic: Working with Operators
• Structural Operations
- 2.3 Patterns**..... 219
Introduction • Finding Expressions That Match a Pattern • Naming Pieces of Patterns • Specifying Types of Expression in
Patterns • Putting Constraints on Patterns • Patterns Involving Alternatives • Flat and Orderless Functions • Functions with
Variable Numbers of Arguments • Optional and Default Arguments • Setting Up Functions with Optional Arguments • Re-
peated Patterns • Patterns for Some Common Types of Expression • An Example: Defining Your Own Integration Function
- 2.4 Transformation Rules and Definitions** 243
Applying Transformation Rules • Manipulating Sets of Transformation Rules • Making Definitions • Special Forms of As-
signment • Making Definitions for Indexed Objects • Making Definitions for Functions • The Ordering of Definitions • Im-
mediate and Delayed Definitions • Functions That Remember Values They Have Found • Associating Definitions with Dif-
ferent Symbols • Defining Numerical Values • Modifying Built-in Functions • Advanced Topic: Manipulating Value Lists
- 2.5 Evaluation of Expressions**..... 267
Principles of Evaluation • Reducing Expressions to Standard Form • Attributes • The Standard Evaluation Procedure
• Non-Standard Evaluation • Evaluation in Patterns, Rules and Definitions • Evaluation in Iteration Functions • Condi-
tionals • Loops and Control Structures • Tracing Evaluation • Advanced Topic: The Evaluation Stack • Advanced Topic:
Controlling Infinite Evaluation • Advanced Topic: Interrupts and Aborts • Compiling *Mathematica* Expressions • Ad-
vanced Topic: Manipulating Compiled Code
- 2.6 Modularity and the Naming of Things**..... 318
Modules and Local Variables • Local Constants • How Modules Work • Advanced Topic: Variables in Pure Functions and
Rules • Dummy Variables in Mathematics • Blocks and Local Values • Blocks Compared with Modules • Contexts • Con-
texts and Packages • Setting Up *Mathematica* Packages • Automatic Loading of Packages
- 2.7 Textual Output** 343
Output Formats • How Output Formats Work • Short and Shallow Output • Textual Output Formats • Output Formats
for Numbers • Tables and Matrices • Defining Your Own Output Forms • Mimicking Mathematical Notation • Generat-
ing Output
- 2.8 Strings, Names and Messages** 365
Text Strings • Advanced Topic: Special and International Characters • Operations on Strings • Converting between Strings
and Expressions • String Patterns • Symbol Names • Advanced Topic: Intercepting the Creation of New Symbols • Mes-
sages • International Messages • Documentation Constructs
- 2.9 The Structure of Graphics and Sound** 394
The Structure of Graphics • Two-Dimensional Graphics Elements • Graphics Directives and Options • Coordinate Systems
for Two-Dimensional Graphics • Labeling Two-Dimensional Graphics • Making Plots within Plots • Density and Con-
tour Plots • Three-Dimensional Graphics Primitives • Three-Dimensional Graphics Directives • Coordinate Systems for
Three-Dimensional Graphics • Plotting Three-Dimensional Surfaces • Lighting and Surface Properties • Labeling Three-
Dimensional Graphics • Advanced Topic: Low-Level Graphics Rendering • Fonts for Text in Graphics • Graphics Primi-
tives for Text • Advanced Topic: Color Output • The Representation of Sound

2.10 Input and Output	477
Reading and Writing <i>Mathematica</i> Files • External Programs • Advanced Topic: Streams and Low-Level Input and Output • Naming and Finding Files • Manipulating Files and Directories • Reading Data • Searching Files • Searching and Reading Strings • Special Topic: Calling External Functions • Advanced Topic: The Structure of <i>MathLink</i>	
2.11 Global Aspects of <i>Mathematica</i> Sessions	513
The Main Loop • Dialogs • Interactive Input • Date and Time Functions • Memory Management • Advanced Topic: System Parameters • Special Topic: Saving the State of a <i>Mathematica</i> Session	

Part 3. Advanced Mathematics in *Mathematica*

3.1 Numbers	534
Types of Numbers • Converting between Different Forms of Numbers • Numerical Precision • Arbitrary-Precision Numbers • Machine-Precision Numbers • Advanced Topic: Indeterminate and Infinite Results	
3.2 Mathematical Functions	550
Naming Conventions • Numerical Functions • Pseudorandom Numbers • Integer and Number-Theoretical Functions • Combinatorial Functions • Elementary Transcendental Functions • Functions That Do Not Have Unique Values • Mathematical Constants • Orthogonal Polynomials • Special Functions • Elliptic Integrals and Elliptic Functions • Statistical Distributions and Related Functions	
3.3 Algebraic Manipulation	591
Structural Operations on Polynomials • Finding the Structure of a Polynomial • Structural Operations on Rational Expressions • Algebraic Operations on Polynomials • Polynomials Modulo Primes • Trigonometric Expressions • Expressions Involving Complex Variables	
3.4 Manipulating Equations	606
The Representation of Equations and Solutions • Equations in One Variable • Simultaneous Equations • Equations Involving Functions • Getting Full Solutions • Advanced Topic: Existence of Solutions • Eliminating Variables • Solving Equations with Subsidiary Conditions • Advanced Topic: Solving Logical Combinations of Equations • Advanced Topic: Equations Modulo Integers • Setting Up Algebraic Transformation Rules	
3.5 Calculus	624
Differentiation • Total Derivatives • Derivatives of Unknown Functions • Advanced Topic: The Representation of Derivatives • Defining Derivatives • Indefinite Integrals • Integrals That <i>Mathematica</i> Can and Cannot Do • Definite Integrals • Defining Integrals • Manipulating Integrals in Symbolic Form • Differential Equations	
3.6 Power Series, Limits and Residues	639
Making Power Series Expansions • Advanced Topic: The Representation of Power Series • Operations on Power Series • Advanced Topic: Composition and Inversion of Power Series • Converting Power Series to Normal Expressions • Solving Equations Involving Power Series • Finding Limits • Residues	
3.7 Linear Algebra	649
Constructing Matrices • Getting Pieces of Matrices • Scalars, Vectors and Matrices • Operations on Scalars, Vectors and Matrices • Multiplying Vectors and Matrices • Matrix Inversion • Basic Matrix Operations • Solving Linear Systems • Advanced Topic: Generalized Linear Algebra • Eigenvalues and Eigenvectors • Advanced Topic: Matrix Decompositions • Advanced Topic: Tensors	
3.8 Numerical Operations on Data	672
Curve Fitting • Approximate Functions and Interpolation • Fourier Transforms	
3.9 Numerical Operations on Functions	683
Numerical Mathematics in <i>Mathematica</i> • The Uncertainties of Numerical Mathematics • Numerical Integration • Numerical Evaluation of Sums and Products • Numerical Solution of Polynomial Equations • Numerical Root Finding • Numerical Solution of Differential Equations • Numerical Minimization • Linear Programming	

Appendix. *Mathematica* Reference Guide

A.1	Basic Objects	710
A.2	Input Syntax	714
A.3	Some General Notations and Conventions.....	723
A.4	Evaluation.....	729
A.5	Patterns and Transformation Rules	733
A.6	Input and Output	738
A.7	<i>Mathematica</i> Sessions and Global Objects.....	741
A.8	Listing of Built-in <i>Mathematica</i> Objects	749
	Index	907