

Contents

1	Introduction to <i>Mathematica</i>	1
1.1	What is <i>Mathematica</i> ?	1
1.2	Getting Help	2
1.3	Installing and Running <i>Mathematica</i>	2
1.4	How the Book is Organized	3
1.5	A Brief Tour of <i>Mathematica</i>	4
1.5.1	Symbolic and Numerical Operations	4
1.5.2	Vector and Matrix Operations	8
1.5.3	2-D and 3-D Graphing	10
1.5.4	User-Defined Functions	20
1.5.5	Data Import and Export	21
1.5.6	<i>Mathematica</i> Packages	22
1.6	References and Recommended Reading	23
2	Special Plots for Geoscience Data	25
2.1	<i>Mathematica</i> Packages You Will Need	25
2.2	Overview	25
2.3	Stem Plots	25
2.3.1	Importing the Data	26
2.3.2	Creating the Stem Plot	26
2.4	Rose Plots	29
2.4.1	Importing the Data	29
2.4.2	Creating the Rose Plot	30
2.5	Ternary Plots	35
2.6	Stereographic Projections	37
2.6.1	Stereographic Projections of Planes	38
2.6.2	Stereographic Projections of Lines	39
2.7	Equal Area Projections	41
2.7.1	Equal Area Projections of Lines	41
2.7.2	Contouring Equal Area Projections	43
2.8	Box and Whisker Plots	47
2.9	Well Logs	49
2.10	References and Recommended Reading	55

3	Manipulating and Solving Equations	57
3.1	<i>Mathematica</i> Packages You Will Need	57
3.2	Basic Symbolic Manipulation	57
3.3	Matrix and Vector Operations	62
3.4	Linear Equation Solving	64
3.4.1	Solve, Roots, and Reduce	64
3.4.2	NSolve and FindRoots	66
3.4.3	Geoscience Examples	68
3.5	Ordinary Differential Equations	78
3.5.1	Manual Manipulation and Integration	78
3.5.2	Solutions Using DSolve and NDSolve	80
3.5.3	Geoscience Examples	81
3.6	Partial Differential Equations	103
3.6.1	Hillslope Diffusion	103
3.6.2	Periodic Heat Flow	109
3.6.3	Topographic Loading of Earth's Crust	113
3.6.4	Two Dimensional Steady Groundwater Flow	119
3.7	References and Recommended Reading	129
4	Random Variables and Univariate Probability Distributions	131
4.1	<i>Mathematica</i> Packages You Will Need	131
4.2	The Concept of Random Variables	131
4.3	Some Continuous Distributions	133
4.3.1	Normal Distribution	133
4.3.2	Log-Normal Distribution	135
4.3.3	Uniform Distribution	136
4.3.4	Extreme Value Distribution	137
4.3.5	Beta Distribution	137
4.3.6	Pareto Distribution	139
4.4	Some Discrete Distributions	140
4.4.1	Poisson Distribution	140
4.4.2	Binomial Distribution	142
4.5	Relating Distributions to Data: Method of Moments	142
4.5.1	How Good Are Those Estimates?	145
4.6	Parametric Hypothesis Testing: t and F tests	147
4.6.1	The t Statistic	148
4.6.2	Critical t Values	149
4.6.3	Comparing Two Means or Variances	152
4.7	Nonparametric Hypothesis Testing: K-S Tests	154
4.8	Generating Random Numbers from Probability Distributions	157
4.9	Care and Feeding of the Random Number Generator	162
4.10	Illustrating the Central Limit Theorem	163
4.11	The Pitfalls of Undersampling	166
4.12	References and Recommended Reading	171

5	Probabilistic Simulation	173
5.1	<i>Mathematica</i> Packages You Will Need	173
5.2	Flood Frequency Modeling	173
5.2.1	Plotting the Data	174
5.2.2	Log-Normal and Extreme Value Distribution Fitting	175
5.2.3	Empirical Cumulative Distribution	177
5.2.4	Comparison of Results	178
5.2.5	Exceedance Probability and Recurrence Intervals	179
5.3	Didn't We Just Have a 100 Year Flood?	181
5.4	Monte Carlo Simulation of a Wetting Front	183
5.5	Monte Carlo Analysis of Infinite Slope Stability	186
5.5.1	Static Factor of Safety	186
5.5.2	Effects of Changing Independent Variable Distributions	189
5.5.3	Conditional Probability: Earthquakes and Slope Stability ...	192
5.6	Apparent Clast Size Distributions: The Outcrop Effect	196
5.6.1	Randomly Rotated Ellipsoids	202
5.7	References and Recommended Reading	211
6	Interpolation and Regression	213
6.1	<i>Mathematica</i> Packages You Will Need	213
6.2	Interpolation or Regression: Which is Appropriate?	213
6.3	Interpolation	214
6.3.1	Finding a Single Interpolating Polynomial	214
6.3.2	Piecewise Polynomial Interpolation	218
6.4	Linear Regression	221
6.4.1	Derivation of Linear Least Squares Equations	222
6.4.2	Residuals	226
6.4.3	Goodness-of-Fit and the Correlation Coefficient	228
6.4.4	Significance of Regression Results: ANOVA	229
6.4.5	Using Fit and Regress	231
6.4.6	Can I Solve for the Independent Variable?	233
6.4.7	Reduced Major Axis Regression: Two Variables with Error .	240
6.5	Nonlinear Regression	244
6.5.1	Nonlinear Least Squares	245
6.5.2	Logistic Regression	247
6.6	References and Recommended Reading	255
7	Visualizing and Analyzing Surfaces	257
7.1	<i>Mathematica</i> Packages You Will Need	257
7.2	Gridded Data	257
7.2.1	Digital Elevation Models	258
7.2.2	Importing SDTS DEM Files	259
7.2.3	Contour Plots	260
7.2.4	Density Plots	263
7.2.5	Three Dimensional Surface Plots	265

7.2.6	Quantitative Terrain Analysis	268
7.2.7	Composite Geomorphic Maps	281
7.3	Irregularly Spaced Data	284
7.3.1	Reciprocal Distance Gridding	290
7.3.2	Thin Plate Spline Gridding	292
7.3.3	A Note About Kriging	294
7.3.4	Adding Well Locations to Surface Plots	294
7.3.5	Comparing Results	296
7.4	Trend Surface Mapping	298
7.5	References and Recommended Reading	305
8	Digital Signal and Image Processing	307
8.1	<i>Mathematica</i> Packages You Will Need	307
8.2	The Nature of Periodic Waveforms	307
8.3	Discrete Fourier Transforms	310
8.4	Autocovariance and Autocorrelation	318
8.5	Filters and Convolution	321
8.5.1	First Differences	322
8.5.2	Moving Averages and Smoothing	325
8.5.3	High-Pass Filtering	327
8.6	Image Processing	328
8.6.1	Importing Digital Images	328
8.6.2	Basic Mathematical Operations	333
8.6.3	Thresholding	337
8.6.4	Smoothing or Blurring	338
8.6.5	Unsharp Masking	340
8.6.6	Edge Detection	342
8.6.7	Using ListInterpolation	345
8.7	Recommended Reading	347
Appendix A Mathematica Functions in the Computational Geoscience		
	Package	349
A.1	Introduction	349
A.2	Plotting and Calculations	349
A.3	Color Functions	351
Appendix B Working with Color		
B.4	<i>Mathematica</i> Packages You Will Need	353
B.5	Specifying Colors in <i>Mathematica</i>	353
B.5.1	Hue, Saturation, and Brightness	353
B.5.2	Red, Green, and Blue (RGB)	355
B.5.3	Cyan, Magenta, Yellow, and Black (CMYK)	358
B.5.4	Other Color Systems	358
B.6	Using Color in Plots and Graphics	359
B.6.1	Plot and ListPlot	359

B.6.2	Contour and Density Plots	360
B.6.3	Surface Plots and Graphics	366
B.6.4	Graphics3D	372