

Walter Gander • Jiri Hirebicek

Solving Problems in Scientific Computing Using Maple and MATLAB⁹

Third, Expanded and Revised Edition 1997

With 161 Figures and 12 Tables



Springer

Contents

Chapter 1. The Tractrix and Similar Curves	1
1.1 Introduction	1
1.2 The Classical Tractrix	1
1.3 The Child and the Toy	3
1.4 The Jogger and the Dog	6
1.5 Showing the Motions with MATLAB	12
1.6 Jogger with Constant Velocity	15
1.7 Using a Moving Coordinate System	17
1.7.1 Transformation for Jogger/Dog	18
1.7.2 Transformation for Child/Toy	20
1.8 Examples	22
References	26
Chapter 2. Trajectory of a Spinning Tennis Ball	27
2.1 Introduction	27
2.2 MAPLE Solution	29
2.3 MATLAB Solution	32
2.4 Simpler Solution for MATLAB 5	35
References	37
Chapter 3. The Illumination Problem	39
3.1 Introduction	39
3.2 Finding the Minimal Illumination Point on a Road	40
3.3 Varying h_2 to Maximize the Illumination	42
3.4 Optimal Illumination	45
3.5 Conclusion	49
References	49
Chapter 4. Orbits in the Planar Three-Body Problem	51
4.1 Introduction	51
4.2 Equations of Motion in Physical Coordinates	52
4.3 Global Regularization	56
4.4 The Pythagorean Three-Body Problem	62
4.5 Conclusions	70
References	72

Chapter 5. The Internal Field in Semiconductors . . .	73
5.1 Introduction.	73
5.2 Solving a Nonlinear Poisson Equation Using MAPLE	74
5.3 MATLAB Solution	80.
References.	81
Chapter 6. Some Least Squares Problems	83
C.I Introduction.	83
6.2 Fitting Lines, Rectangles and Squares in the Plane	83
6.3 Fitting Hyperplanes.	95
References.	101
Chapter 7. The Generalized Billiard Problem	103
7.1 Introduction.	103
7.2 The Generalized Reflection Method	103
7.2.1 Line and Curve Reflection.	104
7.2.2 Mathematical Description.	105
7.2.3 MAPLE Solution.	106
7.3 The Shortest Trajectory Method.	107
7.3.1 MAPLE Solution.	108
7.4 Examples.	108
7.4.1 The Circular Billiard Table.	108
7.4.2 The Elliptical Billiard Table.	113
7.4.3 The Snail Billiard Table.	115
7.4.4 The Star Billiard Table.	115
7.5 Conclusions.	119
References.	121
Chapter 8. Mirror Curves.	123
8.1 The Interesting Waste.	123
8.2 The Mirror Curves Created by MAPLE	123
8.3 The Inverse Problem.	125
8.3.1 Outflanking Manoeuvre.	125
8.3.2 Geometrical Construction of a Point on the Pattern Curve.	126
8.3.3 MAPLE Solution.	127
8.3.4 Analytic Solution.	128
8.4 Examples.	128
8.4.1 The Circle as the Mirror Curve.	128
8.4.2 The Line as the Mirror Curve.	131
8.5 Conclusions.	132
References.	134

Chapter 9. Smoothing Filters.	135
9.1 Introduction.	135
9.2 Savitzky-Golay Filter.	135
9.2.1 Filter Coefficients.	136
9.2.2 Results.	139
9.3 Least Squares Filter.	140
9.3.1 Lagrange Equations.	141
9.3.2 Zero Finder.	143
9.3.3 Evaluation of the Secular Function.	144
9.3.4 MEX-Files.	146
9.3.5 Results.	150
References.	152
Chapter 10. The Radar Problem	155
10.1 Introduction.	155
10.2 Converting Degrees into Radians.	156
10.3 Transformation into Geocentric Coordinates	157
10.4 The Transformations.	160
10.5 Final Algorithm.	162
10.6 Practical Example.	162
References.	164
Chapter 11. Conformal Mapping of a Circle	165
11.1 Introduction.	165
11.2 Problem Outline.	165
11.3 MAPLE Solution.	166
11.4 MATLAB Solution.	170
References.	172
Chapter 12. The Spinning Top.	173
12.1 Introduction.	173
12.2 Formulation and Basic Analysis of the Solution	175
12.3 The Numerical Solution.	180
References.	182
Chapter 13. The Calibration Problem.	183
13.1 Introduction.	183
13.2 The Physical Model Description.	183
13.3 Approximation by Splitting the Solution.	186
13.4 Conclusions.	191
References.	192
Chapter 14. Heat Flow Problems.	193
14.1 Introduction.	193
14.2 Heat Flow through a Spherical Wall.	193
14.2.1 A Steady State Heat Flow Model.	194

14.2.2 Fourier Model for Steady State	195
14.2.3 MAPLE Plots.	196
14.3 Non Stationary Heat Flow through an Agriculture Field.	197
14.3.1 MAPLE Plots.	201
References.	201
Chapter 15. Modeling Penetration Phenomena	203
15.1 Introduction.	203
15.2 Short description of the penetration theory.	203
15.3 The Tate-Alekseevskii model	205
15.3.1 Special case $R_r Y_p$	207
15.3.2 Special case $p_p = p_t = p$	207
15.4 The eroding rod penetration model	209
15.5 Numerical Example.	215
15.6 Conclusions.	218
References.	218
Chapter 16. Heat Capacity of System of Bose Particles.	221
16.1 Introduction.	221
16.2 MAPLE Solution	223
References.	227
Chapter 17. Free Metal Compression.	229
17.1 Introduction.	229
17.2 The Base Expansion	231
17.3 Base Described by One and Several Functions	233
17.4 The Lateral Side Distortion.	235
17.5 Non-centered Bases.	239
17.6 Three Dimensional Graphical Representation of the Distorted Body.	242
17.6.1 Centered base.	242
17.6.2 Non-centered, Segmented Base.	246
17.6.3 Convex Polygon Base.	248
17.7 Three Dimensional Animation.	249
17.8 Limitations and Conclusions.	250
References.	252
Chapter 18. Gauss Quadrature	253
18.1 Introduction.	253
18.2 Orthogonal Polynomials.	254
18.3 Quadrature Rule.	268
18.4 Gauss Quadrature Rule.	269
18.5 Gauss-Radau Quadrature Rule.	270

18.6 Gauss-Lobatto Quadrature Rule.	273
18.7 Weights.	276
18.8 Quadrature Error.	277
References.	280
Chapter 19. Symbolic Computation	
of Explicit Runge-Kutta Formulas	283
19.1 Introduction.	283
19.2 Derivation of the Equations for the Parameters . . .	285
19.3 Solving the System of Equations.	287
19.3.1 Grobner Bases.	289
19.3.2 Resultants.	292
19.4 The Complete Algorithm.	294
19.4.1 Example 1:.	294
19.4.2 Example 2:.	295
19.5 Conclusions.	298
References.	299
Chapter 20. Transient Response of a	
Two-Phase Half-Wave Rectifier.	301
20.1 Introduction.	301
20.2 Problem Outline.	301
20.3 Difficulties in Applying Conventional Codes	
and Software Packages.	304
20.4 Solution by Means of MAPLE	306
References.	312
Chapter 21. Circuits in Power Electronics.	313
21.1 Introduction.	313
21.2 Linear Differential Equations	
with Piecewise Constant Coefficients.	315
21.3 Periodic Solutions.	318
21.4 A MATLAB Implementation	319.
21.5 Conclusions.	324
References.	324
Chapter 22. Newton's and Kepler's laws.	325
22.1 Introduction.	325
22.2 Equilibrium of Two Forces.	325
22.3 Equilibrium of Three Forces.	326
22.4 Equilibrium of Three Forces, Computed from	
the Potential Energy.	328
22.5 Gravitation of the Massive Line Segment	330
22.5.1 Potential and Intensity.	330
22.5.2 The Particle Trajectory.	333

22.6 The Earth Satellite.	335
22.7 Earth Satellite, Second Solution.	336
22.8 The Lost Screw.	338
22.9 Conclusions.	339
References.	340
Chapter 23. Least Squares Fit of Point Clouds	341
23.1 Introduction.	341
23.2 Computing the Translation.	341
23.3 Computing the Orthogonal Matrix.	342
23.4 Solution of the Procrustes Problem.	343
23.5 Algorithm.	344
23.6 Decomposing the Orthogonal Matrix.	345
23.7 Numerical Examples.	347
23.7.1 First example.	347
23.7.2 Second example.	350
References.	351
Chapter 24. Modeling Social Processes.	353
24.1 Introduction.	353
24.2 Modeling Population Migration.	353
24.2.1 Cyclic Migration without Regulation	355
24.2.2 Cyclic Migration with Regulation.	356
24.3 Modeling Strategic Investment.	358
References.	360
Chapter 25. Contour Plots of Analytic Functions . . .	361
25.1 Introduction.	361
25.2 Contour Plots by the contour Command.	361
25.3 Differential Equations.	364
25.3.1 Contour Lines $r = \text{const}$	364
25.3.2 Contour Lines $\angle p = \text{const}$	366
25.4 The Contour Lines $r = 1$ of $/ = e_{r_r}$	368
25.5 The Contour Lines $tp = \text{const}$ of $/ = e_{r_r}$	372
References.	373
Chapter 26. Non Linear Least Squares: Finding the most accurate location of an aircraft . . .	375
26.1 Introduction.	375
26.2 Building the Least Squares Equations.	376
26.3 Solving the Non-linear System.	378
26.4 Confidence/Sensitivity Analysis.	381

Chapter 27. Computing Plane Sundials	385
27.1 Introduction.	385
27.2 Astronomical Fundamentals.	385
27.2.1 Coordinate Systems.	386
27.2.2 The Gnomonic Projection.	388
27.3 Time Marks.	390
27.3.1 Local Real Time.	390
27.3.2 Mean Time.	391
27.3.3 Babylonian and Italic Hours.	396
27.4 Sundials on General Planes.	397
27.5 A Concluding Example.	398
References.	400
Index	401
Index of used MAPLE Commands	407
Index of used MATLAB Commands	411