

1	What can't be ignored	1
1.1	The MATLAB and Octave environments	1
1.2	Real numbers	3
1.2.1	How we represent them	3
1.2.2	How we operate with floating-point numbers	6
1.3	Complex numbers	8
1.4	Matrices	10
1.4.1	Vectors	14
1.5	Real functions	16
1.5.1	The zeros	19
1.5.2	Polynomials	20
1.5.3	Integration and differentiation	22
1.6	To err is not only human	25
1.6.1	Talking about costs	28
1.7	The MATLAB language	30
1.7.1	MATLAB statements	32
1.7.2	Programming in MATLAB	34
1.7.3	Examples of differences between MATLAB and Octave languages	38
1.8	What we haven't told you	38
1.9	Exercises	39
2	Nonlinear equations	41
2.1	Some representative problems	41
2.2	The bisection method	43
2.3	The Newton method	47
2.3.1	How to terminate Newton's iterations	50
2.4	The secant method	51
2.5	Systems of nonlinear equations	52

2.6	Fixed point iterations	56
2.6.1	How to terminate fixed point iterations	62
2.7	Acceleration using Aitken method	63
2.8	Algebraic polynomials	67
2.8.1	Hörner's algorithm	68
2.8.2	The Newton-Hörner method	70
2.9	What we haven't told you	72
2.10	Exercises	74
3	Approximation of functions and data	77
3.1	Some representative problems	77
3.2	Approximation by Taylor's polynomials	79
3.3	Interpolation	80
3.3.1	Lagrangian polynomial interpolation	81
3.3.2	Stability of polynomial interpolation	86
3.3.3	Interpolation at Chebyshev nodes	87
3.3.4	Barycentric interpolation formula	90
3.3.5	Trigonometric interpolation and FFT	93
3.4	Piecewise linear interpolation	98
3.5	Approximation by spline functions	100
3.6	The least-squares method	104
3.7	What we haven't told you	108
3.8	Exercises	110
4	Numerical differentiation and integration	113
4.1	Some representative problems	113
4.2	Approximation of function derivatives	115
4.3	Numerical integration	117
4.3.1	Midpoint formula	118
4.3.2	Trapezoidal formula	120
4.3.3	Simpson formula	121
4.4	Interpolatory quadratures	123
4.5	Simpson adaptive formula	127
4.6	Monte Carlo Methods for Numerical Integration	131
4.7	What we haven't told you	133
4.8	Exercises	134
5	Linear systems	137
5.1	Some representative problems	137
5.2	Linear system and complexity	142
5.3	The LU factorization method	143
5.4	The pivoting technique	154
5.4.1	The <i>fill-in</i> of a matrix	157
5.5	How accurate is the solution of a linear system?	158
5.6	How to solve a tridiagonal system	162

5.7	Overdetermined systems	163
5.8	What is hidden behind the MATLAB command \	166
5.9	Iterative methods	168
5.9.1	How to construct an iterative method	169
5.10	Richardson and gradient methods	174
5.11	The conjugate gradient method	177
5.12	When should an iterative method be stopped?	180
5.13	To wrap-up: direct or iterative?	182
5.14	What we haven't told you	188
5.15	Exercises	188
6	Eigenvalues and eigenvectors	193
6.1	Some representative problems	194
6.2	The power method	196
6.2.1	Convergence analysis	199
6.3	Generalization of the power method	201
6.4	How to compute the shift	203
6.5	Computation of all the eigenvalues	206
6.6	What we haven't told you	209
6.7	Exercises	210
7	Numerical optimization	213
7.1	Some representative problems	214
7.2	Unconstrained optimization	217
7.3	Derivative free methods	219
7.3.1	Golden section and quadratic interpolation methods	219
7.3.2	Nelder and Mead method	223
7.4	The Newton method	227
7.5	Descent (or line search) methods	228
7.5.1	Descent directions	229
7.5.2	Strategies for choosing the steplength α_k	231
7.5.3	The descent method with Newton's directions	237
7.5.4	Descent methods with quasi-Newton directions	238
7.5.5	Gradient and conjugate gradient descent methods	240
7.6	Trust region methods	242
7.7	The nonlinear least squares method	248
7.7.1	Gauss-Newton method	249
7.7.2	Levenberg-Marquardt's method	252
7.8	Constrained optimization	253
7.8.1	The penalty method	259
7.8.2	The augmented Lagrangian method	264
7.9	What we haven't told you	267
7.10	Exercises	268

8 Ordinary differential equations	271
8.1 Some representative problems	271
8.2 The Cauchy problem	274
8.3 Euler methods	275
8.3.1 Convergence analysis	278
8.4 The Crank-Nicolson method	282
8.5 Zero-stability	284
8.6 Stability on unbounded intervals	286
8.6.1 The region of absolute stability	289
8.6.2 Absolute stability controls perturbations	290
8.6.3 Stepsize adaptivity for the forward Euler method	297
8.7 High order methods	300
8.8 The predictor-corrector methods	305
8.9 Systems of differential equations	307
8.10 Some examples	313
8.10.1 The spherical pendulum	313
8.10.2 The three-body problem	317
8.10.3 Some stiff problems	319
8.11 What we haven't told you	325
8.12 Exercises	326
9 Numerical approximation of boundary-value problems	329
9.1 Some representative problems	330
9.2 Approximation of boundary-value problems	332
9.2.1 Finite difference approximation of the one-dimensional Poisson problem	333
9.2.2 Finite difference approximation of a convection-dominated problem	336
9.2.3 Finite element approximation of the one-dimensional Poisson problem	337
9.2.4 Finite difference approximation of the two-dimensional Poisson problem	341
9.2.5 Consistency and convergence of finite difference discretization of the Poisson problem	347
9.2.6 Finite difference approximation of the one-dimensional heat equation	348
9.2.7 Finite element approximation of the one-dimensional heat equation	352
9.3 Hyperbolic equations: a scalar pure advection problem	355
9.3.1 Finite difference discretization of the scalar transport equation	357

9.3.2	Finite difference analysis for the scalar transport equation	359
9.3.3	Finite element space discretization of the scalar advection equation	366
9.4	The wave equation	367
9.4.1	Finite difference approximation of the wave equation	369
9.5	What we haven't told you	373
9.6	Exercises	374
10	Solutions of the exercises	377
10.1	Chapter 1	377
10.2	Chapter 2	380
10.3	Chapter 3	385
10.4	Chapter 4	389
10.5	Chapter 5	394
10.6	Chapter 6	401
10.7	Chapter 7	404
10.8	Chapter 8	411
10.9	Chapter 9	422
	References	429
	Index	435