

# Contents

<b>Foreword to the Second Edition</b>	<b>xi</b>
<b>Foreword to the First Edition</b>	<b>xiii</b>
<b>1 The Computer</b>	<b>1</b>
1.1 The Operating System . . . . .	2
1.1.1 Filesystem . . . . .	3
1.1.2 Commands . . . . .	10
1.1.3 Looking for Help . . . . .	14
1.2 Text Processing Tools – Filters . . . . .	16
1.3 Programming with Emacs . . . . .	20
1.3.1 Calling Emacs . . . . .	21
1.3.2 Interacting with Emacs . . . . .	22
1.3.3 Basic Editing . . . . .	25
1.3.4 Cut and Paste . . . . .	27
1.3.5 Windows . . . . .	28
1.3.6 Files and Buffers . . . . .	29
1.3.7 Modes . . . . .	30
1.3.8 Emacs Help . . . . .	32
1.3.9 Emacs Customization . . . . .	34
1.4 The C++ Programming Language . . . . .	35
1.4.1 The Foundation . . . . .	35
1.5 Gnuplot . . . . .	47
1.6 Shell Scripting . . . . .	52
<b>2 Kinematics</b>	<b>63</b>
2.1 Motion on the Plane . . . . .	63
2.1.1 Plotting Data . . . . .	72
2.1.2 More Examples . . . . .	75
2.2 Motion in Space . . . . .	87
2.3 Trapped in a Box . . . . .	96

2.3.1	The One Dimensional Box . . . . .	97
2.3.2	Errors . . . . .	105
2.3.3	The Two Dimensional Box . . . . .	109
2.4	Applications . . . . .	112
2.5	Problems . . . . .	132
<b>3</b>	<b>Logistic Map</b>	<b>137</b>
3.1	Introduction . . . . .	137
3.2	Fixed Points and $2^n$ Cycles . . . . .	139
3.3	Bifurcation Diagrams . . . . .	146
3.4	The Newton-Raphson Method . . . . .	150
3.5	Calculation of the Bifurcation Points . . . . .	156
3.6	Liapunov Exponents . . . . .	160
3.7	Problems . . . . .	174
<b>4</b>	<b>Motion of a Particle</b>	<b>185</b>
4.1	Numerical Integration of Newton's Equations . . . . .	185
4.2	Prelude: Euler Methods . . . . .	186
4.3	Runge–Kutta Methods . . . . .	198
4.3.1	A Program for the 4th Order Runge–Kutta . . . . .	202
4.4	Comparison of the Methods . . . . .	206
4.5	The Forced Damped Oscillator . . . . .	209
4.6	The Forced Damped Pendulum . . . . .	217
4.7	Appendix: On the Euler–Verlet Method . . . . .	223
4.8	Appendix: 2nd order Runge–Kutta Method . . . . .	227
4.9	Problems . . . . .	230
<b>5</b>	<b>Planar Motion</b>	<b>235</b>
5.1	Runge–Kutta for Planar Motion . . . . .	235
5.2	Projectile Motion . . . . .	240
5.3	Planetary Motion . . . . .	248
5.4	Scattering . . . . .	252
5.4.1	Rutherford Scattering . . . . .	255
5.4.2	More Scattering Potentials . . . . .	263
5.5	More Particles . . . . .	265
5.6	Problems . . . . .	277
<b>6</b>	<b>Motion in Space</b>	<b>281</b>
6.1	Adaptive Stepsize Control for RK Methods . . . . .	282
6.1.1	The rksuite Suite of RK Codes . . . . .	282
6.1.2	Interfacing C++ Programs with Fortran . . . . .	286

6.1.3 The rksuite Driver . . . . .	292
6.2 Motion of a Particle in an EM Field . . . . .	297
6.3 Relativistic Motion . . . . .	298
6.4 Problems . . . . .	310
<b>7 Electrostatics</b>	<b>313</b>
7.1 Electrostatic Field of Point Charges . . . . .	313
7.2 The Program – Appetizer and ... Desert . . . . .	316
7.3 The Program – Main Dish . . . . .	325
7.4 The Program - Conclusion . . . . .	331
7.5 Electrostatic Field in the Vacuum . . . . .	336
7.6 Results . . . . .	343
7.7 Poisson Equation . . . . .	344
7.8 Problems . . . . .	351
<b>8 Diffusion Equation</b>	<b>355</b>
8.1 Introduction . . . . .	355
8.2 Heat Conduction in a Thin Rod . . . . .	357
8.3 Discretization . . . . .	358
8.4 The Program . . . . .	360
8.5 Results . . . . .	363
8.6 Diffusion on the Circle . . . . .	365
8.7 Analysis . . . . .	369
8.8 Problems . . . . .	373
<b>9 The Anharmonic Oscillator</b>	<b>375</b>
9.1 Introduction . . . . .	375
9.2 Calculation of the Eigenvalues of $H_{nm}(\lambda)$ . . . . .	377
9.3 Results . . . . .	387
9.4 The Double Well Potential . . . . .	392
9.5 Problems . . . . .	401
<b>10 Time Independent Schrödinger Equation</b>	<b>405</b>
10.1 Introduction . . . . .	405
10.2 The Infinite Potential Well . . . . .	408
10.3 Bound States . . . . .	420
10.4 Measurements . . . . .	430
10.5 The Anharmonic Oscillator - Again... . . . . .	436
10.6 The Lennard–Jones Potential . . . . .	441
10.7 Problems . . . . .	443

<b>11 The Random Walker</b>	<b>449</b>
11.1 (Pseudo)Random Numbers . . . . .	450
11.2 Using Pseudorandom Number Generators . . . . .	462
11.3 The MIXMAX Random Number Generator . . . . .	467
11.4 Random Walks . . . . .	470
11.5 Problems . . . . .	479
<b>12 Monte Carlo Simulations</b>	<b>483</b>
12.1 Statistical Physics . . . . .	484
12.2 Entropy . . . . .	487
12.3 Fluctuations . . . . .	490
12.4 Correlation Functions . . . . .	493
12.5 Sampling . . . . .	495
12.5.1 Simple Sampling . . . . .	495
12.5.2 Importance Sampling . . . . .	497
12.6 Markov Processes . . . . .	497
12.7 Detailed Balance Condition . . . . .	499
12.8 Problems . . . . .	501
<b>13 Simulation of the <math>d = 2</math> Ising Model</b>	<b>503</b>
13.1 The Ising Model . . . . .	503
13.2 Metropolis . . . . .	509
13.3 Implementation . . . . .	512
13.3.1 The Program . . . . .	517
13.3.2 Towards a Convenient User Interface . . . . .	523
13.4 Thermalization . . . . .	534
13.5 Autocorrelations . . . . .	537
13.6 Statistical Errors . . . . .	543
13.6.1 Errors of Independent Measurements . . . . .	545
13.6.2 Jackknife . . . . .	547
13.6.3 Bootstrap . . . . .	549
13.7 Appendix: Autocorrelation Function . . . . .	550
13.8 Appendix: Error Analysis . . . . .	557
13.8.1 The Jackknife Method . . . . .	557
13.8.2 The Bootstrap Method . . . . .	562
13.8.3 Comparing the Methods . . . . .	565
13.9 Problems . . . . .	569
<b>14 Critical Exponents</b>	<b>577</b>
14.1 Critical Slowing Down . . . . .	579
14.2 Wolff Cluster Algorithm . . . . .	580

14.3 Implementation . . . . .	587
14.3.1 The Program . . . . .	589
14.4 Production . . . . .	594
14.5 Data Analysis . . . . .	597
14.6 Autocorrelation Times . . . . .	605
14.7 Temperature Scaling . . . . .	608
14.8 Finite Size Scaling . . . . .	614
14.9 Calculation of $\beta_c$ . . . . .	616
14.10 Studying Scaling with Collapse . . . . .	621
14.11 Binder Cumulant . . . . .	631
14.12 Appendix: Scaling . . . . .	635
14.12.1 Binder Cumulant . . . . .	635
14.12.2 Scaling . . . . .	640
14.12.3 Finite Size Scaling . . . . .	642
14.13 Appendix: Critical Exponents . . . . .	645
14.13.1 Definitions . . . . .	645
14.13.2 Hyperscaling Relations . . . . .	646
14.14 Problems . . . . .	646
<b>Bibliography</b>	<b>650</b>
<b>Index</b>	<b>659</b>