Contents

Preface χV So we're all on the same page... xvii What is science? xviii To the Student xix To the Teacher **Contact Information** $\mathbf{X}\mathbf{X}$ **Acknowledgments** XXi Introduction to SNB 1 Why SNB? The Basics 2 Physics à la mode: Math M or Text T 8 Creating Mathematical Expressions Evaluate = and Evaluate Numerically 11 Scientific Notation 13 Substitution and Endpoint Evaluation **Solving Equations** 17 Solve Exact 18 Solve Numeric

24

Systems of Equations

1

Contents

The Compute Menu 25

Simplify and Expand 25

Factor 26

Rewrite and Combine 28

Check Equality 29

Polynomials 31

Power Series 32

Definitions Figure 1

师

35

Other Good Stuff 37

Computing In-place 37

Making Assumptions About Variables 37

Limits 40

A Few Words About Calculus J

46

 \mathcal{S}

42

Units

Converting Units 47

User-Defined Units 51

Plotting 52

Plot 2D Rectangular 4 54

Other 2-Dimensional Plots 55

Plot 3D Rectangular 4 58

Cylindrical and Spherical Plots 60

Plotting Data 63

Fitting a Curve to Data 63

Differential Equations 67

Solve ODE Exact and Laplace 68

Solve ODE Numeric 70

2 One-Dimensional Kinematics 83

Constant Acceleration 83

Displacement and Position 83

Velocity and Acceleration 84

Equations of Motion 86

Signs of the Times 88

Free Fall 89

Varying Acceleration 91

Displacement, Velocity, and Acceleration 91

Equations of Motion 93

Gravity and Air Resistance 96

Resisting Air Resistance is Futile 97

Long-Distance Free Fall 99

Problems 102

3 Vectors 105

Components of a Vector 107

Magnitude and Direction 108

Adding Vectors 111

The Component Method 112

The SNB Method 113

The Graphing Method 115

Unit Vectors 119

Multiplying Vectors 120

Dot Product 121

Cross Product 122

4 Projectile Motion 127

No Air Resistance 127

Trajectory 132
Time of Flight 134
Maximum Height 135

Linear Air Resistance 137

Trajectory 141
Time of Flight and Range 143
Maximum Height 145
Turn Off the Air! 146
Turn Down the Air! 147

Quadratic Air Resistance 151

Height-Dependent Air Resistance 152

Problems 154

5 Newton's Laws of Motion 157

Newton's First Law 157

Newton's Second Law for Constant Forces 158

Newton's Second Law for Varying Forces 165

Time-Dependent Forces 165
Velocity-Dependent Forces 167
Position-Dependent Forces 170

Newton's Third Law 173

Problems 175

6 Conservation Laws 179

Definitions 179

Conservation of Energy 181

Work 181

The Work-Energy Theorem 185

Potential Energy 186

Mechanical Energy is Conserved 188 A Complete Bookkeeping 191

Conservation of Momentum 193

Collisions in 1-Dimension 193
Collisions in 2-Dimensions 196

Rockets 199

Deep Space 199
Launch 202
Air Resistance 207
Varying Gravity and Air Resistance 213

Problems 216

7 Circular Motion 221

Uniform Circular Motion 222

The Rotating Umbrella 224

Rotational Kinematics 227

The Compact Disk 229

Newton's Second Law and Circular Motion 233

Uniform Circular Motion and the 2nd Law 233 Non-Uniform Circular Motion and the 2nd Law 235 Sliding on a Sphere 236

Problems 248

8 Harmonic Motion 251

Simple Harmonic Motion, Simply 251

Energy and SHM 254

Not-Quite-as-Simple Harmonic Motion 255

Energy and SHM, Again 257

Damped Harmonic Motion 259

Underdamped ($\beta^2 < \omega_0^2$) 259 Critically Damped ($\beta^2 = \omega_0^2$) 261 Overdamped ($\beta^2 > \omega_0^2$) 262

Contents

Driven Harmonic Motion 263

Constant Driving Force, no Damping 263
Sinusoidal Driving Force, no Damping 264
Constant Driving Force with Damping 265
Sinusoidal Driving Force with Damping 267

Small Oscillations 270

Not-so-Simple Harmonic Motion 272

Problems 275

9 Central Forces 279

Equations of Motion 279

Newtonian Gravitation 285

Kepler's Laws 286

The Effective Potential 292

Two Special Forces 296

The 3-d Harmonic Oscillator 296
The Inverse-Square Force 299

Numerical Stuff 303

Problems 305

10 Fluids 309

Density and Pressure 309

Static Fluids 311

Buoyancy 312

Fluids in Motion 314

Bernoulli's Equation 316

Applications of Bernoulli's Equation 318

A More Realistic Approach 320

Flow in a Pipe 321

Stokes' Law 330

11 Temperature and Heat 335

Temperature Scales 335

Absolute Temperature 337

Heat and Work 338

Heat Flow 339

Change in Temperature: Specific Heat 339

Change in State: Latent Heat 340

Calorimetry 341

Varying Specific Heat 344

The Specific Heat of Solids 345

Problems 353

12 Special Relativity 359

The Two Postulates 360

The Consequences 361

Time Dilation 363

Length Contraction 364

Addition of Velocities 365

Simultaneity 367

The Lorentz Transformation 367

Space-Time 370

Relativistic Momentum and Energy 375

Relativistic Collisions 378

Relativistic Dynamics 382

Four-Vectors 387

A Topics in Classical Physics 397

Newton's Nose-Cone Problem 397

Simple Shapes 398

Frusta and Fudges 403

Newton's Minimizer 409

Indented Tips and the Minimizer 411

The Shape of the Eiffel Tower 414

An Interesting Classical Orbit 417

Fisher's Crystal 421

Problems 428

B Topics in Modern Physics 435

The Tale of the Traveling Triplets 435

Trip 1: Constance goes to Vega 435

Relativistic Interlude: Constant Acceleration 437

Trip 2: Axel goes to Vega 441

What happens on the way to Vega... 443

Orbits in General Relativity 445

Angular Momentum 447

Precessing Ellipses and Periodic Orbits 451

Be the Ball: Embedding Diagrams 456

Classical Lifetime of a Hydrogen Atom 460

Missed It By That Much 460

Can Special Relativity Save the Day? 462

Quantum Mechanical Bound States 465

Infinite Square Well ("Particle in a Box") 467

Finite Square Well 470

V-shaped Linear Well 477

Problems 483

References and Suggested Reading 491

Index 495