

Advanced Physics in Creation

Table of Contents

Module #1: Units and Vectors Revisited

Introduction	1
Units Revisited	1
A Review of Vectors	5
Unit Vectors	12
The Dot Product	15
The Physical Significance of the Dot Product	18
The Cross Product	20
The Physical Significance of the Cross Product	26
Summing Up	28

Module #2: Kinematics

Introduction	39
Position Versus Time Graphs	39
Velocity Versus Time Graphs	44
The Major One-Dimensional Motion Equations	49
Experiment 2.1: Measuring Your Vertical Pitching Speed	53
Air Resistance and Terminal Velocity	55
Experiment 2.2: The Effect of Cross Section on Air Resistance	56
Kinematics in Two Dimensions	59

Module #3: Newton's Laws

Introduction	83
Newton's Three Laws of Motion	84
Inertial Reference Frames and Inertial Mass	85
Newton's Second Law: A Few Reminders	89
Experiment 3.1: Building and Using Atwood's Machine	96
Newton's Second Law: Some Detailed Applications	98
Experiment 3.2: Measuring the Coefficient of Kinetic Friction	107
A Few Words About Newton's Third Law	109

Module #4: Energy and Momentum

Introduction	125
Review of Energy Concepts and Equations	125
Experiment 4.1: Ping Pong Pendulums	127
More Applications of Energy Concepts	130
Power	139
Momentum and Impulse	141
Experiment 4.2: Conservation of Momentum and Energy	142
Collisions in Two Dimensions	148

Module #5: Rotational Motion

Introduction	169
The Center of Mass	169
Experiment 5.1: The Center of Mass	173
Torque and Static Rotational Equilibrium	174
Experiment 5.2: Static Rotational Equilibrium	175
A Few Terms in Rotational Motion	180
Rotational Dynamics	185
Rotational Energy	192
Angular Momentum	194
Experiment 5.3: The Direction of the Angular Momentum Vector	195

Module #6: Oscillations and Waves

Introduction	209
The Mass/Spring System	210
A Detailed Description of the Mass/Spring System	213
The Pendulum	219
Experiment 6.1: The Simple Pendulum and the Physical Pendulum	220
Transverse and Longitudinal Waves	224
Experiment 6.2: Wave motion and Standing Waves	225
The Propagation of Waves	227
A Mathematical Description of a Harmonic Wave	230
Reflection and Superposition of Waves	233
Standing Waves	237

Module #7: Sound and Light

Introduction	249
Sound Waves	249
Experiment 7.1: Sound Waves in a Bottle and the “Bottle Paradox”	252
Standing Sound Waves	254
Beats	258
The Doppler Effect	260
Light: Electromagnetic Waves	262
Experiment 7.2: Interference of Light Waves	262
A Quick Review of Reflection and Refraction	267
Flat Mirrors	270
Curved Mirrors and the Mirror Equation	271
Lenses	275

Module #8: Gravity and Relativity

Introduction	289
Kepler's Laws and Gravity	289
Gravity and Extended Bodies	293
True Weight and Measured Weight	295
Gravitational Potential Energy	297
Einstein's Special Theory of Relativity	301
Time Dilation and Length Contraction	305
The Twin Paradox	311
The Famous Equation	312
Einstein's General Theory of Relativity	314
Experiment 8.1: Simulating Curved Spacetime	317

Module #9: Heat

Introduction	329
Temperature Scales	330
Temperature Changes Due to Heat	331
Phase Changes Due to Heat	335
Experiment 9.1: The Energy Associated With a Phase Change	335
Volume and Length Changes as a Result of Heat	339
Experiment 9.2: Measuring the Coefficient of Volume Expansion for a Gas	340
The Behavior of Gases	342
The Speed of Gas Molecules	346
Heat Transfer in Gases	353

Module #10: Thermodynamics

Introduction	363
The First Three Laws of Thermodynamics	363
A More Detailed Look at the First Law of Thermodynamics	367
A More General Way to Calculate Work	371
A Few Terms Related To The First Law of Thermodynamics	373
Experiment 10.1: Adiabatic Compression and Expansion	374
Cyclic Processes and The First Law of Thermodynamics	378
The Second Law of Thermodynamics	383
Heat Engines and the Carnot Cycle	386
The Third Law of Thermodynamics	392

Module #11: Electrostatics

Introduction	401
Coulomb's Law	402
Experiment 11.1: A Repulsive Application of Coulomb's Law	406
Electric Fields	407
A Quantitative Description of the Electric Field	410
Insulators, Conductors, Semiconductors, and Superconductors	416
Experiment 11.2: Conductors and Insulators	417
The Electric Field of a Conductor	422
Experiment 11.3: There Is No Electric Field Inside a Conductor	423

Module #12: Electrical Potential Energy and Electric Potential

Introduction	439
Electrical Potential Energy	439
Electric Potential	444
Capacitors and Uniform Electric Fields	448
Experiment 12.1: Making a Leyden Jar	449
The Electric Field and Energy of a Capacitor	455
Capacitors with Dielectrics	458

Module #13: DC Electric Circuits

Introduction	469
Resistance	469
Experiment 13.1: The Factors Which Influence Resistivity	471
A Review of Circuits, Ohm's Law, and Other Equations	475
Combinations of Resistors	479
Experiment 13.2: Resistors in Series and Parallel	479
Kirchhoff's Rules	483
Batteries, Electromotive Force, and Internal Resistance	491
Resistance-Capacitance (RC) Circuits	494
One Final Note	498

Module #14: Magnetism and Electromagnetic Induction

Introduction	513
A Review of Magnetic Fields and Their Source	513
Charged Particles Moving in Magnetic Fields	516
Cyclotrons	521
Magnetic Fields and Current-Carrying Wires	523
Motional EMF	526
Electromagnetic Induction	530
Alternating Current	536

Module #15: Atomic Physics

Introduction	549
The Photoelectric Effect: Light as a Particle	549
The Bohr Model of the Atom	554
A Detailed Look at the Bohr Model	556
The Bohr Model and Atomic Spectra	561
The Size of an Atom	566
Moving From the Bohr Model to the Quantum Mechanical Model	567

Module #16: Nuclear Physics

Introduction	581
Binding Energy	581
The Strong Nuclear Force	584
The Stability of a Nucleus	585
Radioactivity	587
Artificial Radioactivity	592
The Rate of Radioactive Decay	593
The Dangers of Radioactivity	595
Radioactive Dating	597
Other uses of Radioactivity and Ionizing Radiation	600
Nuclear Reactions	601
Using Nuclear Reactions to Make Energy	605