01 Physics and Measurement [] (see chem chap 1)
01-01 **The SI System**
01-02 **Standard Unit for Length, Mass, and Time**
01-03 **Derived Units**
01-04 **The Building Blocks of Matter** [] atoms, molecules
01-05 **Density and Atomic Mass** [] amu
01-06 **Dimensional Analysis**
01-07 **Conversion of Units**
01-08 **Order-of-Magnitude Calculations**
01-09 **Significant Digits and Measurements**
01-10 **Elementary Error Analysis**
01-11 **Mathematical and Scientific Notation** [] (see chem 01:09)
01-12 **Coordinate Systems**
01-13 **Mathematics Overview**
01-14 **Scientific Method**
01-15 **Scaling**
01-16 **Problem Solving Strategy**
01-17 **Measurement Tools**
01-99 Associated problems in Chapter 01

02 Motion in One Dimension
02-01 **Displacement** [] $\Delta x = x_f - x_i$
02-02 **Velocity and Speed** [] $v = \frac{\Delta x}{\Delta t}$
02-03 **Average Velocity for Motion along a Straight Line** [] $\overline{v} = \frac{v_i + v_f}{2}$
02-04 **Instantaneous Velocity and Speed** [] $v = \frac{dx}{dt}$
02-05 **Acceleration** [] $a = \frac{\Delta v}{\Delta t}$, $a = \frac{dv}{dt}$
02-06 **One-Dimensional Motion with Constant Acceleration** [] $v_f = v_o + a\,t$, *etc.*
02-07 **Freely Falling Objects**
02-08 **One-Dimensional Motion: Calculus Techniques** [] area under curve, $v = \int a\,dt$, *etc.*
02-09 **Relative Velocities**
02-10 **Frame of Reference**
02-99 Associated problems in Chapter 02

03 Vectors
03-01 **Coordinate Systems and Frames of Reference** [] $x = r\,\cos\theta$, $y = r\,\sin\theta$
03-02 **Vector and Scalar Quantities**
03-03 **Some Properties of Vectors** [] add, subtr, negate
03-04 **Methods of Solving Triangles** [] law of sines, cosines
03-05 **Graphical Addition of Vectors** [] head to tail, *etc.*
03-06 **Components of a Vector** [] $a_x = a\,\cos\theta$, $a_y = a\,\sin\theta$
03-07 **Adding Vector Components**
03-08 **Unit Vectors** [] $\vec{r} = r_x\,\hat{\imath} + r_y\,\hat{\jmath}$
03-09 **Vector Kinematics**
03-10 **The Vector Dot (Scalar) Product**
03-11 **The Vector Cross Product**
03-99 Associated problems in Chapter 03

04 Motion in Two Dimensions
04-01 **Position and Displacement**
04-02 **Average and Instantaneous Velocity**
04-03 **Average and Instantaneous Acceleration**
04-04 **Two-Dimensional Motion with Constant Acceleration**
04-05 **Graphical Solutions**
04-06 **Projectile Motion**
04-07 **Uniform Circular Motion** [] $a_c = \frac{v^2}{r}$, period $T = \frac{2\,\pi\,r}{v}$
04-08 **Tangential and Radial Acceleration**
04-09 **Relative Velocity** [] cross river
04-10 **Relative Acceleration**
04-11 **Relative Motion at High Speeds**
04-99 Associated problems in Chapter 04

05 The Laws of Motion
05-01 **The Concept of Force**
05-02 **Newton's First Law and Inertial Frames** [] frame w/o accel
05-03 **Inertial Mass**
05-04 **Newton's Second Law** [] $F = m\,a$
05-05 **Weight**
05-06 **Contact and Normal Forces**
05-07 **Hooke's Law** [] $F = -k\,x$
05-08 **Combining Forces**
05-09 **Newton's Third Law** [] $f_{12} = -f_{21}$
05-10 **Free Body Diagrams in Problem Solving**
05-11 **Static Applications of Newton's Law**
05-12 **Dynamic Applications of Newton's Law**
05-13 **Friction** [] $F = \mu\mathcal{N}$
05-14 **Other Resistive Forces (Terminal Velocity)** [] air drag, Stokes' Law
05-15 **The Fundamental Forces of Nature**
05-99 Associated problems in Chapter 05

06 Circular Motion and Newton's Laws
06-01 **Newton's Second Law Applied to Uniform Circular Motion** [] $F_c = m\,a_c = m\,\frac{v^2}{r}$
06-02 **Banked and Unbanked Curves**
06-03 **Nonuniform Circular Motion** [] vert circles, child on swing, roller coaster
06-04 **Circular Motion in Accelerated Frames** [] passenger in car, merry-go-round
06-05 **Circular Motion in the Presence of Resistive Forces**
06-06 **Numerical Modeling (Euler's Method) in Particle Dynamics**
06-99 Associated problems in Chapter 06

07 Work and Energy
07-01 **Forms of Energy**
07-02 **Kinetic Energy**
07-03 **Work** [] $W = F\,\Delta x$
07-04 **Work: a General Constant Force**
07-05 **Work: the Gravitational Force**
07-06 **Work: a Spring Force** [] $W = -\frac{1}{2}\,k\,x^2$
07-07 **Work: a General Varying Force** [] $W = \int \vec{F}\cdot d\vec{x}$

07-08 **Kinetic Energy and the Work-Energy Theorem** [] $\sum W = \Delta K = K_f - K_i$
07-09 **The Nonisolated System – Conservation of Energy** [] system interacts w/ environment
07-10 **Kinetic Friction** [] $\Delta E_{int} = f_k\, d$
07-11 **Power** [] $P = \frac{W}{t}$, $P = \vec{F} \cdot \vec{v}$
07-12 **Work and Energy in Three Dimensions**
07-13 **Energy and the Automobile**
07-14 **Kinetic Energy at High Speeds**
07-15 **Simple and Compound Machines**
07-99 Associated problems in Chapter 07

08 Potential Energy and Conservation of Energy
08-01 **Potential Energy** [] gravit: $U_g = m\, g\, h$
08-02 **Spring Potential Energy** [] $U_s = \frac{1}{2}\, k\, x^2$
08-03 **Conservative and Nonconservative Forces**
08-04 **Conservative Forces and Potential Energy**
08-05 **Conservation of Mechanical Energy** [] $E_{mech} = K + U$
08-06 **Changes in Mechanical Energy**
08-07 **Relationship Between Conservative Forces and Potential Energy** [] $F = -\frac{dU}{dx}$
08-08 **Energy Diagrams and the Equilibrium of a System** [] U *vs* x
08-09 **Work Done on a System by an External Force**
08-10 **Conservation of Energy in General**
08-11 **Mass-Energy Equivalence** [] $E = m\, c^2$
08-12 **Quantization of Energy**
08-99 Associated problems in Chapter 08

09 Linear Momentum and Collisions
09-01 **Linear Momentum** [] $\vec{p} = m\, \vec{v}$, $\sum \vec{F} = \frac{d\, \vec{p}}{dt}$
09-02 **Impulse and Momentum** [] $d\vec{p} = \vec{F}\, dt$, $I = \int \vec{F}\, dt$
09-03 **Conservation of Linear Momentum**
09-04 **Elastic Collisions** [] momen and KE conserv, $v_{1i} - v_{2i} = v_{2f} - v_{1f}$
09-05 **Inelastic Collisions** [] stick together, Ballistic pendulum
09-06 **One-Dimensional Collisions**
09-07 **Two- and Three-Dimensional Collisions**
09-08 **The Center of Mass** [] $x_{CM} = \frac{\sum m_i\, x_i}{\sum m_i}$, $x_{CM} = \frac{1}{M} \int x\, dm$
09-09 **Finding the Center of Mass by Integration**
09-10 **Motion of a System of Particles (Explosions)** [] $\vec{v} = \frac{d\, \vec{r}_{CM}}{dt}$, $\vec{a} = \frac{d\, \vec{v}_{CM}}{dt}$,
09-11 **Energy of a System of Particles**
09-12 **Energy and Momentum Conservation in Collisions**
09-13 **Center of Mass Reference Frame**
09-14 **Rocket Propulsion**
09-99 Associated problems in Chapter 09

10 Rotation of a Rigid Object About a Fixed Axis
10-01 **Angular Position, Velocity and Acceleration** [] $s = r\, \theta$, $\omega = \frac{d\, \theta}{dt}$
10-02 **Kinematic Equations for Uniformly Accelerated Rotational Motion** [] $\omega_f = \omega_i + \alpha\, t$, *etc.*
10-03 **Vector Nature of Angular Quantities** [] righthand rule

10-04 **Relationships Between Angular and Linear Quantities** [] $v = r\,\omega$, $a = r\,\alpha$
10-05 **Rotational Kinetic Energy** [] $I = \sum m_i\, r_i^2$, $K_R = \frac{1}{2}\, I\, \omega^2$
10-06 **Calculation of Moments of Inertia** [] $I = \int r^2\, dm$, Parallel Axis Th: $I = I_{CM} + M\, D^2$ (D dist CM → rotational axis)
10-07 **Torque** [] $\tau = F\, d$, (NOT vectors)
10-08 **Relationship Between Torque and Angular Acceleration** [] $\sum \tau = I\, \alpha$
10-09 **Work, Power, and Energy in Rotational Motion** [] $dW = \vec{F} \cdot d\vec{s}$, $\sum W = \int I\, \omega\, d\omega$
10-10 **Problem Solving in Rotational Dynamics**
10-99 Associated problems in Chapter 10

11 Rolling Motion, Angular Momentum, and Torque
11-01 **Rotational Plus Translational Motion: Rolling**
11-02 **The Kinetic Energy of Rolling** [] $K = \frac{1}{2}\, I_{CM}\, \omega^2 + \frac{1}{2}\, M\, v_{CM}^2$
11-03 **The Forces of Rolling**
11-04 **The Yo-Yo**
11-05 **The Torque Vector** [] $\vec{\tau} = \vec{r} \times \vec{F}$
11-06 **Angular Momentum of a Particle** [] $\vec{L} = \vec{r} \times \vec{p}$, $\sum \vec{\tau} = \frac{d\,\vec{L}_{rot}}{dt}$
11-07 **General Motion: Angular Momentum, Torque of a System of Particle** [] $\sum \vec{\tau}_{ext} = I\, \alpha$
11-08 **Rotation of a Rigid Body About a Fixed Axis** [] seesaw, *etc.*
11-09 **Rotational Imbalance**
11-10 **Conservation of Angular Momentum**
11-11 **Precession: Gyroscopes and Tops**
11-12 **Rotating Frames of Reference: Inertial Forces**
11-13 **Coriolis Effect**
11-14 **Quantization of Angular Momentum**
11-99 Associated problems in Chapter 11

12 Static Equilibrium and Elasticity
12-01 **The Conditions for Equilibrium of a Rigid Object** [] rotation, translation
12-02 **Solving Statics Problems**
12-03 **Stability and Balance: Center of Gravity**
12-04 **Levers and Pulleys**
12-05 **Bridges and Scaffolding**
12-06 **Arches and Domes**
12-07 **Couples** [] two opposing forces
12-08 **Other Objects in Static Equilibrium** [] ladder, seesaw
12-09 **Static Equilibrium in an Accelerated Frame**
12-10 **Elasticity: Stress and Strain** [] Young's/shear/bulk modulus
12-11 **Fracturing** [] support columns, shear
12-99 Associated problems in Chapter 12

13 Oscillatory Motion
13-01 **Simple Harmonic Motion** [] $x(t) = A\, \cos(\omega\, t + \phi)$, $\omega = \sqrt{\frac{k}{m}}$, $v = \frac{d\,x}{dt}$, $a = \frac{d\,v}{dt}$
13-02 **Mass Attached to a Spring** [] $\omega = \frac{k}{m}$, $f = \frac{1}{T}$, $\omega = \frac{2\,\pi}{T}$, $x = A\, \cos\omega\, t$, $v = -\omega\, A\, \sin\omega\, t$, $a = -\omega^2\, A\, \cos\omega\, t$, $T = 2\,\pi\,\sqrt{\frac{m}{k}}$
13-03 **Forces in Simple Harmonic Motion**
13-04 **Energy in Simple Harmonic Motion** [] $E = \frac{1}{2}\, k\, A^2$

13-05 **The Simple Pendulum** [] $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{L}{g}}$
13-06 **The Physical Pendulum and Torsion Pendulum**
13-07 **Simple Harmonic Motion Related to Uniform Circular Motion** [] $\frac{A}{v_o} = \sqrt{\frac{m}{k}}$, $T = 2\pi\sqrt{\frac{m}{k}}$, $\omega = 2\pi f = \sqrt{\frac{k}{m}}$
13-08 **Damped Oscillations**
13-09 **Forced Oscillations: Resonance**
13-99 Associated problems in Chapter 13

14 The Law of Gravity
14-01 **Newton's Law of Gravity**
14-02 **Gravitational Force Due to a System of Particles** [] $F_{net} = \sum F_i$
14-03 **Free Fall Acceleration and the Gravitational Force** [] gravit force from $F \propto \frac{g}{r^2}$
14-04 **Gravitation Inside the Earth**
14-05 **Kepler's Laws: Plantary and Satellite Motion** [] $\frac{dA}{dt} = \frac{L}{2Mp} =$ const, $T^2 = \frac{4\pi^2}{G m_S} a^3 = K_s a^3$, geosyn satellite
14-06 **The Gravitational Field**
14-07 **Gravitational Potential Energy** [] $U = \int F\, dr$, $U = -\frac{G m_1 m_2}{r}$
14-08 **Escape Velocity** [] $v = \sqrt{\frac{2 G m_s}{R_E}}$
14-09 **Energy: Planetary and Satellite Motion** [] black holes, $E = K + U = \frac{1}{2} m v^2 - \frac{G M m}{r}$, circle: $E = -\frac{G M m}{r}$, ellipse: $E = \frac{G m_1 m_2}{2a}$
14-10 **Gravitational Force: Extended Object & Particle**
14-11 **Gravitational Force: Particle & Spherical Mass**
14-12 **Principle of Equivalence**
14-99 Associated problems in Chapter 14

15 Fluid Mechanics
15-01 **States of Matter** [] solid, liqiuid, gas, plasma
15-02 **Density and Specific Gravity**
15-03 **Pressure** [] $P = \frac{F}{A}$, $dF = P\, dA$
15-04 **Fluids at Rest: Variation of Pressure with Depth** [] $P = P_0 + \rho g h$
15-05 **Pressure Measurements (Atmospheric, Gauge)**
15-06 **Pascal's Principle (Hydraulics)**
15-07 **Buoyant Forces and Archimedes' Principle**
15-08 **Fluid Dynamics**
15-09 **Streamlines and the Equation of Continuity** [] $A_1 V_1 = A_2 V_2 =$ constant
15-10 **Bernoulli's Equation** [] $P + \frac{1}{2}\rho v^2 + \rho g h =$ constant, Venturi tube, Torricelli's Law
15-11 **Transport Phenomena** [] diffusion, osmosis, Fick's Law, Stokes: $F_r = 6\pi\eta r v$, sedimentation, centrifugation
15-12 **Other Applications of Fluid Dynamics** [] lift on plane, spinning ball, atomizer
15-13 **Energy from the Wind**
15-14 **Viscosity** [] $\eta = \frac{F L}{\Delta V}$
15-15 **Surface Tension and Capillarity** [] Poiseuille's Law: $\Delta P = \frac{8\eta L}{\pi r^4} I_v$, Reynold's number: $R_N = \frac{\rho v d}{\eta}$
15-16 **Pumps: the Heart**
15-99 Associated problems in Chapter 15

16 Wave Motion

16-01 **Wave Characteristics and Propagation** [] $f = \frac{1}{T}$, $\omega = \frac{2\pi}{f}$, $v = f\,\lambda$, amplitude
16-02 **Transverse and Longitudinal Waves**
16-03 **Speed of a Traveling Wave** [] fluid: $v = \sqrt{\frac{B}{\rho}}$, gas: $v = \sqrt{\frac{\gamma R T}{m}}$, $v = \frac{dx}{dt} = -\frac{\omega}{t}$
16-04 **Energy Conservation** [] $P = 2\,\pi^2\,v\,\rho\,f^2\,D_M^2$, spherical $I = \frac{\overline{P}}{4\,\pi\,r^2}$, ampl $D_m \propto \frac{1}{r}$
16-05 **One-Dimensional Traveling Waves** [] $y = f\,(x \pm v\,t)$, $v = \frac{dx}{dt}$
16-06 **Periodic Waves (Harmonic, Electromagnetic)** [] $y = A\,\sin(k\,x + \delta)$, $k = \frac{2\pi}{\lambda}$
16-07 **Superposition and Interference of Waves**
16-08 **The Speed of Waves on Strings** [] $v = \sqrt{\frac{T}{\mu}}$
16-09 **Reflection and Transmission of Waves**
16-10 **Refraction of Waves**
16-11 **Diffraction of Waves**
16-12 **Sinusoidal Waves** [] $x = A\,\cos\,\omega\,t$, $v = -A\,\omega\,\sin\,\omega\,t$, $a = A\,\omega^2\,\cos\,\omega\,t = -\omega^2\,x$
16-13 **Energy Transmitted by Waves on Strings** [] $P = \frac{1}{2}\,\mu\,\omega^2\,A^2\,v$
16-14 **The Linear Wave Equation** [] $\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2}\,\frac{\partial^2 y}{\partial t^2}$
16-15 **Phasors**
16-99 Associated problems in Chapter 16

17 Sound Waves

17-01 **Characteristics of Sound Waves** [] rarefraction, compression
17-02 **Speed of Sound Waves** [] $v = \sqrt{\frac{B}{\rho}}$, $v = \sqrt{\frac{Y}{\rho}}$, (Bulk/Young's modulus)
17-03 **Periodic Sound Waves** [] $\Delta P = \Delta P_{max}\,\sin\,(k\,x - \omega\,t)$
17-04 **Energy and Intensity of Sound Waves** [] $I = \frac{P}{A}$, decibles: $\beta = 10\,\log\left(\frac{I}{I_0}\right)$, loudness
17-05 **The Doppler Effect** [] $f' = \left(\frac{v \pm v_s}{v \mp v_s}\right)\,f$, shock waves, mach $= \frac{v_{source}}{v_{wave}}$
17-06 **Quality of Sound (Noise)**
17-07 **The Ear**
17-08 **Sources of Musical Sound**
17-09 **Digital Sound Recording**
17-10 **Motion Picture Sound**
17-11 **Sonar, Ultrasound, and Ultrasound Imaging**
17-99 Associated problems in Chapter 17

18 Superposition and Standing Waves

18-01 **Superposition of Sinusoidal Waves**
18-02 **Interference of Sinusoidal Waves** [] max/min, constr: $\Delta r = (2\,n)\,\frac{\lambda}{2}$, destr: $\Delta r = (2\,n + 1)\,\frac{\lambda}{2}$
18-03 **Standing Waves in General** [] $y = (2\,A\,\sin\,k\,x)\,\cos\,\omega\,t$, antinodes at $(2\,n - 1)\,\frac{\lambda}{4}$
18-04 **Standing Waves in a String Fixed at Both Ends** [] $\lambda_n = \frac{2\,L}{n}$, $f_n = \frac{v}{\lambda_n} = n\,\frac{v}{2\,L}$, $f_n = \frac{n}{2\,L}\sqrt{\frac{T}{\mu}}$, harmonics
18-05 **Forced Vibrations and Resonance**
18-06 **Standing Waves in Air Columns** [] open: $f_n = n\,\frac{v}{2\,L}$, closed: $f_n = (2\,n - 1)\,\frac{v}{4\,L}$
18-07 **Standing Waves in Rods, Plates, and Membranes**
18-08 **Complex Waves** [] pitch
18-09 **Beats: Interference in Time** [] $f_{beat} = f_1 - f_2$

18-10 **Shock Waves and the Sonic Boom**
18-11 **Harmonic Analysis and Synthesis**
18-12 **Wave Packets and Dispersion**
18-99 Associated problems in Chapter 18

19 Temperature
19-01 **Atomic Theory of Matter** [] atomic mass, molec mass, Avogadro's number, Brownian
19-02 **The Zeroth Law of Thermodynamics: Thermal Equilibrium**
19-03 **Celsius and Fahrenheit Temperature Scales**
19-04 **The Constant-Volume Gas Thermometer and the Kelvin Scale**
19-05 **Thermal Expansion of Solids and Liquids** [] $\Delta L = \alpha\, L_i\, \Delta T$, $\Delta V = \beta\, V_i\, \Delta T$
19-06 **Macroscopic Description of an Ideal Gas** [] $P\,V = N\,R\,T$, mole, Avogadro, Boltzman's: $P\,V = N\,k_B\,T$
19-07 **Problem Solving: Ideal Gas Law** [] Boyle, Charles
19-99 Associated problems in Chapter 19

20 Heat and the First Law of Thermodynamics
20-01 **Heat and Thermal Energy** [] mech equation of heat: $J \leftrightarrow$ cal
20-02 **Internal Energy**
20-03 **Heat Capacity and Specific Heat** [] $Q = m\,c\,\Delta T$
20-04 **Heat Capacity of Gases** [] $dE_{int} = C_v\,dT$, $C_p = C_v + n\,R$, $C_v = \frac{3}{2}\,n\,R$, $C_p = \frac{5}{2}\,n\,R$
20-05 **Heat Capacity of Solids** [] Dulong-Petit, $c' = 3\,R$
20-06 **Latent Heat** [] phase change $Q = \pm m\,L$
20-07 **Phase Diagrams**
20-08 **Calorimetry**
20-09 **Work and Heat in Thermodynamic Processes** [] $W = -\int P\,dV$
20-10 **The First Law of Thermodynamics** [] $\Delta E = Q + W$
20-11 **Work and the PV Diagram for a Gas** [] $P\,V$ curves
20-12 **Some Applications of the First Law of Thermodynamics** [] isobaric: $W = -P\,\Delta V$
20-13 **Heat and Energy Transfer** [] conduction rate $= k\,A\,\frac{T_h - T_c}{L}$, home insulation, net radiation rate: $\sigma\,A\,e\,T^4$, Dewar flask
20-14 **Global Warming and Greenhouse Gases**
20-99 Associated problems in Chapter 20

21 The Kinetic Theory of Gases
21-01 **Molecular Model of an Ideal Gas** [] $P = \frac{2}{3}\,\frac{N}{V}\left(\frac{1}{2}\,m\,\overline{v}^2\right)$, $k = \frac{3}{2}\,n\,R\,T = \frac{3}{2}\,n\,k_B\,T$, $U = \frac{3}{2}\,n\,R\,T$, $\frac{1}{2}\,m\,\overline{v}^2 = \frac{3}{2}\,k_B\,T$
21-02 **Specific Heat of an Ideal Gas** [] $Q = m\,c\,\Delta T$, $Q = n\,C_v\,\Delta T$, $Q = n\,C_p\,\Delta T$
21-03 **Adiabatic Processes for an Ideal Gas** [] $\Delta E_{int} = W$, $P\,V^\gamma =$ constant
21-04 **The Equipartition of Energy** [] Dulong-Petit Law
21-05 **The Boltzmann Distribution Law** [] $n_v(E) = n_0\,e^{-E/(k_b\,T)}$
21-06 **Pressure, Temperature, and RMS Speed** [] $v_{rms} = \sqrt{\frac{3\,R\,T}{M}}$
21-07 **Distribution of Molecular Speeds** [] $N_v = 4\,\pi\,N\left(\frac{m}{2\,\pi\,k_B\,T}\right)^{3/2} v^2\,e^{-m\,v^2/(2\,k_B\,T)}$, probable speed
21-08 **Translational Kinetic Energy**
21-09 **Mean Free Path** [] $\ell = \frac{1}{\sqrt{2}\,\pi\,d^2\,n_v} = \frac{k_B\,T}{\sqrt{2}\,\pi\,P\,d^2}$
21-10 **Van der Waals' Equation of State** [] $\left(P + \frac{a}{v^2}\right)(V - b) = R\,T$

21-11 **Vapor Pressure and Humidity** [] partial press
21-12 **Diffusion**
21-13 **Failure of the Equipartition Theorem**
21-99 Associated problems in Chapter 21

22 Heat Engines, Entropy, & Thermodynamics
22-01 **The Second Law of Thermodynamics** [] $\varepsilon = \frac{Q_h - Q_c}{Q_n}$ $(\Delta S \geq 0)$
22-02 **Heat Engines**
22-03 **Reversible and Irreversible Processes**
22-04 **The Carnot Engine** [] $\varepsilon = 1 - \frac{T_c}{T_h}$
22-05 **Gasoline and Deisel Engines** [] Otto cycle, efficiency: $\varepsilon = 1 - \frac{1}{(V_1/V_2)^{\gamma-1}}$, $\gamma = \frac{C_p}{C_v}$
22-06 **Heat Pumps and Refrigerators** [] COP $= \frac{Q_c}{W}$
22-07 **Entropy** [] $dS = \frac{d\,Q_r}{T}$
22-08 **Entropy Changes in Irreversible Processes** [] (total entropy cannot decrease)
22-09 **Entropy on a Microscopic Scale** [] (measure of disorder) $S \equiv k_B \ln W$
22-10 **Human Metabolism** [] metabolic rate, $\frac{\Delta U}{\Delta t} = \frac{Q}{\Delta t} + \frac{W}{\Delta t}$, $\frac{\Delta U}{\Delta t} = 4.8\,\frac{\Delta V_{O_2}}{\Delta t}$
22-11 **Energy Availability: Heat Death**
22-12 **Statistical Interpretation of Entropy and the Second Law**
22-13 **Third Law: Maximum Efficiencies**
22-99 Associated problems in Chapter 22

23 Electric Fields
23-01 **Static Electricity: Electric Charge**
23-02 **Quantized Charge** [] protons, electrons
23-03 **Insulators and Conductors**
23-04 **Induced Charge: the Electroscope**
23-05 **Coulomb's Law** [] $F = k\,\frac{q_1\,q_2}{r^2}$, $k = \frac{1}{4\,\pi\,\epsilon_0}$
23-06 **Conserved Charge** [] ${}^{238}\mathrm{U} \rightarrow {}^{234}\mathrm{Th} + 4\,\mathrm{He}$, $e^- + e^- \rightarrow \gamma + \gamma$, $\gamma \rightarrow e^- + e^+$, decay, annhilation, pair production
23-07 **The Electric Field** [] $E = \frac{F}{q_0} = k\,\frac{q}{r^2}$, $F = q\,E$
23-08 **Electric Field Due to a Point Charge** [] test charge q_0, $F = \frac{q\,q_0}{r^2}$, $E = \frac{F}{q_0} = k\,\frac{q}{r^2}$, momentum $\vec{P}(c \cdot m)$
23-09 **Electric Field Due to an Electric Dipole** [] $E = 2\,k\,\frac{p}{z^3}$
23-10 **Electric Field Due to a Line of Charge** [] charged ring: $E = k\,\frac{-q\,z}{(z^2+q^2)^{3/2}}$, R radius of ring
23-11 **Electric Field Due to a Charged Sheet** [] charged disk: $E = \frac{\sigma}{2\,\epsilon_0}\left(1 - \frac{z}{\sqrt{z^2 - R^2}}\right)$
23-12 **Electric Field Due to a Continuous Charge Distribution**
23-13 **Electric Field Lines**
23-14 **Electric Fields and Conductors**
23-15 **A Point Charge in a Electric Field** [] $F = q\,E = m\,a$
23-16 **A Dipole in a Electric Field** [] water molecule, torque: $\vec{\tau} = \vec{p} \times \vec{E}$
23-17 **Motion of Charged Particles in a Uniform Electric Field** [] $F = q\,E = m\,a$
23-18 **The Oscilloscope**
23-99 Associated problems in Chapter 23

24 Gauss's Law

24-01 **Electric Flux** [] $\Phi = \int \vec{E} \cdot d\vec{A}$
24-02 **Gauss's Law** [] $\Phi = \frac{q_{encl}}{\epsilon_0}$
24-03 **Application: Charged Insulators**
24-04 **Application: Charged Isolated Conductors**
24-05 **Application: Cylindrical Symmetry** [] line of charge: $E = \frac{\lambda}{2\,\pi\,\epsilon_0\,r}$
24-06 **Application: Planar Symmetry** [] sheet of charge: $E = \frac{\sigma}{2\,\epsilon_0}$
24-07 **Application: Spherical Symmetry** [] spherical shell: $E = k\,\frac{q}{r^2}$, field inside shell: $E = 0$, uniform charge: $E = k\,\frac{q\,r}{R^3}$, (r radius encl, R radius of charge distrib)
24-08 **Conductors in Electrostatic Equilibrium** [] $E = \frac{\sigma}{\epsilon_0}$, conductor surface
24-09 **Experimental Proof of Gauss' Law and Coulomb's Law**
24-99 Associated problems in Chapter 24

25 Electric Potential
25-01 **Electric Potential Energy** [] $\Delta U = -q \int \vec{E} \cdot \vec{ds}$
25-02 **Potential Difference and Electric Potential** [] $\Delta V = \int \vec{E} \cdot \vec{ds}$, $V = \frac{U}{q}$, $\Delta V = -\frac{W}{q}$
25-03 **Equipotential Surfaces**
25-04 **Calculating the Potential from the Field** [] $\Delta V = -\int \vec{E} \cdot \vec{ds}$,
25-05 **Potential & Energy: Point Charges** [] $V = k_e\,\frac{q}{r}$
25-06 **Potential & Energy: Systems of Point Charges**
25-07 **Potential & Energy: Electric Dipoles** [] $U = -\vec{P} \cdot \vec{E}$, $W = \int T\,dQ$
25-08 **Potential & Energy: Continuous Charge Distributions** [] $V = k_e \int \frac{d\,q}{r}$
25-09 **Potential & Energy: Charged Conductor** [] $\Delta V = 0$, corona discharge
25-10 **Calculating the Field from the Potential** [] $E = -\frac{d\,V}{dr}$
25-11 **Electrostatic Potential Energy: the Electron Volt**
25-12 **The Millikan Oil Drop Experiment**
25-13 **Cathode Ray Tube: TV, Computer Monitors, and Oscilloscopes**
25-14 **The Van de Graaff Generator and Other Applications**
25-99 Associated problems in Chapter 25

26 Capacitance and Dielectrics
26-01 **Definition of Capacitance** [] $C = \frac{q}{V}$
26-02 **Calculation of Capacitance** [] $C = \frac{\epsilon_0\,A}{d}$
26-03 **Combinations of Capacitors**
26-04 **Energy Stored in a Charged Capacitor** [] $U = \frac{1}{2}\,C\,(\Delta V)^2$, $W = \int_0^Q \frac{q}{C}\,dq = \frac{Q^2}{2\,C}$, energy density: $u = \frac{U}{A\,d} = \frac{1}{2}\,\kappa\,\epsilon_0\,E^2$
26-05 **Capacitors with Dielectrics** [] $C = \kappa\,C_0$, $C = \kappa\,\frac{\epsilon_0\,A}{d}$
26-06 **Dielectrics from a Molecular Level** [] dielectric doesn't fill space, piezoelectric effect
26-07 **Dielectrics and Gauss' Law** [] $\epsilon \oint \kappa\,\vec{E} \cdot d\vec{A} = q$
26-08 **Electric Dipole in an External Electric Field** [] $\vec{\tau} = \vec{p} \times \vec{E}$, polar, nonpolar
26-09 **Electrostatic Applications**
26-99 Associated problems in Chapter 26

27 Current and Resistance
27-01 **Electric Current** [] $I = \frac{d\,Q}{dt}$, $q = \int dq = \int I\,dt$
27-02 **Current Density and Drift Speed** [] $\vec{J} = n\,q\,\vec{v}$, current density: $i = q\,n\,A\,v_d$
27-03 **Resistance and Resistivity** [] $R = \rho\,\frac{\ell}{A}$, $\rho = \frac{m_e}{n\,e^2\,\tau}$, (average collision time τ)
27-04 **Ohm's Law** [] $V = I\,R$

27-05 **Microscopic View of Ohm's Law** [] mean time between collisions of electrons
27-06 **Resistance and Temperature** [] $\rho = \rho_0 \left[1 + \alpha\,(T - T_0)\right]$, $R = R_0 \left[1 + \alpha\,(T - T_0)\right]$,
27-07 **Semiconductors**
27-08 **Superconductors**
27-09 **Electrical Energy and Power** [] $P = I\,V = \frac{V^2}{R} = I^2\,R$
27-10 **Power in Household Circuits**
27-11 **Electrical Hazards: Leakage Currents**
27-12 **Electrical Energy in the Heart**
27-99 Associated problems in Chapter 27

28 Direct Current Circuits
28-01 **Electromotive Force and Terminal Voltage** [] $\Delta V = \mathcal{E} - I\,r$
28-02 **Work, Energy, and EMF** [] $\mathcal{E} = \frac{dW}{dq}$
28-03 **Resistance: Series Circuits**
28-04 **Resistance: Series/Parallel Combinations**
28-05 **Potential Difference Between Two Points**
28-06 **Complicated Circuits: Kirchoff's Rules**
28-07 **RC Circuits** [] $I = \frac{\mathcal{E}}{R}\,e^{-t/(RC)}$, $q = C\,\mathcal{E}\left[1 - e^{-t/(RC)}\right] = Q\left[1 - e^{-t/(RC)}\right]$
28-08 **Electrical Instruments: Ammeter and Voltmeter**
28-09 **Household Wiring and Electrical Safety**
28-10 **Conduction of Electrical Signals by Neurons**
28-11 **Transducers and the Thermocouple**
28-99 Associated problems in Chapter 28

29 Magnetic Fields
29-01 **Magnetic Fields and Forces** [] Lorenz force: $\vec{F} = q\,\vec{v} \times \vec{B}$
29-02 **Magnetism from Electric Currents**
29-03 **Magnetic Force on a Current-Carrying Conductor** [] $\vec{F} = i\,\vec{L} \times \vec{B}$
29-04 **Torque on a Current Loop in a Uniform Magnetic Field** [] $\vec{\tau} = I\,\vec{A}\times\vec{B}$, $\vec{\tau} = \vec{\mu}\times\vec{B}$, mag dipole moment: $\mu = N\,I\,A$
29-05 **Motion of a Charged Particle in a Magnetic Field** [] $q\,v\,B = m\,\frac{v^2}{r}$
29-06 **Applications of the Motion of Charged Particles in a Magnetic Field** [] Lorenz force: $\vec{F} = q\,\vec{E} + q\,\vec{v} \times \vec{B}$
29-07 **Crossed Fields: Discovery of the Electron**
29-08 **The Hall Effect** [] Hall voltage: $\Delta V_H = \frac{I\,B}{n\,q\,t} = \frac{R_H\,I\,B}{t}$, drift velocity
29-09 **Galvanometers, Motors, Loudspeakers**
29-10 **Cyclotrons and Synchrotrons** [] cyclotron: $\omega = \frac{q\,B}{m}$
29-11 **Mass Spectrometer**
29-99 Associated problems in Chapter 29

30 Sources of the Magnetic Field
30-01 **The Biot-Savart Law** [] $d\vec{B} = \frac{\mu_0}{4\,\pi}\,\frac{I\,d\,\vec{s}\times\vec{r}}{r^2}$
30-02 **Magnetic Field Due to a Straight Wire** [] $B = \frac{\mu_0\,I}{2\,\pi\,r}$
30-03 **Magnetic Force Between Two Parallel Conductors** [] $F_B = \mu_0\,\frac{\ell\,I_1\,I_2}{2\,\pi\,a}$
30-04 **Ampere's Law**
30-05 **The Magnetic Field of Current Loops**
30-06 **The Magnetic Field Along the Axis of a Solenoid** [] $B = \mu_o\,\frac{N}{\ell}\,I = \mu_0\,n\,I$, $n = \frac{N}{\ell}$
30-07 **A Current-Carrying Coil as a Magnetic Dipole**

30-08 **Magnetic Flux** [] $\Phi_B = \int \vec{B} \cdot d\vec{A}$

30-09 **Gauss's Law in Magnetism** [] $\int \vec{B} \cdot d\vec{A} = 0$

30-10 **Displacement Current and the Generalized Ampere's Law** [] $I_B = \epsilon_0 \frac{dQ_E}{dt}$, $\int \vec{B} \cdot \vec{ds} = \mu_0 I + \mu_0 \epsilon_0 \frac{dQ_E}{dt}$

30-11 **Magnetism and Electrons: Spin**

30-12 **Magnetism in Matter** [] Curie const, $M = C \frac{B}{T}$, $H = n I$, mag moments

30-13 **Diamagnetism**

30-14 **Paramagnetism**

30-15 **Ferromagnetism**

30-16 **Magnetic Field of the Earth**

30-99 Associated problems in Chapter 30

31 Faraday's Law

31-01 **Faraday's Law of Induction** [] (field changes) $\mathcal{E} = -\frac{dQ_B}{dt}$, $\mathcal{E} = -N \frac{dQ_B}{dt}$

31-02 **Motional EMF** [] (conductor moves in magnetic field) $q E = q v B$, $\mathcal{E} = B H v = B \ell v$, $\Delta V = B \ell v - I r$

31-03 **Lenz's Law** [] magnetic field opposes Δflux

31-04 **Induced EMF in a Moving Conductor** [] $\oint \vec{E} \cdot d\vec{s} = -\frac{dQ_B}{dt}$

31-05 **Induced Electric Fields**

31-06 **Electric Field from a Changing Magnetic Flux**

31-07 **Generators and Motors** [] back *emf*

31-08 **Eddy Currents**

31-09 **Maxwell's Equations** [] general Lorenz Force: $\vec{F} = q \vec{E} + q \vec{v} \times \vec{B}$

31-10 **Sound Systems, Computer Memory, the Seismograph**

31-99 Associated problems in Chapter 31

32 Inductance

32-01 **Inductors and Inductance** [] $L = N \frac{\Phi_B}{\ell}$, solenoid: $L = \mu_0 n^2 \ell A$

32-02 **Self-Inductance, Self-Induced EMF** [] $\mathcal{E} = -L \frac{dI}{dt} = N \frac{d\Phi}{dt}$

32-03 **RL Circuits** [] $I = \frac{\mathcal{E}}{R}\left(1 - e^{-t/\tau}\right)$, $L \frac{di}{dt} + R i = \mathcal{E}$

32-04 **Energy in a Magnetic Field** [] $U_B = \frac{1}{2} L I^2$, $P = L I \frac{dI}{dt}$

32-05 **Energy Density of a Magnetic Field** [] density: $u_B = \frac{B^2}{2\mu_0}$, $U_B = \int u_B \, dV$

32-06 **Mutual Inductance** [] $M_{12} = \frac{N_2 Q_{12}}{I_1}$, $\mathcal{E} = -M \frac{di}{dt}$, $\mathcal{E}_2 = -N_2 \frac{dQ_{21}}{dt} = -M_2 \frac{dI_1}{dt}$

32-07 **Oscillations in an LC Circuit**

32-08 **The RLC Circuit**

32-09 **Critical Magnetic Fields**

32-10 **Magnetic Properties of Superconductors**

32-99 Associated problems in Chapter 32

33 Alternating Current Circuits

33-01 **AC Sources** [] generators

33-02 **Phasors**

33-03 **Resistors in an AC Circuit** [] $I_{rms} = \frac{1}{\sqrt{2}} I_{max}$, $P = I_{rms}^2 R$, $\Delta V_{rms} = \frac{1}{\sqrt{2}} \Delta V_{max}$

33-04 **Inductors in an AC Circuit** [] $X_L = \omega L$, $I_{max} = \frac{\Delta V_{\max}}{X_L}$

33-05 **Capacitors in an AC Circuit** [] $i = \omega C \Delta V_{max} \sin\left(\omega t + \frac{\pi}{2}\right)$

33-06 **LC and RLC Circuits** [] $Z_{series} = \sqrt{R^2 + (X_L - X_C)^2}$; $Z_{parallel} = \frac{1}{\sqrt{1/R^2 + (1/X_L - 1/X_C)^2}}$

33-07 **The RLC Series Circuit** [] $Z = \sqrt{R^2 + (X_L - X_C)^2}$, $\Delta V_{max} = I_{max}\, Z$, $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$
33-08 **Damped Oscillations in an RLC Circuit**
33-09 **Power in an AC Circuit** [] $P = I_{rms}\, \Delta V_{rms}\, \cos\phi = I_{rms}^2\, R$
33-10 **Resonance in a Series RLC Circuit** [] $I_{rms} = \frac{\Delta V_{rms}}{\sqrt{R^2+(X_L-X_C)^2}}$, $\omega_0 = \frac{1}{\sqrt{L\,C}}$
33-11 **Impedance Matching**
33-12 **Filter Circuits**
33-13 **The Transformer and Power Transmission** [] $I_1\, \Delta V_1 = I_2\, \Delta V_2$
33-14 **Three-Phase AC**
33-99 Associated problems in Chapter 33

34 Electromagnetic Waves

34-01 **Maxwell's Equations and Hertz's Discoveries** [] $\int \vec{E} \cdot d\vec{A} = \frac{q}{\epsilon_0}$, $\int \vec{B} \cdot d\vec{A} = 0$, $\int \vec{E} \cdot d\vec{s} = \frac{d\,\Phi_B}{dt}$, $\int \vec{B} \cdot d\vec{s} = \mu_0\, I + \epsilon_0\, \mu_0\, \frac{d\,\Phi_E}{dt}$, $\vec{F} = q\,\vec{E} + q\,\vec{v} \times \vec{B}$
34-02 **Plane Electromagnetic Waves** [] $\frac{\partial^2 E}{\partial x^2} = \mu_0\, \epsilon_0\, \frac{\partial^2 E}{\partial t^2}$, $\frac{\partial^2 B}{\partial x^2} = \mu_0\, \epsilon_0\, \frac{\partial^2 B}{\partial t^2}$, $E = E_{max}\, \sin(k\,x - \omega\,t)$, $B = B_{max}\, \sin(k\,x - \omega\,t)$
34-03 **Speed of Electromagnetic Waves** [] $c = \frac{1}{\sqrt{\mu_0\, c_0}}$, $\frac{E_{max}}{B_{max}} = \frac{E}{B} = c$
34-04 **Energy Carried by Electromagnetic Waves: Poynting Vector** [] (intensity)
34-05 **Momentum and Radiation Pressure** [] complete absorption: $p = \frac{U}{c}$, absorption: $P = \frac{S}{c}$, reflection: $P = \frac{2\,S}{c}$
34-06 **Radiation from an Infinite Current Sheet**
34-07 **The Production of Electromagnetic Waves by an Antenna**
34-08 **Properties of Electromagnetic Waves**
34-09 **The Spectrum of Electromagnetic Waves**
34-10 **The Doppler Effect for Electromagnetic Waves**
34-11 **Radio and Television**
34-99 Associated problems in Chapter 34

35 The Nature of Light and Geometric Optics

35-01 **The Nature of Light** [] $E = h\,\nu$
35-02 **Wave-Particle Duality**
35-03 **The Speed of Light** [] $v = f\,\lambda$, Romer's, Fizeau's
35-04 **Reflection**
35-05 **Transmission and Refraction** [] $\frac{\sin\theta_2}{\sin\theta_1} = \frac{v_2}{v_1} = \text{const}$, $n = \frac{c}{v}$
35-06 **The Law of Refraction** [] $n_1\, \sin\theta_1 = n_2\, \sin\theta_2$
35-07 **Dispersion and Prisms** [] rainbows
35-08 **Huygens' Principle** [] (every pt on wavefront propagates new wave) 3 types: $\lambda \ll d$, $\lambda = d$, $\lambda \gg d$
35-09 **Total Internal Reflection** [] $\sin\theta_c = \frac{n_2}{n_1}$
35-10 **Fermat's Principle** [] least time determines path
35-11 **Mixing Pigments**
35-12 **Luminous Intensity** [] luminous flux
35-99 Associated problems in Chapter 35

36 Geometric Optics

36-01 **Two Types of Image** [] real, virtual
36-02 **Images Formed by Flat Mirrors** [] $M = \frac{h'}{h}$, one/two mirrors

36-03 **Images Formed by Concave Mirrors** [] $M = \frac{h'}{h} = -\frac{q}{p}$, $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$
36-04 **Images Formed by Convex Mirrors** [] $M = \frac{h'}{h} = -\frac{q}{p}$, $\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$
36-05 **Spherical Mirrors: Ray Tracing**
36-06 **Images Formed by Refracting Surfaces** [] $\frac{n_1}{p} + \frac{n_2}{q} = \frac{n_2 - n_1}{R}$
36-07 **Atmospheric Refraction**
36-08 **Images Formed by Thin Lenses**
36-09 **Combinations of Lenses and Mirrors**
36-10 **Thin Lenses: Ray Tracing**
36-11 **Lensmaker's Equation** [] $\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$
36-12 **The Camera** [] f-number $= \frac{f}{D}$
36-13 **The Eye and Corrective Lenses**
36-14 **The Simple Magnifier** [] $M = \frac{25\text{ cm}}{f}$
36-15 **The Compound Microscope**
36-16 **The Telescope**
36-17 **Lens and Mirror Aberrations**
36-99 Associated problems in Chapter 36

37 Interference of Light Waves
37-01 **Conditions for Interference** [] coherent, identical wavelengths
37-02 **Double Slit Interference: Young's Experiment** [] constr: $\delta = d \sin\theta_{max} = m\,\lambda$, destr: $d \sin\theta_{min} = \left(m + \frac{1}{2}\right)\lambda$
37-03 **Coherence**
37-04 **Intensity Distribution of the Double-Slit Interference Pattern** [] $I = I_{max} \cos^2\left(\frac{\pi\, d \sin\theta}{\lambda}\right)$
37-05 **Phasor Addition of Waves**
37-06 **Change of Phase Due to Reflection**
37-07 **Interference in Thin Films** [] $\lambda_n = \frac{\lambda}{n}$, λ in free space, constr: $2\,n\,t = \left(m + \frac{1}{2}\right)\lambda$, destr: $2\,n\,t = m\,\lambda$
37-08 **The Michelson Interferometer**
37-09 **Using Interference to Read CDs and DVDs**
37-99 Associated problems in Chapter 37

38 Diffraction and Polarization
38-01 **Diffraction**
38-02 **Huygens' Principle and Diffraction**
38-03 **Huygens' Principle and the Law of Refraction**
38-04 **Single-Slit Diffraction** [] destr: $\sin\theta_{min} = m\,\frac{\lambda}{2}$
38-05 **Intensity in Single-Slit Diffraction** [] $I = I_{max}\left[\frac{\sin(\beta/2)}{\beta/2}\right]^2$
38-06 **Using Phasors to Add Harmonic Waves**
38-07 **Fraunhofer and Fresnel Diffraction**
38-08 **Resolution of Single-Slit and Circular Apertures** [] slit: $\theta_{min} = \frac{\lambda}{a}$, circ: $\theta_{mix} = 1.22\,\frac{\lambda}{D}$, Raleigh
38-09 **Resolution of Telescopes and Microscopes: the λ Limit**
38-10 **Resolution of the Human Eye and Useful Magnification**
38-11 **Diffraction by a Double Slit**
38-12 **The Diffraction Grating** [] $d \sin\theta_{max} = m\,\lambda$
38-13 **Gratings: Dispersion and Resolving Power**

38-14 **X-Rays** [] Bragg, constr: $2\,d\,\sin\theta = m\,\lambda$
38-15 **Diffraction of X-Rays by Crystals** [] Bragg, constr: $2\,d\,\sin\theta = m\,\lambda$
38-16 **Polarization of Light Waves** [] Malus: $I = I_0\,\cos^2\theta$
38-17 **Polarization by Reflection** [] Brewster: $n = \tan\theta_p$
38-18 **The Spectrometer and Spectroscopy**
38-99 Associated problems in Chapter 38

39 Relativity [] $\gamma = \frac{1}{\sqrt{1-v^2/c^2}}$
39-01 **Galilean Coordinate Transformations** [] principles of Newtonian relativity, $x = x' + v\,t'$, $y = y'$, $z = z'$, $t = t'$, $u = u' + v$
39-02 **Lorentz Coordinate Transformations** [] $x = \gamma\,(x' + v\,t')$, $y = y'$, $z = z'$, $t = \gamma\,(t' + v\,x'/c^2)$, $u_x = \frac{u'_x+v}{1+v\,v'/c^2}$
39-03 **Postulates: Speed of Light** [] constancy of c
39-04 **The Michelson-Morley Experiment**
39-05 **Consequences of Special Relativity** [] equivalence, simultaneity
39-06 **The Lorentz Transformation for Displacements** [] $L = \frac{L_p}{\gamma}$
39-07 **The Lorentz Transformation for Time** [] $\Delta t = \gamma\,\Delta t_p$, t_p at rest
39-08 **The Lorentz Transformation for Velocities** [] $u'_x = \frac{u_x - v}{1-u_x\,v/c^2}$, u_y and u_z affected also (S' moving at v)
39-09 **Relativistic Momentum and Relativistic Form of Newton's Laws** [] $\vec{p} = \gamma\,m\,\vec{u} = \frac{m\,\vec{u}}{\sqrt{1-u^2/c^2}}$, $\vec{F} = \frac{d\,\vec{p}}{dt}$
39-10 **Relativistic Energy** [] $K = (\gamma - 1)\,m\,c^2$, $E_R = m\,c^2$, $E_{tot} = K + m\,c^2 = \gamma\,m\,c^2$, energy-momentum relationship: $E^2 = p^2\,c^2 + (m\,c^2)^2$
39-11 **Mass as a Measure of Energy** [] conservation of mass-energy: $E_i = \frac{m_i\,c^2}{\sqrt{1-u_i^2/c^2}}$, $\kappa = (\gamma - 1)\,m\,c^2$, fission, fusion
39-12 **Photon Momentum** [] $p = \frac{h\,f}{c} = \frac{h}{\lambda}$, $E = p\,c$
39-13 **Conservation of Relativistic Momentum, Mass, and Energy**
39-14 **Doppler Shift for Light**
39-15 **Pair Production and Annihilation**
39-16 **Matter and Antimatter**
39-17 **General Relativity and Accelerating Reference Frames** [] gravitational redshift
39-99 Associated problems in Chapter 39

40 The Quantum Theory of Light
40-01 **The Photon, the Quantum of Light** [] spin, no mass, $E = h\,f$, $f = \frac{c}{\lambda}$
40-02 **Hertz's Experiments: Light as an Electromagnetic Wave** [] $E_n = n\,h\,f$
40-03 **Blackbody Radiation and Planck's Hypothesis** [] $e_f = J(f, T)$, $e_{tot} = \int_0^\infty e_f\,df = \sigma\,T^4$, Wien's, Stefan's, $E_n = n\,h\,f$, Planck's: $u(f,t)\,df = \frac{8\,\pi\,f^2}{c^3}\left[\frac{h\,f}{e^{h\,f/(k_B\,T)}-1}\right]\,df$
40-04 **Light Quantization and the Photoelectric Effect** [] $K_{max} = \frac{1}{2}\,m_e\,v_{max}^2 = e\,V_s$, photoelectric: $K_{max} = h\,f - \phi$
40-05 **The Compton Effect** [] $\Delta\lambda = \frac{h}{m_e\,c}\,(1 - \cos\theta)$, energy conserv: $E + m_e\,c^2 = E' + E_e$, Compton wavelength: $\frac{h}{m\,c}$, Bragg scattering: $n\,\lambda = 2\,d\sin\theta$
40-06 **Particle-Wave Complementarity, Duality: Double Slits** [] (Davidson-Germer is 42:03)
40-07 **Effect of Gravity on Light** [] $f' = f\left(1 - \frac{G\,m}{R_s\,c^2}\right)$, $\frac{\Delta f}{f} = \frac{g\,H}{c^2}$, red shift for white dwarf

40-08 **The Wave Function**
40-09 **Electron Microscopes**
40-99 Associated problems in Chapter 40

41 The Particle Nature of Matter

41-01 **The Atomic Nature of Matter** [] spectrum, Balmer series, $\frac{1}{\lambda} = \frac{1}{R_H}\left(\frac{1}{4} - \frac{1}{n^2}\right)$
41-02 **The Composition of Atoms** [] Faraday's law of electrolysis: $m = \frac{1\,(\text{molar mass})}{(96500\,c)(\text{valence})}$, Rutherford model, Thomson, $\frac{e}{m_e}$ tube, Millikan oil drop
41-03 **Molecules**
41-04 **The Bohr Atom** [] spectral series, Balmer series, $\Delta E = h\,f$, $m_e\,v\,r = n\,\hbar$, Kirchoff, $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, Balmer lines $E = -\frac{k_e^2}{2\,r}$, $E_n = -\frac{k\,e^2}{2\,a_0\,n^2} = \frac{13.606}{n^2}$ eV, $r_n = \frac{n^2\,\hbar^2}{m_e\,k\,e^2}$, theoretical: $\frac{1}{\lambda} = \frac{f}{c} = \frac{k\,e^2}{2\,a_0\,h\,c}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$
41-05 **Quantum Model of the Hydrogen Atom** [] quantization of angular momentum and energy, Bohr's correspondence principal, $L = m_e\,v\,r = n\,\hbar$, $\frac{d\,E}{dL} = \frac{m_e\,k^2\,e^4}{L^3}$, $E = -\frac{1}{2}\,\frac{m_e k^2 e^4}{L^2}$, quantum number restrictions: $1 < n < \infty$, $0 < \ell < n - 1$, $-\ell < m_\ell < \ell$
41-06 **Franck-Herz Experiment**
41-99 Associated problems in Chapter 41

42 Matter Waves

42-01 **de Broglie Waves** [] $\lambda = \frac{h}{p}$, $m_e\,v\,r = n\,\hbar$, $f = \frac{E}{\hbar}$
42-02 **The Time Independent Schrödinger Equation** [] $-\frac{\hbar^2}{2\,m}\,\frac{\partial^2\Psi}{\partial x^2} + U(x)\,\Psi(x) = i\,\hbar\,\frac{\partial\Psi}{\partial t}$, $-\frac{\hbar^2}{2\,m}\,\frac{\partial^2\Psi}{\partial x^2} + U(x)\,\Psi(x) = E\,\Psi(x)$
42-03 **The Davisson-Germer Experiment**
42-04 **Fourier Integrals** [] $f = \frac{1}{\sqrt{2\,\pi}}\int a(x)\,e^{i\,k\,x}\,dx$
42-05 **The Heisenberg Uncertainty Principle** [] $\Delta p\,\Delta x = \frac{1}{2}\,\hbar$, $\Delta E\,\Delta t \geq \frac{1}{2}\,\hbar$
42-06 **Wave Groups and Dispersion** [] phase velocity: $v_p = \frac{\omega}{\kappa}$, group velocity: $v_g = \frac{d\,\omega}{dk}\big|_{k_0}$, phase vel for matter waves: $v_p = c\,\sqrt{1 + \left(\frac{m\,c}{\hbar\,k}\right)^2}$, matter wave packets
42-07 **Wave-Particle Duality** [] electron diffraction, (cannot measure wave and particle properties simultaneously), Ψ
42-08 **String Waves and Matter Waves** [] Bragg
42-99 Associated problems in Chapter 42

43 Quantum Mechanics in One Dimension

43-01 **The Hydrogen Atom** [] $E_n = -\frac{13.6\text{ eV}}{n^2}$
43-02 **The Born Interpretation** [] $P(x)\,dx = |\Psi(x,t)|^2\,dx$, normalization $\int|\Psi|^2\,dx = 1$, $\int_{-\infty}^{\infty}|\Psi|^2\,dx = 1$, probabilities: $P(x) = \int_a^b|\Psi|^2\,dx$
43-03 **The Time-Dependent Schrödinger Equation**
43-04 **Wavefunction for a Free Particle** [] $\Psi = A\,e^{i\,(k\,x - \omega\,t)} = A\,|\cos(k\,x - \omega\,t) + i\,\sin(k\,x - \omega\,t)|$
43-05 **Wavefunctions in the Presence of Forces** [] $-\frac{\hbar^2}{2\,m}\,\frac{\partial^2\Psi}{\partial x^2} + U(x)\,\Psi = i\,\hbar\,\frac{\partial\,\Psi}{\partial t}$, (Schröd)
43-06 **Particle in a Box** [] (infinite box), quantum number n, $E_n = \frac{\hbar^2\,k^2}{2\,m} = \frac{n^2\,\pi^2\,\hbar^2}{2\,m\,L^2}$, stationary states: $\Psi_n = A\,\sin\left(\frac{n\,\pi\,x}{L}\right)$,
43-07 **Energies of a Trapped Electron** [] $E_n = \frac{h^2}{8\,m\,L^2}\,n^2$
43-08 **Wave Functions of a Trapped Electron** [] $\Psi_n = A\,\sin\left(\frac{n\,\pi}{L}\,x\right)$, prob: $P(x) =$

$\Psi_n^2(x)\,dx$, prob density: $\Psi_n^2(x) = A^2\,\sin^2\left(\frac{n\,\pi}{L}\,x\right)$

43-09 **The Finite Square Well** [] $E_n \approx \frac{n^2\,\pi^2\,\hbar^2}{2\,m\,(L+2\,\delta)^2}$, $\delta = \frac{1}{\alpha} = \frac{\hbar}{\sqrt{2\,m\,(U-E)}}$

43-10 **More Electron Traps** [] nanocrystallites, quantum dots, corrals

43-11 **Two- and Three-Dimensional Electron Traps** [] rectangular box

43-12 **The Quantum Oscillator** [] $\frac{\partial^2\Psi}{\partial x^2} = \frac{2\,m}{\hbar^2}\left(\frac{1}{2}\,m\,\omega^2\,x^2 - E\right)\Psi(x)$, harmonic oscillator $E_n = \left(n+\frac{1}{2}\right)\hbar\,\omega$

43-13 **Expectation Values** [] average position: $\langle x\rangle = \int x\,|\Psi|^2\,dx$, average momentum: $\langle p\rangle = m\,\frac{d\,\langle x\rangle}{dt} = \int \Psi^*\,\left(\frac{\hbar}{i}\right)\,\frac{\partial\,\Psi}{\partial x}\,dx$

43-14 **Observables and Operators** [] $\langle Q\rangle = \int \Psi^*\,[Q]\,\Psi\,dx$, $\Delta Q = \sqrt{\langle Q^2\rangle - \langle Q\rangle^2}$

43-99 Associated problems in Chapter 43

44 Tunneling Phenomena

44-01 **The Square Barrier** [] reflection coeff: $F = \frac{|B|^2}{|A|^2}$, transmission coeff: $T = \frac{|F|^2}{|A|^2}$

44-02 **Barrier Penetration: Some Applications** [] alpha decay, tunneling through Coulomb barrier, barrier: $T(E) = \exp\left[-\frac{2}{\hbar}\,\sqrt{2\,m}\,\int\sqrt{U(x)-E}\,dx\right]$, field emission: $T(E) = \exp\left(-\frac{4\,\sqrt{2\,m}\,|E|^{3/2}}{3\,e\,\hbar}\,\frac{1}{\mathcal{E}}\right)$, decay of black holes

44-03 **Decay Rates**

44-04 **The Scanning Tunneling Microscope**

44-99 Associated problems in Chapter 44

45 Quantum Mechanics in Three Dimensions

45-01 **Three-Dimensional Schrödinger Equation** [] $-\frac{\hbar^2}{2\,m}\,\nabla^2\,\Psi + U(r)\,\Psi = i\,\hbar\,\frac{\partial\Psi}{\partial t}$, Laplacian: $\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$,

45-02 **Particle in a Three-Dimensional Box** [] time-independent Schrödinger equation for particle with energy $E = \hbar\,\omega$: $-\frac{\hbar^2}{2\,m}\,\nabla^2\,\Psi(r) + U(r)\,\Psi(r) = E\,\Psi(r)$, discrete energies: $E = \frac{1}{2\,m}\,\left(|p_x|^2 + |p_y|^2 + |p_z|^2\right) = \frac{\pi^2\,\hbar^2}{2\,m\,L^2}\,\left(n_1^2 + n_2^2 + n_3^2\right)$, where $|p_x| = \hbar\,k_1 = n_1\,\frac{\pi\,\hbar}{L}$, *etc.*

45-03 **Central Forces and Angular Momentum** [] $|\vec{L}| = \sqrt{\ell\,(\ell+1)}\,\hbar$, $L_z = m_\ell\,\hbar$

45-04 **Space Quantization** [] $\cos\theta = \frac{L_z}{|\vec{L}|} = \frac{m_\ell}{\sqrt{\ell\,(\ell+1)}}$

45-05 **Quantization of Angular Momentum and Energy** [] L_z is sharp, $|\vec{L}|$ is sharp, E is sharp, $U = U(r) + \frac{\ell\,(\ell+1)\,\hbar^2}{2\,m\,r^2}$, $L = m_e\,v\,r = n\,\hbar$, $\frac{d\,E}{dL} = \frac{m_e\,k^2\,e^4}{L^3}$, $E = -\frac{1}{c}\,\frac{m_e\,k^2\,e^4}{L^2}$

45-06 **Atomic Hydrogen and Hydrogen-like Ions** [] $E_n = -\frac{k\,e^2}{2\,a_o}\,\left(\frac{z^2}{\hbar^2}\right)$, $\ell = 0, 1, 2, ..., n-1$, ground state: $P(r) = |g|^2 = r^2\,|R|^2$, $\langle r\rangle = \int_0^\infty r\,P(r)\,dr$, $\langle f\rangle = \int_0^\infty f\,P\,dr$

45-99 Associated problems in Chapter 45

46 Atomic Structure

46-01 **Some Properties of Atoms**

46-02 **Atomic Spectra**

46-03 **Orbital Magnetism and the Normal Zeeman Effect** [] $\vec{\mu} = \frac{q}{2\,m}\,\vec{L}$, $\vec{\tau} = \vec{\mu}\times\vec{B}$, $U = -\vec{\mu}\cdot\vec{B}$,

46-04 **Electron Spin** [] μ_s, $S_z = m_s\,\hbar$, $|\vec{S}| = \sqrt{s\,(s+1)}\,\hbar = \frac{\sqrt{3}}{2}\,\hbar$, $\vec{\mu} = \vec{\mu}_o + \vec{\mu}_s = -\frac{e}{2\,m_e}\,\left(\vec{L} + g\,\vec{S}\right)$

46-05 **The Spin-Orbit Interaction and Other Magnetic Effects** [] $|\vec{J}| = \sqrt{j\,(j+1)}\,\hbar$

46-06 **Angular Momenta and Magnetic Dipole Moments**
46-07 **The Stern-Gerlach Experiment**
46-08 **Magnetic Resonance**
46-09 **Electron Clouds** [] prob of finding electron
46-10 **Exchange Symmetry and the Exclusion Principle** [] bosons: $\Psi(r_1, r_2) = \Psi(r_2, r_1)$, fermions: $\Psi(r_1, r_2) = -\Psi(r_2, r_1)$
46-11 **Multiple Electrons in Rectangular Traps**
46-12 **Electron Interactions and Screening Effects** [] Thomas-Fermi atom, quantum defects, Hartree's self-consistent fields
46-13 **The Periodic Table** [] electron configuraton, Hund's rule
46-14 **Isotopes**
46-15 **X-Ray Spectra and Moseley's Law**
46-16 **Atomic Transitions** [] jump levels, ground/excited states
46-17 **Lasers and Holography**
46-18 **How Lasers Work** [] absorption, spontaneous/simulated emission, population inversion, semiconductor lasers
46-99 Associated problems in Chapter 46

47 Statistical Physics
47-01 **The Maxwell-Boltzmann Distribution** [] $n(v)\,dV = ...$, equipart of energy: $\frac{1}{2}\,m\,\overline{v}_x^2 = \frac{1}{2}\,k_B\,T$, $\frac{1}{2}\,m\,\overline{v}^2 = \sum \frac{1}{2}\,m\,v^2 = \frac{3}{2}\,k_B\,T$
47-02 **Quantum Statistics, Indistinguishability and the Pauli Exclusion Principle** [] Bose-Einstein, Fermi-Dirac
47-03 **Applications of Bose-Einstein Statistics** [] blackbody radiation, phonons $C = \frac{dU}{dT}$
47-04 **An Application of Fermi-Dirac Statistics: The Free-Electron Gas Theory of Metals** [] density of states
47-99 Associated problems in Chapter 47

48 Molecular Structure
48-01 **Bonding Mechanisms** [] ionic/covalent/hydrogen bonds
48-02 **Weak (van der Waals) Bonds**
48-03 **Polyatomic Molecules**
48-04 **Diatomic Molecules: Molecular Rotation and Vibration** [] $E_{net} = \frac{L^2}{2\,I}$, $E_{rot} = \frac{\hbar^2}{2\,I_{cm}}\,l\,(l+1)$, $E_{vib} = \left(\nu + \frac{1}{2}\right)\,\hbar\,\omega$, anharmonic effect
48-05 **Molecular Spectra** [] rotat-vibr spectrum
48-06 **Electron Sharing and the Covalent Bond** [] hydrogen molec ion, molecular orbitals/atoms/wavefunctions, bonding/antibonding orbitals of He^+
48-07 **Bonding in Complex Molecules** [] $\sigma\,,\pi$ bonds, heteronuclear molec
48-99 Associated problems in Chapter 48

49 The Solid State
49-01 **Bonding in Solids** [] ionic, atomic cohesive energy, covalent, metallic, molec crystals, amorphous solids
49-02 **Electrical Properties of Solids**
49-03 **Energy Levels in a Crystalline Solid**
49-04 **Insulators**
49-05 **Metals** [] Fermi energy
49-06 **Classical Free-Electron Model** [] Ohm's Law, drift speed, current density, heat con-

ductivity, Wiedemann Franz Law, Lorenz number
49-07 **Quantum Theory of Metals** [] v_F instead of v_{rms}, quantum free path, Mattheissen's rule
49-08 **Band Theory of Solids** [] energy gap, isolated atom approach, conduction metals/insulators/semiconductors, electron wave reflections
49-09 **Semiconductor Devices** [] solar cells, junction transistor
49-10 **Doped Semiconductors** [] n-type, p-type
49-11 **The p-n Junction** [] semiconductor diodes
49-12 **The Junction Rectifier**
49-13 **The Light-Emitting Diode (LED)**
49-14 **Transistors and Integrated Circuits**
49-99 Associated problems in Chapter 49

50 Superconductivity
50-01 **Magnetism in Matter** [] mag moments, mag field strength, mag permeable, mag hysteresis, paramagnetism, Curie's law: $M = C\,\frac{B}{T}$, diamagnetism
50-02 **A Brief History of Superconductivity** [] critical temp, mag fld
50-03 **Some Properties of Type I Superconductors** [] critical temp, penetration depth
50-04 **Type II Superconductors** [] vortex state
50-05 **Other Properties of Superconductors** [] persistent currents, coherent lengths, flux quantization
50-06 **Electronic Specific Heat**
50-07 **BCS Theory** [] isotope effect, Cooper pair
50-08 **Energy Gap Measurements** [] single particle tunneling, EM absorption
50-09 **Josephson Tunneling** [] *dc* and *ac* effects, quantum interference
50-10 **High-Temperature Superconductivity**
50-11 **Applications of Superconductivity**
50-99 Associated problems in Chapter 50

51 Nuclear Structure
51-01 **Discovering the Nucleus** [] Rutherford, Geiger, Marsden
51-02 **Some Nuclear Properties** [] isotopes, charge, mass, size, structure, nuclear stability, spin magnetic moments, magnetic resonance, MRI, NMR
51-03 **Binding Energy and Nuclear Forces** [] charge independent
51-04 **Nuclear Models** [] liquid-drop, independent-particle, collective, combined
51-05 **Radioactivity** [] positron, decay constant
51-06 **Decay Processes**
51-07 **Alpha Decay** [] ^{4}He
51-08 **Beta Decay** [] neutrino ν
51-09 **Gamma Decay**
51-10 **Half-Life and Rate of Decay**
51-11 **Decay Series**
51-12 **Radioactive Dating**
51-13 **Measuring Radiation Dosage**
51-14 **Natural Radioactivity**
51-99 Associated problems in Chapter 51

52 Nuclear Physics Applications
52-01 **Nuclear Reactions** [] Q values

52-02 **Reaction Cross Section**
52-03 **Interactions Involving Neutrons** [] neutron capture
52-04 **Nuclear Fission**
52-05 **A Model for Nuclear Fission**
52-06 **Nuclear Reactors** [] chain reaction, neutron leakage
52-07 **A Natural Nuclear Reactor**
52-08 **Nuclear Fusion** [] thermonuclear reactions, fusion, Lawson's criterion, magnetic field confinement, inertial confinement
52-09 **Thermonuclear Fusion in the Sun and Other Stars**
52-10 **Controlled Thermonuclear Fusion** [] magnetic, inertial confinement
52-11 **Recent Fusion Energy Developments**
52-12 **Interaction of Particles with Matter** [] heavy charged particles, pair production: $I = I_o\, e^{-\mu x}$
52-13 **Radiation Damage in Matter** [] roentgen, the rad
52-14 **Radiation Detectors** [] ion/cloud/bubble/closed chambers, Geiger counter, neutron detectors, dosiometry
52-15 **Radiation Therapy**
52-16 **Tracers**
52-17 **Tomography Imaging: CAT Scans and Emission Tomography**
52-18 **NMR and MRI**
52-99 Associated problems in Chapter 52

53 Particle Physics

53-01 **Elementary Particles** [] high energy
53-02 **The Fundamental Forces in Nature** [] strong, weak, EM, gravitational
53-03 **Particle Accelerators and Detectors** [] cyclotron, synchrotron, linear accelerator, particle detectors, colliding beams
53-04 **Particle Exchange**
53-05 **Particles and Antiparticles** [] pair production, electron-positron annhilation, $e^+ + e^- \rightarrow 2\,\gamma$
53-06 **Mesons and the Beginning of Particle Physics** [] π^-, μ^-
53-07 **Classification of Particles** [] hadrons, leptons, baryons, mesons
53-08 **Conservation Laws** [] baryon/lepton number
53-09 **Particle Stability and Resonances**
53-10 **Antiproton in a Bubble Chamber**
53-11 **Leptons**
53-12 **Hadrons**
53-13 **Strange Particles and Strangeness** [] karon, lambda, sigma
53-14 **Elementary Particle Production; Measurement of Properties** [] resonance particles, energy in particle production
53-15 **The Eightfold Way** [] patterns in particles
53-16 **Quarks** [] charm, colored quarks, gluons
53-17 **Electroweak Theory and the Standard Model**
53-18 **Quasars**
53-19 **Grand Unified Theory** [] symmetry breaking, string theory, supersymmetry
53-99 Associated problems in Chapter 53

54 Astrophysics and Cosmology

54-01 **Stars and Galaxies**

54-02 **The Birth and Death of Stars** [] luminosity, H-R diagram, main sequence
54-03 **General Relativity: Gravity and the Curvature of Space** [] principle of equivalence, black holes, Schwarzschild radius: $R = \frac{2GM}{c^2}$
54-04 **The Expanding Universe** [] red shift, Hubble law, quasars
54-05 **The Cosmic Connection**
54-06 **Cosmic Background Radiation**
54-07 **Dark Matter**
54-08 **The Big Bang**
54-09 **Early History of the Universe** [] eras
54-10 **The Future of the Universe**
54-11 **Problems and Perspectives**
54-99 Associated problems in Chapter 54

55 Probability Distributions
55-01 **Uncertainites**
55-02 **Parent and Sample Distributions**
55-03 **Mean and Standard Deviation of Distributions**
55-04 **Binomial Distribution**
55-05 **Poisson Distribution**
55-06 **Gaussian or Normal Error Distribution**
55-07 **Lorentzian Distribution**
55-99 Associated problems in Chapter 55

56 Error Analysis [] (see 01:11)
56-01 **Instrumental and Statistical Uncertainties**
56-02 **Propagation of Errors**
56-03 **Specific Error Formulas**
56-04 **Application of Error Equations**
56-99 Associated problems in Chapter 56

57 Estimates of Mean and Errors
57-01 **Method of Least Squares**
57-02 **Statistical Fluctuations**
57-03 χ^2 **Test of a Distribution**
57-99 Associated problems in Chapter 57

58 Monte Carlo Techniques
58-01 **Introduction**
58-02 **Random Numbers**
58-03 **Random Numbers from Probability Distributions**
58-04 **Specific Distributions**
58-05 **Efficiency**
58-99 Associated problems in Chapter 58

59 Least-Squares Fit to a Straight Line
59-01 **Dependent and Independent Variables**
59-02 **Method of Least Squares**
59-03 **Minimizing** χ^2
59-04 **Error Estimation**

59-05 **Some Limitations of the Least-Squares Method**
59-06 **Alternate Fitting Methods**
59-99 Associated problems in Chapter 59

60 Least-Squares Fit to a Polynomial
60-01 **Determinate Solution**
60-02 **Matrix Solution**
60-03 **Independent Parameters**
60-04 **Nonlinear Functions**
60-99 Associated problems in Chapter 60

61 Least-Squares Fit to an Arbitrary Function
61-01 **Nonlinear Fitting**
61-02 **Searching Parameter Space**
61-03 **Grid-Search Mechod**
61-04 **Gradient-Search Method**
61-05 **Expansion Methods**
61-06 **The Marquardt Method**
61-07 **Comments on the Fits**
61-99 Associated problems in Chapter 61

62 Fitting Composite Curves
62-01 **Lorentzian Peak on Quadratic Background**
62-02 **Area Determination**
62-03 **Composite Plots**
62-99 Associated problems in Chapter 62

63 Direct Application of the Maximum-Likelihood Method
63-01 **Maximum-Likelihood Method**
63-02 **Computer Example**
63-99 Associated problems in Chapter 63

64 Testing the Fit
64-01 χ^2 **Test of Goodness of Fit**
64-02 **Linear-Correlation Coefficient**
64-03 F **Test**
64-04 **Confidence Intervals**
64-05 **Monte Carlo Tests**
64-99 Associated problems in Chapter 64