Concepts and Topics Expected to be Covered in Undergraduate Physics
(Revised 13 May 2009)

Mechanics (elementary)

Typical textbooks:

Young and Freedman, *University Physics*
Halliday, Resnick and Walker, *Fundamentals of Physics*
Ohanian and Markert, *Physics for Engineers and Scientists*

vectors
Newton's laws of motion
work and energy
conservative forces (gravity: uniform and $1/r^2$, ideal spring)
conservation of energy
motion of center of mass
conservation of momentum
kinematics of rotation
rigid body rotation
conservation of angular momentum
equilibrium: force and torque equations
Newton's law of gravitation
oscillations (simple harmonic motion)
waves on a string: wavelength, frequency, velocity

Mechanics (intermediate)

Typical textbooks:

Taylor, *Classical Mechanics*
Hamill, *Intermediate Dynamics*
Fowles and Cassiday, *Analytical Mechanics*

Above topics in greater depth, plus

using differential equations
velocity and acceleration in polar and spherical coordinates
damped and driven harmonic oscillator
coupled harmonic oscillators
- normal modes

Lagrange equations of motion (one or more dimensions)
rocket motion
central force motion
- effective potential energy
- planetary motion: Kepler's laws

rigid body motion
- rotational equation of motion
- parallel-axis theorem
- precession of gyroscope

accelerated coordinate systems

fictitious forces
principal axes
free symmetric top

gravitation
Newton's spherical shell theorem
tides

Electricity and magnetism (elementary)

Typical textbooks: see list for elementary mechanics

Coulomb's law
electric field
Gauss's law and applications
electrostatic potential
energy of a system of charges
electrical energy density
capacitance
current and current density
resistivity and resistance
power in circuit elements
Kirchhoff rules: voltage (loop) and current (node)
RC circuits
magnetic force and magnetic field
Biot-Savart law
Ampere's law and applications
torque on a current loop
Faraday's law and motional emf
self-inductance
magnetic energy density
RL circuits
AC circuits
LC and RLC oscillations
Maxwell's equations (integral form)
plane electromagnetic waves
light
laws of reflection and refraction
total internal reflection
lenses and mirrors
two-slit interference
diffraction grating

Electricity and magnetism (intermediate)

Typical textbook: Griffiths, *Introduction to Electrodynamics*

Above topics in greater depth, plus

vector operators: gradient, divergence, curl, Laplacian

Maxwell's equations in differential form
solutions of Laplace's equation (in rectangular, spherical, cylindrical coordinates)
multipole expansion of V: monopole and dipole terms
image charges in an infinite conducting plane
$\boldsymbol{E}$, $\boldsymbol{D}$ and $\boldsymbol{P}$ in a dielectric
boundary conditions on $\boldsymbol{E}$ and $\boldsymbol{D}$
using Biot-Savart law
divergence and curl of $\boldsymbol{B}$
magnetic vector potential
$\boldsymbol{B}$, $\boldsymbol{H}$ and $\boldsymbol{M}$ in a magnetic material
boundary conditions on $\boldsymbol{B}$ and $\boldsymbol{H}$
wave equation using complex wave functions
reflection and refraction at a boundary
reflection and transmission (Fresnel coefficients)

Modern physics

Typical textbook: Bernstein, Fishbane and Gasiorowicz, *Modern Physics*

special relativity
- postulates
- Lorentz transformation
- time dilation and length contraction
- relativistic energy and momentum conservation

photoelectric effect
Compton scattering
DeBroglie wavelength
X-ray diffraction
electron diffraction
Bohr model of the H atom
uncertainty principle
Schrödinger equation
- wave function and probability
- stationary states and time-independent Schrödinger equation
- solutions for square well
- barrier penetration

Angular momentum rules (qualitative)
Quantum numbers of the Hydrogen atom

Quantum mechanics

Typical textbook: Griffiths, *Introduction to Quantum Mechanics*

Schrödinger equation
probability
normalization
momentum operator
stationary states and time-independent Schrödinger equation
barriers and wells

square well (infinite and finite)
harmonic oscillator
free particle and wave packets
Hermitian operators and observables
Dirac notation
Schrödinger equation in spherical coordinates
spherical harmonics
hydrogen atom
angular momentum operators and eigenvalues
spin and Pauli spin matrices
addition of angular momentum
bosons and fermions
two-particle systems and exchange forces
atoms and periodic table
quantum statistical mechanics
    Maxwell-Boltzmann
    Fermi-Dirac
    Bose-Einstein
time-independent perturbation theory
hydrogen fine structure
Zeeman effect
time-dependent perturbation theory
absorption, emission and stimulated emission (Einstein coefficients)

Thermodynamics and statistical physics

Typical textbook: Adkins, *Equilibrium Thermodynamics*

thermodynamic variables
temperature
thermodynamic equilibrium
zeroth law
work, heat and internal energy
first law
heat capacities
ideal gases
second law
refrigerators and heat pumps
heat engines
entropy
Carnot cycle
thermodynamic potentials
Maxwell relationships
irreversibility
phase transitions