Topics

Mechanics

- One-dimensional motion in a conservative system with an arbitrary potential. The concept of turning points.
- Equilibrium of mechanical systems.
- Lagrangian methods.
- The simple harmonic oscillator. Free and damped oscillations, inclusion of external forces, resonance. Calculation of the natural frequency for small oscillations about the minimum of an arbitrary potential.
- Motion in a central potential. Conservation of angular momentum.
- Rotational motion about a single axis; angular momentum and rotational energy. The gyroscope. Rolling.
- Oscillations and wave propagation in strings and membranes. Normal modes for particular boundary conditions. Solution to initial-value problem.

Suggested textbooks:
- Thornton and Marion, *Classical Dynamics of Particles and Systems*
- Fowles and Cassiday, *Analytical Mechanics*
- Morin, *Introduction to Classical Mechanics*

Quantum Mechanics

- Measurements in quantum mechanics: expectation values, possible measurement outcomes and their probabilities. The relevance of commutation relations to measurement. The uncertainty principle.
- Bound-state problems, properties of the spectrum and the wavefunctions (most importantly 1D Dirac δ-function, 1D/2D/3D square well, 1D/2D/3D harmonic oscillator).
Scattering in 1D. Transmission and reflection from a barrier/well. Quantum tunneling.

Symmetry of the Hamiltonian, implications for symmetry of the wavefunctions, and their usage to simplify calculations/analysis of quantities (e.g., energy spectrum, matrix elements, etc.).

Time-independent non-degenerate perturbation theory: energy corrections to second order; wave function to first order.

Time-independent degenerate perturbation theory. Lifting of degeneracy.

-Time dependent perturbation theory: first order wave function corrections and the meaning of interaction matrix elements between states.

Motion in a central potential. Hydrogen states wavefunctions and energies.


Angular momentum and spin (half-integer and integer). Spin-1/2 matrices. Addition rules. Hamiltonians with coupling of spin to another spin and to orbital angular momentum.


Suggested textbooks:
- D. J. Griffiths *Introduction to Quantum Mechanics*
- Gasiorowicz, *Quantum Physics*
- Beiser, *Concepts of Modern Physics*

**Electricity and Magnetism**

The electric field due to a static charge distribution. The magnetic field due to a static current distribution. Fields from electric and magnetic dipoles.

Boundary value problems involving slabs, cylinders and spheres. Laplace’s and Poisson’s equation.

Fields in matter. Polarization, magnetization.

Conducting matter. Ohm’s Law.


Electromagnetic wave propagation in vacua and in matter. Reflection and transmission for dielectric and conducting media.

Motion of a charged particle under the Lorentz force. The Hall Effect.
Dipoles (electric and magnetic) in external fields.

Fundamental circuits, e.g. RLC, RC, LC.

Poynting flux. Energy, momentum, and angular momentum of the field.

Suggested textbooks:
- D. J. Griffiths, Introduction to Electrodynamics
- Lorrain and Corson, Electromagnetic Fields

**Thermal and Statistical Physics**

- The first, second, and third laws of thermodynamics and their applications.
- Elementary kinetic theory. Cross section, mean-free-path, collision time.
- Ideal gases, non-ideal gases, and the Joule-Thomson process.
- Adiabatic, isothermal, and isochoric processes. The physics of heat engines.
- The Maxwell relations and their use to determine relationships between thermodynamic variables. Equations of state.
- Thermodynamics of phase transitions including heat of fusion, latent heat, and entropy changes. The Clausius-Clapeyron equation.
- Microcanonical, canonical, and grand canonical ensembles, and their connection to thermodynamics.
- Calculation of partition functions and their use to calculate the physical properties. This includes systems with discrete energy spectra and phase space integration.
- Heat capacity of gases with translational and rotational degrees of freedom. The Dulong-Petit and Einstein models for the heat capacity.
- Maxwell and Boltzmann distributions.
- Brownian motion and random walk. Thermal diffusion.

Suggested textbooks:
- F. Reif, Fundamentals of Statistical and Thermal Physics
- H. B. Callen, Thermodynamics and an Introduction to Thermostatistics
- K. Stowe, Introduction to Statistical Mechanics and Thermodynamics