

# TOPICS

## MECHANICS

- Identification of symmetries and conserved quantities. Application of conservation laws.
- 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.
- Coupled harmonic oscillators. Normal modes of a system of masses, springs and pendula. Solution to initial-value problem.
- Rotational motion about a single axis; angular momentum and rotational energy.

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 uncertainty principle.
- Superposition states. Time evolution of superposition states. Amplitudes of the constituent states and their probabilistic interpretation.
- Bound-state problems, properties of the spectrum and the wavefunctions (most importantly 1D Dirac  $\delta$ -function, 1D/2D/3D square well, 1D/2D/3D harmonic oscillator).
- Scattering in 1D. Transmission and reflection from a barrier/well. Quantum tunneling.
- Time-independent non-degenerate perturbation theory: energy corrections to second order; wave function to first order.

- Time-independent degenerate perturbation theory. Lifting of degeneracy.
- Motion in a central potential. Hydrogen states wavefunctions and energies.
- Angular momentum and spin (half-integer and integer). Spin- $\frac{1}{2}$  matrices. Addition rules. Hamiltonians with coupling of spin to another spin and to orbital angular momentum.
- Energy of a spin in an external magnetic field. Spin precession.

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.
- Faraday's Law. Electromagnetic induction.
- 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.
- Poynting flux.

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.
- Adiabatic, isothermal, and isochoric processes.
- 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.
- 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.
- Bose and Fermi statistics. Electron degeneracy in metals. Bose-Einstein condensation. Calculation of the energy distribution of a blackbody and the energy flux.
- 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*