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. 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.

☐ Superposition states. Solutions to initial-value problems for 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 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.

☐ Identical particles. Exchange symmetry and interaction. Pauli exclusion principle.

☐ Angular momentum and spin (half-integer and integer). Spin matrices. Addition rules. Hamilitonians 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.

☐ 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 to physical systems (see below).

☐ 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 calcuate 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*