Classical Mechanics

Goldstein, Poole, and Safko (Classical Electrodynamics, third edition) and Strogatz (Nonlinear Dynamics and Chaos).

- Lagrange's Equations and d'Alembert's Principle
  - Electromagnetic potentials
  - Applications
- Variational Principles
  - Calculus of variations
  - Nonholonomic systems and constraints
  - Conservation Theorem
- Rigid body motion
  - Theory of rotations, finite and infinitesimal
  - Euler angles
  - Coriolis effect
  - Inertia Tensor
  - Applications
- Small oscillations
  - Eigenvalue problem
  - Normal modes and frequencies

- Hamilton's Equations and Hamilton Jacobi Equation
  - Variables for Hamilton's Equations
  - Canonical transformations via generating functions
  - Applications of Hamilton-Jacobi
  - Time-dependent perturbation theory
- Nonlinear Equations
  - One dimensional equations and Bifurcations
  - Linear and nonlinear equations in two dimensions; limit cycles

Electricity and Magnetism

References:

Jackson (Classical Electrodynamics) and Landau-Lifshitz (The Classical Theory of Fields).

- Introductory Mathematics
  - Elements of distribution theory and the δ-function
  - Four-vector notation
  - Maxwell and Lorentz-force Equations in 4-vector and component forms.
  - Integral forms oaf Maxwell's equations
  - Magnetic monopoles
  - Gauge transformation and gauge fixing
  - Typical vector potentials for prescribed $\vec{E}, \vec{B}$.
  - Energy and its conservation law; Poynting vector
  - The action principle
- Simple Problems of Charged Particles in External Fields
  - Motion of charged particle in static $\vec{E}, \vec{B}$ fields
  - Coulombs law and multi-pole expansions
  - Magnetic dipole moment
- Wave Propagation
- Green's Functions for Poisson's Equation
  - General theory
  - Method of images
  - Separation of variables
- Dielectrics: Definitions and Boundary Value Problems
- Magnetostatics

- Concluding lectures
  - Magnetic monopoles
  - GUTS and proton decay
  - Parity and time reversal

Quantum Mechanics

- Linear Vector Space Formalism
  - Linear dependence, dimension, basis
  - Inner product, operators, matrix isomorphism
  - Hermitian and unitary operators
  - Diagonalization. infinite dimensional LVS's
- Postulates
  - Connection between physical system and LVS
  - Position and momentum operators
  - Measurement
  - Dynamics
- Solvable problems in one dimension
  - Free particle
  - Square well
  - Scattering and tunneling
  - Linear harmonic oscillator
    - Solution in coordinate representation
    - Solution with raising/lowering operators
  - Hydrogen atom radial equation
- Miscellaneous topics
  - Ehrenfest's theorem
  - Uncertainty principle
  - Generalization to N degrees of freedom
  - Identical particles
  - Addition of angular momentum
  - Irreducible tensor operators and the Wigner-Eckart theorem
- Scattering theory

- Born approximation
  - Partial wave analysis

- Symmetries
  - Translations in space and time
  - Reflection of coordinates and parity
  - Rotations, generators of rotations, and angular momentum
  - Vector operators
  - Simultaneous operators of $\mathbf{J}$ and J_z
  - Spherical harmonics
  - Rotationally invariant problems
    * Free particle in 3D
    * Particle in spherical "square" well
    * Isotropic harmonic oscillator

- Spin
  - Pauli matrices; Eigenstates of $\vec{S} \cdot \hat{n}$.
  - Particle with magnetic moment in magnetic field
  - Magnetic resonance

- Approximations
  - Time independent perturbation (including degeneracy)
  - WKB approximation
  - Variational method
  - Time-dependent perturbation theory, application to radiation

Relativistic quantum mechanics

  - Free Klein Gordon field
  - Quantization of free photon
  - Dirac equation; properties and uses

Statistical Mechanics and Thermodynamics

References: Unless otherwise noted, the main bibliographic source is: Pathria, Statistical Mechanics, 2^{nd} edition

Key to other annotations:

No further annotation → fully discussed in coursework (lecture, assigned readings, and/or assigned problems).

* → discussed in coursework, but may appear on exam in lesser sophistication than other topics.

- Elements of Thermodynamics (refs: Goostein, Reif, Pathria)
  - Four Laws of Thermodynamics
  - Carnot Engine
  - Ideal Gas, van der Waals Gas
  - Thermodynamic Potentials and Response Functions
  - Manipulation of thermodynamics quantities
- Elements of Probability * (ref: Reif)
  - Binomial distribution
  - Poisson distribution
  - Central Limit Theorem, Normal distribution
- Statistical Mechanics: Ensemble Theory; connection with thermodynamic quantities and applications
  - Microcanonical Ensemble
  - Canonical Ensemble
  - Grand Canonical Ensemble
- Statistical Mechanics: Density Matrix Formulation *
- Statistical Mechanics: Classical Ideal Gas
- Statistical Mechanics: Fermi-Dirac and Bose-Einstein Statistics; Quantum Gases

  - Bose Gas & Bose-Einstein condensation
    * Superfluids: mostly LHe phenomenology (refs: Huang, Goodstein)
    * Blackbody Radiation
    * Phonons (Debye model)
  - Fermi Gas (applications: spin systems, metals, stars)

- Statistical Mechanics: Corrections to the Ideal Gas Law*

- Statistical Mechanics: Phase Transitions (refs: Pathria, Plischke & Bergersen, Goodtein, Huang)
  - Thermodynamics
  - Mean Field Theory (applications: Ising, van der Waals)
  - Landau theory
  - Critical exponents and scaling*