

# Topics for the Qualifying Examination

## Classical Mechanics

### Newtonian Dynamics

- Newton's laws
- Conservation laws

### Lagrangian Dynamics

- Generalized coordinates
- D'Alembert's principle
- Lagrange's equations
- Hamilton's principle of least action
- Symmetries and conservation laws (Noether's theorem)

### The two-body central force problem

- Reduction to the one-body problem
- Effective potential
- Kepler's problem
- Classical scattering

### Small Oscillations

- Equilibrium and linearization of the equations of motion
- Normal coordinates and normal modes

### Rigid-Body Motion

- Angular momentum and kinetic energy
- Inertia tensor
- Euler's equations
- Euler angles
- Compound pendulum, symmetric top

### Special Relativity

- Lorentz transformation
- Relativistic kinematics
- Relativistic dynamics

### Hamiltonian Dynamics

- Hamilton's equations
- Poisson brackets
- Symmetries and conserved quantities
- Canonical transformations and generating functions

## Electricity and Magnetism

### Electrostatics

- Electric field and potential
- Gauss's Law Surface charge distributions
- Poisson's and Laplace's equations
- Electric field in matter and dielectrics
- Multipole expansion

### Boundary-value problems

- Method of images
- Separation of variables
- Orthogonal functions and expansion
- Spherical coordinates and spherical harmonics
- Legendre functions
- Cylindrical coordinates and Bessel functions

### Magnetostatics

- Magnetic field and vector potential
- Ampere's law
- Magnetic moment, torque
- Boundary-value problems
- Magnetic field in matter

### Electrodynamics

- Faraday's law of induction
- Energy in a magnetic field
- Maxwell's equations
- Poynting's theorem
- Lorentz transformation of fields
- Four-tensor formulation of Maxwell's equations

### Electromagnetic waves

- Plane waves
- Polarization
- Energy and momentum in electromagnetic waves

### Radiation

- Dipole radiation
- Power radiated by a point charge

## Statistical Mechanics

### Thermodynamics

- Thermodynamic equilibrium
- The first and second laws of thermodynamics
- Entropy
- Thermodynamic potentials
- Third Law of thermodynamics

### The Principles of Statistical Mechanics

- Statistical distributions and classical statistics
- Density matrix and quantum statistics
- Liouville's theorem
- The Microcanonical ensemble
- Entropy in statistical mechanics
- Second and third laws in statistical mechanics

### The Canonical and Grand-canonical Ensembles

- Gibbs distribution
- The partition function
- Equipartition theorem
- The grand-canonical ensemble
- Fluctuations in equilibrium

### Identical Particles

- Classical ideal gas of identical particles
- Maxwell-Boltzmann distribution
- Quantum ideal gas of identical particles
- Fermi gas and Fermi-Dirac statistics
- Bose gas and Bose-Einstein statistics
- Bose-Einstein condensation
- Photons and black body radiation
- Phonons

## Quantum Mechanics

### Quantum Kinematics and Dynamics

- Postulates of quantum mechanics
- Configuration space vs. Hilbert space
- Wave function vs. state vector
- Time evolution in Schrodinger and Heisenberg pictures
- Uncertainty principle

### Simple 1D Problems

- Particle in a box
- Free particle
- Delta function potential

### Harmonic Oscillator

- Eigenstates and spectrum
- Raising and lowering operators

### Symmetries

- Continuous symmetries (translations, rotations)
- Discrete symmetries (parity, time reversal)

### Angular momentum

- Orbital angular momentum
- Spin
- Angular momentum algebra
- Rotation group
- Tensor operators
- Addition of angular momenta

### Hydrogen atom

### Charged particle in a magnetic field

### Approximation methods

- Time-independent perturbation theory
- Time-dependent perturbation theory
- Variational methods