I. Classical Mechanics

1. **Newton's laws of motion**: equations of motion for a particle, superposition.

2. **Central force problem**: reduction to a 1-D problem, Newton's universal law of gravitation, gravitational potential, Keplerian orbits.

3. **Reference frames**: transformations between moving observers, transformations to rotating frames, special relativity, relativistic momentum and energy, relativistic form of Newton's law.

4. **Elastic and inelastic collisions**: conservation of energy and momentum, Rutherford scattering, hard-sphere scattering, scattering cross sections.

5. **Dynamics of a system of particles:** center-of-mass, moment of inertia, rotational kinetic energy, linear and angular momentum of a system, Newton's laws in angular form, collisions involving rotation.

6. **Dynamics of rigid bodies**: inertia tensor, principal axes, Euler angles, Euler's equations for a rigid body, free motion of a symmetric top.

7. **Oscillations:** simple harmonic oscillator, damped oscillations, transients and steady-state oscillations with a harmonic driving force, superposition, Fourier series, nonlinear oscillations.

8. **Coupled oscillators**: weak coupling, general coupled oscillations, normal modes and normal coordinates, superposition.

9. **Dynamics of continuous media**: the wave equation, generic solutions, phase velocity, group velocity, wave packets, dispersion, coupling to discrete oscillators, standing waves, reflection and transmission, refraction.

10. **Statics:** conditions for equilibrium, stability and metastability, small oscillations in presence of a perturbation.

11. **Hamilton's principle**: the action, Lagrange's equation of motion, Lagrange's equations with constraints.

12. **Hamilton's equations of motion**: Hamiltonian form of conservation laws, Poisson brackets.

13. **Canonical transformations**: canonical coordinates, generating functions.

14. **Hamilton-Jacobi method**: Hamilton's principle function, Hamilton's characteristic function, action-angle variables.

II. Electromagnetism

1. **Electrostatics**: Coulomb's force law, Gauss's law, electric potential, superposition, boundary conditions for conductors, the method of images, Greens functions solutions, the dipole field and multipole expansion.

2. **Electric fields in dielectrics**: polarization, electric displacement, linear dielectrics, boundaries between different dielectrics.

3. **Magnetostatics**: the Lorentz force law, Biot-Savart law, Ampere's law, the vector potential, boundary conditions for conductors.

4. **Magnetic fields in matter**: magnetization, magnetic field H, linear magnetic materials, ferromagnets, superconductors.

5. **Electrodynamics:** Faraday's law for magnetic induction, Maxwell's equations, classes of boundary conditions, energy density and the Poynting vector, momentum flow.

6. **Gauge symmetry**: gauge transformations and gauge invariance.

7. **Electromagnetic waves**: in vacuum, in dielectric media, in conductors, polarization, reflection and refraction at a plane interface.

8. **Standing waves**: modes in a cavity, wave guides, optical fibers.

9. **Radiation and scattering**: electric and magnetic dipole radiation, scattering by a harmonically bound charge.

10. **Diffraction:** single-slit and double-slit diffraction, interferometers, Gaussian beams, diffraction-limited optics.

11. **Frame transformations**: fields in rotating frames, Lorentz transformation of fields, the electromagnetic field tensor, boosting of E and B fields.

12. **Interactions of charges with fields**: free motion of charges in external fields, forces on current-carrying conductors, forces on dielectrics.

III. Statistical Physics

1. **Thermodynamics**: quasistatic processes, reversible and irreversible processes, first and second laws of thermodynamics, entropy.

2. **Forms of energy**: heat and work, internal energy, Helmhotz and Gibbs free energies, enthalpy, Legendre transformations between forms.

3. **Intrinsic state variables**: temperature, pressure, chemical potential, chemical equilibrium, spontaneous processes.

4. **The ideal gas**: Maxwellian velocity distribution, dilute gas partition function, heat capacities for different molecular classes, the equation of state.

5. **Heat engines and refrigerators**: efficiency of a cycle, Carnot engines and maximal efficiency allowed by second law.

6. **Phase transitions**: equations of state, first-order phase transitions, phase diagrams, equilibrium phase co-existence.

7. **Statistical ensembles**: microcanonical, canonical, grand canonical, meaning of temperature, partition functions for each ensemble, equipartition theorem, meaning of entropy.

8. **State counting**: Boltzman statistics, the Boltzman factor, state counting with identical particles, the Gibb's factor, Bose statistics, Fermi statistics.

9. **Blackbody radiation**: Raleigh-Jeans law, Stefan-Boltzman law, Planck's hypothesis, equation of state of the photon gas, radiated power.

10. **Paramagnetism**: the classical spin system, the Ising model of ferromagnetism (mean field).

11. **Fermi gas**: density of states, partition function, pressure, chemical potential.

12. **Debye theory of solids**: heat capacity, the phonon gas.

13. **Transport coefficients**: mean free path, viscosity, thermal conductivity, diffusion in a dilute gas, electrical conductivity in a conductor.

14. **Fluctuations**: the random walk, Brownian motion, electrical noise in a circuit.

15. **Non-ideal gas**: scattering effects, time evolution of phase-space density, Boltzmann equation, equation of state of non-ideal gas.

Quantum Mechanics

1. **State vectors and observables**: the Hilbert space, Hermetian operators, commutation relations, completeness relations, eigenvalues and eigenstates, expectation values, projection and quantum measurement.

2. **Two-state problems**: raising and lowering operators, commutation relations, quantum oscillations, the ammonia molecule.

3. **Free particle motion**: Gaussian wave packets, continuum state normalization, de-Broglie and Compton wavelengths, the Heisenberg uncertainty principle, meaning of the wave function, particle interference.

4. **Angular momentum**: angular momentum algebra, addition rules, spin, spinors and spin-1/2, Pauli matrices, state counting, degeneracy.

5. **Bound states in 1-D**: the time-independent Schrodinger equation, the infinite square well and finite square well, barrier penetration and tunneling, the simple harmonic oscillator, raising and lowering operator formulation.

6. **Bound states in 3-D**: reduction to 1-D for central potentials, spherical harmonics, 3-D harmonic oscillator, the hydrogen atom, radial wave function solutions for spherical well, fine and hyperfine corrections for the hydrogen atom.

7. **Approximate methods**: time-independent perturbation theory, the WKB approximation, variational methods, Bohr-Sommerfeld quantization condition.

8. **Symmetries**: symmetry transformations and unitary operators, Noether's theorem, continuous symmetries, discrete symmetries.

9. **Motion in an external field**: gauge transformations, Landau levels in an external magnetic field, magnetic resonances.

10. **Scattering states**: general form for in-states, out-states, elastic scattering amplitude, the partial wave expansion, phase shifts, scattering length, effective range, resonances, the Froissart bound.

11. **Elementary scattering theory**: the S matrix, the Lipmann-Schwinger equation, the T matrix, the optical theorem, the Born approximation, dispersion relations.

12. **Time-dependent problems**: Schrodinger and Heisenberg equations of motion, time-dependent perturbation theory, Fermi's golden rule, metastability and decay, electric dipole transition rates.

13. **Identical Particles**: creation and annihilation operators, bosonic and fermionic commutation relations, state counting in systems of multiple fermions, bosons, coherent states.

14. **Relativistic quantum mechanics**: the Dirac equation, free solutions, negative energy states and antiparticles, non-relativistic reduction, zitterbewegung.