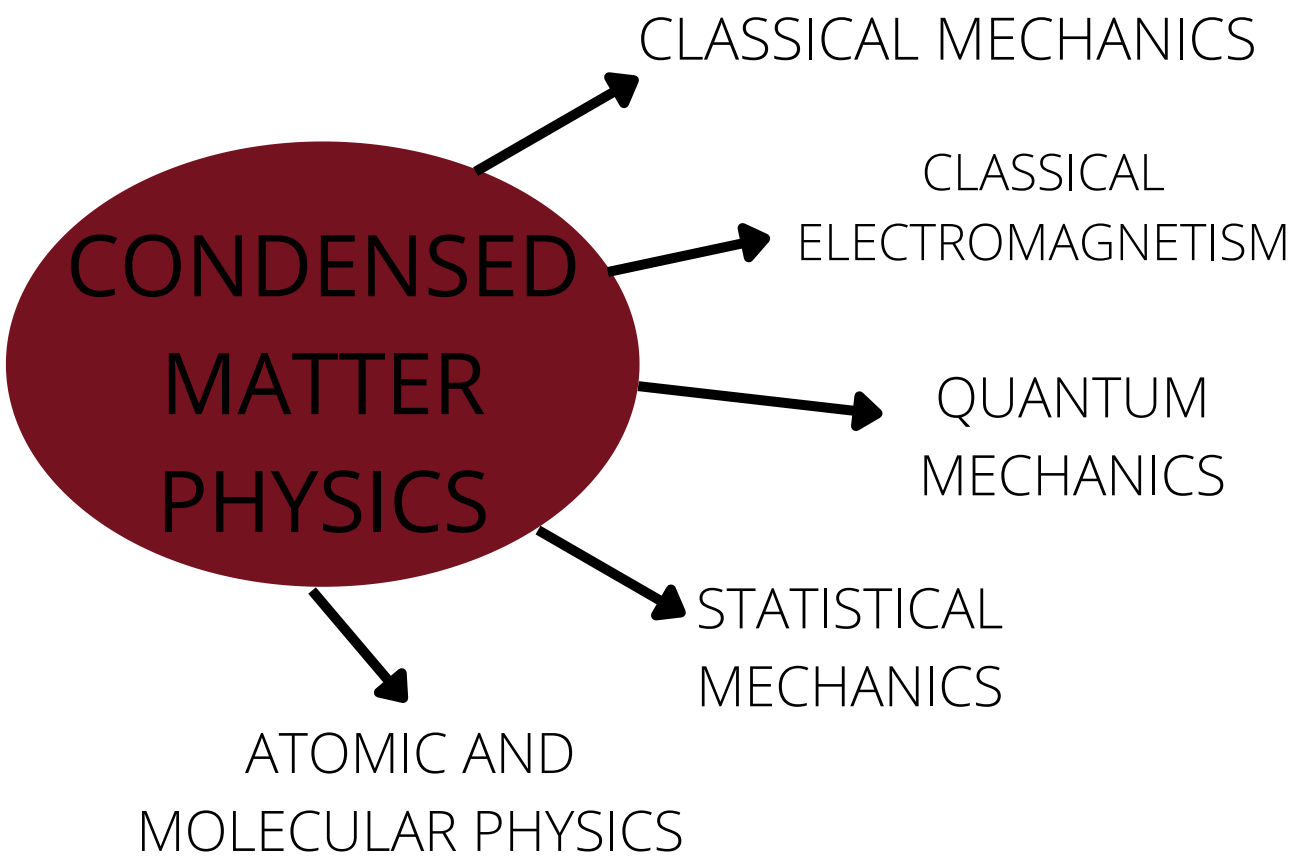
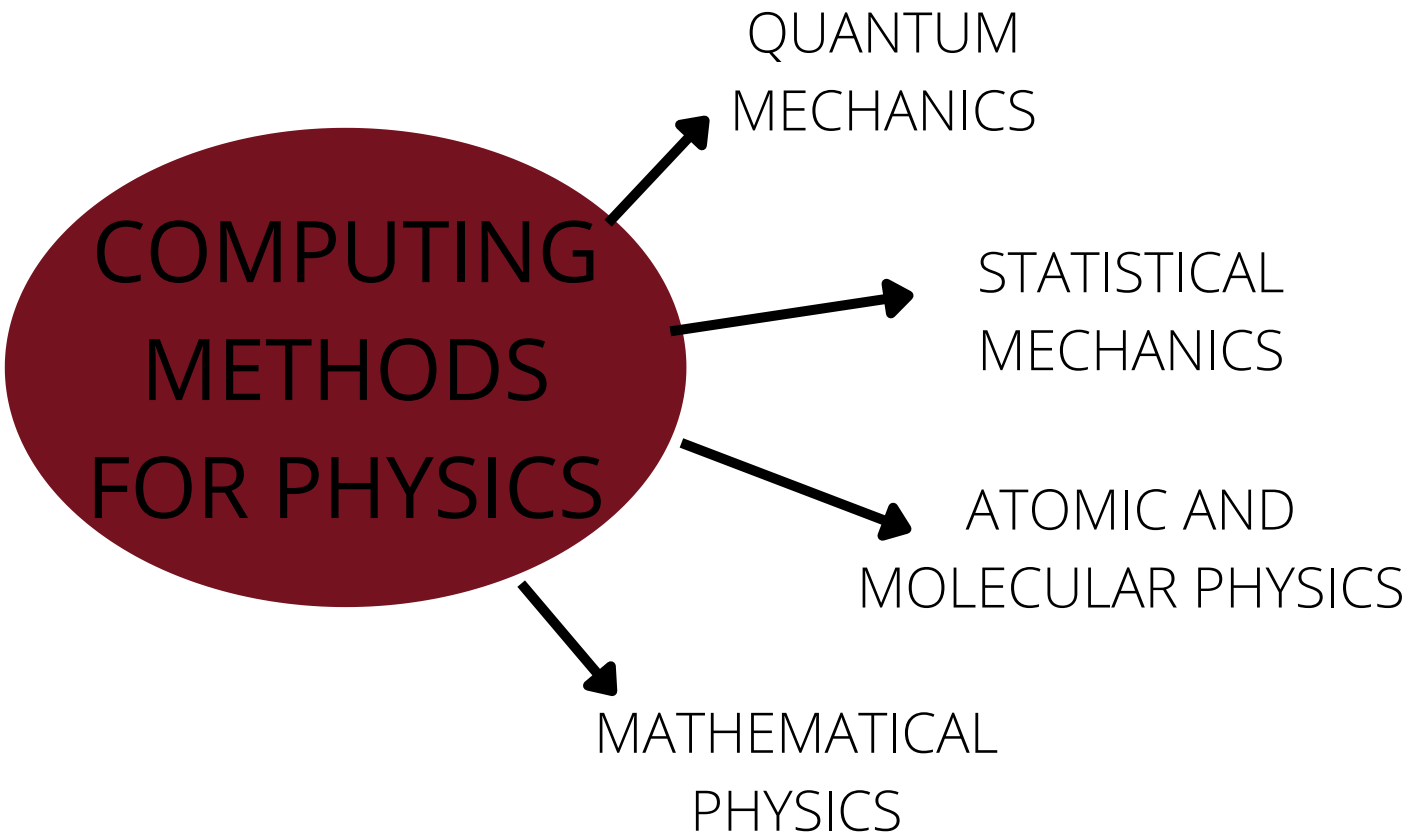
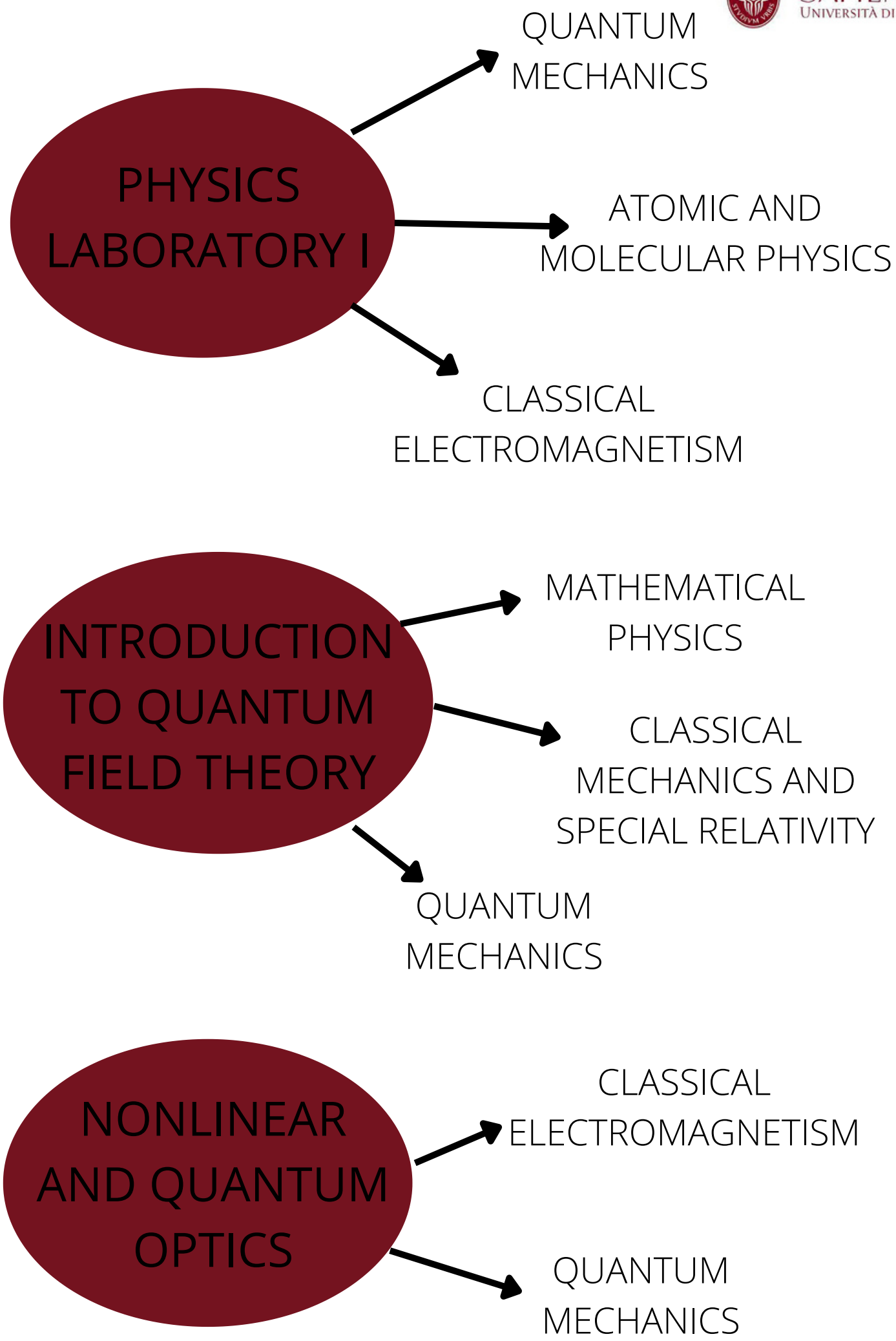
PREREQUISITES






PHYSICS LABORATORY I
QUANTUM MECHANICS
ATOMIC AND MOLECULAR PHYSICS
CLASSICAL ELECTROMAGNETISM
INTRODUCTION TO QUANTUM FIELD THEORY
MATHEMATICAL PHYSICS
CLASSICAL MECHANICS AND SPECIAL RELATIVITY
QUANTUM MECHANICS
NONLINEAR AND QUANTUM OPTICS
CLASSICAL ELECTROMAGNETISM
QUANTUM MECHANICS

CLASSICAL MECHANICS AND SPECIAL RELATIVITY

Some general concepts of analytical mechanics and special relativity as presented in undergraduate textbooks. In the following we will refer to the undergraduate textbook: H. Goldstein, C. P. Poole, and J. L. Safko, Classical Mechanics, Addison-Wesley (GPS) Topics: a) Survey of elementary principles: mechanics of a particle, mechanics of a system of particles, constraints, D'Alembert's principle and Lagrange's equations (Chapt. 1 of GPS) b) Oscillations: formulation of the problem, the eigenvalue equation and the principal axis transformation, frequencies of free vibration and normal coordinates (Chapt. 6 of GPS) c) The Hamilton equations of motion and the Legendre transformations (Chapt. 8 of GPS) d) Canonical transformations, Poisson brackets and Liouville's theorem (Chapt. 9 of GPS) e) Special relativity (Sections 7.1 – 7.7 of Chapt. 7 of GPS).

CLASSICAL ELECTROMAGNETISM

Some general concepts of electromagnetism as presented in undergraduate textbooks. In the following we will refer to the undergraduate textbook: D. Halliday, R. Resnick, and K. S. Crane, Physics - part II, John Wiley & Sons (HRC) Topics: a) Electric charge and Coulomb's law: electric charge, conductors and insulators, Coulomb's law, continuous charge distributions, conservation of charge (Chapt. 25 of HRC) b) The electric field of point charges and charge distributions (Chapt. 26 of HRC) c) The flux of the electric field and Gauss' law (Chapt. 27 of HRC) d) Electric potential energy and potential: definitions, determination of the potential from the field and viceversa, potential of point charges and charge distributions, equipotential surfaces, the potential of a charged conductor (Chapt. 28 of HRC) e) The electric properties of materials: conductors and insulators in an electric field, Ohm's law and ohmic materials (Chapt. 29 of HRC) f) Capacitance and capacitors (Chapt. 30 of HRC) g) DC circuits: electric current and electromotive force (Chapt. 31 of HRC) h) The magnetic field: the magnetic force on a moving charge, circulating charges, the Hall effect (Chapt. 32 of HRC)

STATISTICAL MECHANICS

Some general concepts of classical and quantum statistical mechanics as presented in undergraduate textbooks. In the following we will refer to the undergraduate textbook: K. Huang, Statistical Mechanics, John Wiley & Sons (Hua) Topics: a) Classical statistical mechanics: the postulate of classical statistical mechanics, microcanonical ensemble, derivation of thermodynamics, equipartition theorem, classical ideal gas (Chapt. 6 of Hua) b) Canonical and grand canonical ensemble. Energy fluctuations in the canonical ensemble and density fluctuations in the grand canonical ensemble, the chemical potential; equivalence of the canonical and the grand canonical ensemble (Chapt. 7 of Hua) c) Quantum statistical mechanics. The postulate of quantum statistical mechanics, ensembles in quantum statistical mechanics. Ideal gas: microcanonical and grand-canonical ensemble (Chapt. 8 of Hua) d) Fermi systems: the equation of state of an ideal Fermi gas (Chapt. 11 of Hua) e) Bose systems: photons and Planck distribution, Bose-Einstein condensation (Chapt. 12 of Hua)

ATOMIC AND MOLECULAR PHYSICS

Some general concepts of atomic and molecular physics as presented in undergraduate textbooks. In the following we will refer to the undergraduate textbook: B. H Bransden & C. J. Joachain, Physics of atoms and molecules, Longman Scientific & Technical (BJ) Topics: a) One-electron atoms: the Schroedinger equation for one-electron atoms, energy levels. the eigenfunctions of the bound states (Chapt. 5 of BJ) b) Two-electron atoms: the Schroedinger equation for two-electron atoms, spin-wave functions and the role of the Pauli exclusion principle; level scheme of two-electron atoms (Chapt. 6 of BJ) c) Many-electron atoms: the central field approximation, the periodic system of the elements (Chapt. 7 of BJ) d) Molecular structure: the general nature of the molecular structure, the Born-Oppenheimer separation for diatomic molecules, electronic structure of diatomic molecules, the structure of polyatomic molecules (Chapt. 9 of BJ)

QUANTUM MECHANICS

Some general concepts of quantum mechanics as presented in undergraduate textbooks. In the following we will refer to the undergraduate textbook: J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley (Sak) Topics: a) Fundamental concepts: kets, bras, operators, Hilbert space, basis, matrix representation, measurements, observables, and uncertainty relations, position, momentum, and translation, wave functions in position and momentum space (Chapt. 1 of Sak) b) Quantum dynamics: time evolution, Schroedinger equation, Schroedinger and Heisenberg representation, harmonic oscillator, finite-depth and infinite-depth square well (Chapt. 2 of Sak) c) Theory of angular momentum: rotations and angular momentum commutation relations, spin 1/2 systems and finite rotations, eigenvalues and eigenstates of angular momentum, orbital angular momentum, addition of angular momenta and Clebsch-Gordan coefficients (Chapt. 3 of Sak) d) Symmetry in quantum mechanics: symmetries, conservation laws, degeneracies. Discrete symmetries, parity (space inversion). Lattice translations as a discrete symmetry. The timereversal discrete symmetry (Chap. 4 of Sak) e) Approximation methods. Time-independent perturbation theory (degenerate and nondegenerate case). Time-dependent perturbation theory (Chap. 5 of Sak).

MATHEMATICAL PHYSICS

The student is supposed to have a sound mathematical background in calculus and linear algebra. Moreover he should have a very good knowledge of some advanced topics, which can be found, e.g. in: Mathematical Methods for Physicists by G. B. Arfken and H. J. Weber, 6 th ed., Elsevier, Academic Press.
1. Vector Analysis (Ch. 1); 2. Vector Analysis in different coordinates (Ch. 2, Sec. 2.1, 2.2, 2.3, 2.4, 2.5); 3. Determinants and matrices (Ch .3); 4. Symmetries, Angular momentum algebra (Ch. 4, Sec. 4.1, 4.2, 4.3, 4.4); 5. Complex analysis (Ch. 6 and Ch. 7); 6. Fourier series (Ch. 14, Sec. 14.1, 14.2, 14.3, 14.4); 7. Fourier transform (Ch .15, Sec. 15.1, 15.2, 15.3, 15.4, 15.5, 15.6).

COMPUTING METHODS

The student should have some knowledge of the C programming language and of the Unix environment. In particular he should be acquainted with concepts like: Flow diagrams, conditions and If statements, for and while loops, arrays, pointers, functions, file input/output. Moreover, he should be able to use simple numerical methods for integration, like the Euler and the Monte Carlo method, and for the solution of simple differential equations. As an introduction to C and a review of the basic concepts, one can use any book on C Programming or one of the many free web resources available online, e.g.: https://www.learn-c.org https://www.coursera.org/specializations/c-programming Numerical methods are presented in, e.g., Numerical Recipes in C: The Art of Scientific Computing, Book by B. P. Flannery, S. Teukolsky, W. H. Press, and W. T. Vetterling. The relevant topics can be found in (chapters of Numerical Recipes): Chap. 1, Preliminaries; Chap. 4, Integration (Sec. 4.0, 4.1, 4.2, 4.3); Chap. 7, Random Numbers (Sec. 7.0, 7.1); Chap. 12, Fast Fourier Transform (Sec. 12.0, 12.1, 12.2, 12.3, 12.4);
Chap. 14, Statistical Description of Data (Sec. 14.0, 14.1, 14.2, 14.3); Chap. 15, Modeling of Data (Sec. 15.0, 15.1, 15.2, 15.3, 15.4); Chap. 17, Integration of Ordinary Differential Equations (Sec. 17.0, 17.1).

DATA ANALYSIS

Some general concepts in data analysis. The relevant material can be found in: Data Reduction and Error Analysis for the Physical Sciences by P.R. Bevington and D.K. Robinson, Third Edition, Mc Graw-Hill.
1. Uncertainties (Ch. 1); 2. Probability distributions (Ch. 2); 3. Estimates of Mean and Errors (Ch. 3); 4. Monte Carlo Techniques (Ch. 4); 5. Least Squares Fit to a Straight Line (Ch. 5); 6. Least Squares Fit to a Polynomial (Ch. 6).

SYLLABUS

Mastery of the following topics is recommended:

1. CLASSICAL MECHANICS
reference text:
H. Goldstein, C. P. Poole, and J. L. Safko
Classical Mechanics, Addison-Wesley

chapter 1 Survey of elementary principles
- mechanics of a particle
- mechanics of a system of particles
- contraints
- D'Alambert's principle and Lagrange's equations

chapter 6 Oscillations
- formulation of the problem
- the eigenvalue equation and the principal axis transformation
- frequencies of free vibration and normal coordinates

chapter 8 The Hamilton equations of motion
- Legendre transformations and the Hamilton equations of motion

chapter 9 Canonical transformations
- the equations of canonical transformations
- Poisson brackets
- Liouville's theorem

2. CLASSICAL ELECTROMAGNETISM

reference text:
D. Halliday, R. Resnick, and K. S. Crane
Physics - part II, John Wiley & sons

chapter 25 Electric charge and Coulomb's law
- electric charge
- conductors and insulators
- Coulomb's law
- continuous charge distributions
- conservation of charge

chapter 26 The electric field
- the electric field
- the electric field of point charges
- the electric field of continuous charge distributions

chapter 27 Gauss' law
- the flux of the electric field
- Gauss' law

chapter 28 Electric potential energy and potential
- electric potential energy
- electric potential
- calculating the potential from the field
- potential due to point charges
- potential due to continuous charge distributions
- calculating the field from the potential
- equipotential surfaces
- the potential of a charged conductor

chapter 29 The electric properties of materials
- types of materials
- a conductor in an electric field
- ohmic materials
- Ohm's law
- an insultatori in an electric field

chapter 30 Capacitance
- capacitors
- capacitance

chapter 31 DC circuits
- electric current
- electromotive force

chapter 32 The magnetic field
- the magnetic force on a moving charge
- circulating charges
- the Hall effect

3. QUANTUM MECHANICS
reference text:
J. J. Sakurai
Modern Quantum Mechanics, Addison-Wesley
chapter 1 Fundamental concepts
- kets, bras, operators
- base kets and matrix representation
- measurements, observables, and uncertainty relations
- position, momentum, and translation
- wave functions in position and momentum space

chapter 2 Quantum dynamics
- time evolution and the Shroedinger equation
- the Shroedinger versus the Heisenberg picture
- simple harmonic oscillator
- Schroedinger's wave equation

chapter 3 Theory of angular momentum
- rotations and angular momentum commutation relations
- spin 1/2 systems and finite rotations
- eigenvalues and eigenstates of angular momentum
- orbital angular momentum
- addition of angular momenta

chapter 4 Symmetry in quantum mechanics
- symmetries, conservation laws, and degeneracies
- discrete symmetries, parity, or space inversion
- lattice translation as a discrete symmetry
- the time-reversal discrete symmetry

chapter 5 Approximation methods
- time independent perturbation theory: non degenerate case
- time independent perturbation theory: the degenerate case

4. STATISTICAL MECHANICS
reference text:
K. Huang
Statistical Mechanics, John Wiley & sons

chapter 6 Classical statistical mechanics
- the postulate of classical statistical mechanics
- microcanonical ensemble
- derivation of thermodynamics
- equipartition theorem
- classical ideal gas

chapter 7 Canonical ensemble and grand canonical ensemble
- canonical ensemble
- energy fluctuations in the canonical ensemble
- grand canonical ensemble
- density fluctuations in the grand canonical ensemble
- the chemical potential
- equivalence of the canonical ensemble and grand canonical ensemble

chapter 8 Quantum statistical mechanics
- the postulate of quantum statistical mechanics
- ensembles in quantum statistical mechanics
- the ideal gases: micro canonical ensemble
- the ideal gases: grand canonical ensemble

chapter 11 Fermi systems
- the equation of state of an ideal Fermi gas

chapter 12 Bose systems
- photons
- Bose-Einstein condensation

5. ATOMIC AND MOLECULAR PHYSICS
reference text:
B. H Bransden & C. J. Joachain
Physics of atoms and molecules, Longman Scientific & Technical

chapter 3 One-electron atoms
- the Scheoedinger equation for one-electron atoms
- energy levels
- the eigenfunctions of the bound states

chapter 6 Two-electron atoms
- the Scheoedinger equation for two-electron atoms
- spin wave functions and the role of the Pauli exclusion principle
- level scheme of two-electron atoms

chapter 7 Many-electron atoms
- the central field approximation
- the periodic system of the elements

chapter 9 Molecular structure
- general nature of molecular structure
- the Born-Oppenheimer separation for diatomic molecules
- electronic structure of diatomic molecules
- the structure of polyatomic molecules