Prerequisites for the Master program in Physics in Rome Sapienza

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)

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 time-reversal 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).

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)

NUCLEAR AND SUBNUCLEAR PHYSICS

Some general concepts of nuclear and subnuclear physics as presented in undergraduate textbooks. These topics are of particular interest for students enrolling in the Particle and Astroparticle Physics track.

Topics:

- Atomic physics: Discovery of nucleus and nucleons.
- Nuclear physics: nucleus properties and nuclear models
- Radioactivity: Alfa, beta and gamma decays
- Relativistic kinematics. Scattering. Cross section and decay branching fraction
- Interaction of particles with matter
- Particle detectors and accelerators
- Invariance principles and conservation laws: parity, charge conjugation, time reversal
- Spin and helicity
- Isospin
- Quark model and hadronic resonances
- Leptons, hadrons and elementary families of matter
- Fundamental interactions of particles: weak, electromagnetic and strong interactions.

Much of the material can be found in in Chapters 1, 2, 3, 4, 5 of
David Griffiths, Introduction to Elementary Particles
(https://www.wiley.com/en-us/Introduction+to+Elementary+Particles+%2C+2nd%2C+Revised+Edition-p-9783527406012)
and in Chapters 1 and 2 of
William R. Leo, Techniques for Nuclear and Particle Physics Experiments
(https://www.springer.com/us/book/9783540572800)

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).

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, 6th 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).