

# Fisica (2023)

## 80327 - Nuclear and Subnuclear Physics

[PDF](#), [ADOC](#).

### Learning outcomes

The student acquires and consolidates the basic concepts on nuclear physics and particle physics with applications and exercises.

Course contents

Nuclear physics

Units of measurement in nuclear and subnuclear physics. The study of microscopic systems, the cross section. The properties of microscopic particles. Kirchhoff's theory of diffraction. The calculation of the cross sections, differential diffusion section, absorption section, optical theorem, diffraction of an absorbing circular disk.

The nucleus and its constituents. The nuclear radius, differential cross section of neutrons on nuclei.

Nuclear binding energy, the concept of binding energy, experimental data. The drop model of the nucleus, terms of volume, surface, Coulomb, asymmetry and pairing, Weizsacker formula.

Review of quantum mechanics, wave function, energy and momentum, orbital and spin angular momentum, sum of angular moments. Identical particles, symmetry and antisymmetry of the wave function, spin-statistics theorem.

The nucleus as a gas of fermions, counting the quantum mechanical states of a microscopic particle in a volume, the expression of the nuclear binding energy.

The shell model of the nucleus, the nuclear potential, separation energies, the Saxon-Wood potential, spin-orbit interaction in electromagnetism, spin-orbit interaction in the strong interaction between nucleons, comparison with experimental data.

Elementary particle physics

A look at the standard model, the concept of particle, antiparticle and flavor quantum numbers, lepton quarks and hadrons, weak and strong electromagnetic interactions, the parameters of the standard model.

General aspects of the Standard Model. The estimate of the relative intensity of interactions, the emergence of the concept of quantized field: the Klein-Gordon equation. The description of natural interactions. Real and virtual quanta, QED processes, experimental tests, a hint to gauge theories.

Strong interactions. The negative omega baryon, color and gluon charges, flavor structure of strong

interactions, isospin, asymptotic freedom and confinement. Flavor quantum numbers. The quark model of hadrons, structure of hadrons, spin masses and electric charges, mesons, baryons and antibaryons. The quark model of mesons, mesons with light quarks, excited meson states, decay schemes and the OZI rule. The quark model of baryons.

The weak interaction. The beta decay, the neutrino, the analogy with electrodynamics, the antineutrino and the W field, diffusion and capture processes, universality of the weak interaction. Symmetry concept in physics. The violation of parity in weak interactions. Elements of the electroweak theory, meaning of parity violation, isospin and weak hypercharge, a mention of the Higgs mechanism. A hint of the mixing of flavor.

## 43006 - Physics of Matter

[PDF](#), [ADOC](#).

### Learning outcomes

At the end of the class the student will have acquired: a) fundamental principles of statistical physics,

Course contents

Module I semester:

Probability Theory: Real random variables. Single-variable probability function. Probability distributions. Dirac's Delta function. Changes of variables. The Gaussian. Characteristic functions. Many-variables distributions. Correlations. Sum of independent variables and Central Limit Theorem.

Statistical Thermodynamics: from Dynamics to Thermodynamics: Empirical thermodynamics: the 3 Principles. Heat and Temperature. From Dynamics to Thermodynamics: heat exchanges as generalized scattering events. Thermodynamic functions as time averages. Liouville theorems for Hamiltonian classical systems. Micro-canonic, Canonic. Grand-canonic systems. Ergodic systems. Partition of a micro-canonic system into canonic sub-systems. Thermodynamic limit. (In)Distinguishability. Boltzmann's method. Derivation of Temperature and Entropy. Boltzmann Principle as a theorem.

Non degenerate systems: Distinguishable harmonic oscillators. Non-degeneracy limit. Continuum limit. The Perfect Gas. Equipartition Theorem. Maxwell-Boltzmann Distribution. Perfect Gases in the gravitational field: Barometric Formula. Deriving Archimede's Principle. Atomic and molecular gases. Thermal equilibrium of chemical reactions: the Mass Action Law and Saha Formula.

Degenerate Gases: Bosons and Fermions. Chemical potential. Continuum limit for Bosons: Bose-Einstein Condensation. Condensation temperature. Massless bosons and gases of quantum oscillators. Black Body and Planck Formula. Degenerate Fermions and Fermi level. Insulators and conductors from a band spectrum picture. Sommerfeld expansions for conductors. Effective Fermions.

Module II semester:

Atomic Models: Atomic spectroscopy, Thomson's model, Rutherford's model, Bohr's model, Franck-Hertz experiment, Sommerfeld model

One-electron atom (H): The Schroedinger equation and its solution for the Hydrogen atom: energy levels and eigenfunctions of the bound states; radial distribution density. Orbital angular momentum and magnetic dipole moment; Stern-Gerlach experiment; Spin, Spin-orbit interaction. Dirac equation, perturbative solutions; Fine structure; Lamb shift and hyperfine structure. Selection rules and transition rates; Spectral line width and shapes.

Two-electron atom (He): The Schroedinger equation for two-electron atoms: ortho and para states. Spin wave functions and the Pauli exclusion principle. Energy level scheme for two-electron atoms. Ground state and excited states; Coulomb integral and exchange integral.

Many-electron atoms: The central field approximation; Hartree-Fock model and Slater determinants. The periodic table of the elements. X-ray spectra, Moseley's law. Corrections to the central field approximation: L-S coupling and j-j coupling. Zeeman effect.

Molecules: Molecular structures. Ionic and covalent bond. The H<sub>2</sub><sup>+</sup> ion; Bonding and antibonding orbitals; Born-Oppenheimer approximation, LCAO method. Molecular roto-vibrational spectra (harmonic and anharmonic approximation)

Crystalline solids: Introduction to the band theory in solids; Crystalline and periodic structures; Bloch theorem, electrons in a solid; electron wave function in a lattice; Insulating, semiconducting and conducting materials.

Readings/Biblio

## 10801 - Laboratory of Electronics

[PDF](#), [ADOC](#).

### Learning outcomes

At the end of the course, the student has a basic knowledge of : the physics of the main electronic devices based on semiconductors and their applications, the implementation of circuits with discrete and integrated components in the framework of analogue and digital electronics, the related methods of measurement and analysis of experimental data. In particular the student will be able to: implement electronic circuits and measure their functional characteristics, estimate the errors, including the systematic ones, on the laboratory measurements, analyze with a computer the experimental data taken in the Physics laboratory by writing C++ programs and by using statistical and graphical tools and compare the results with theory.

Course contents

Basic principles of semiconductor device physics. The junction diode : characteristics and applications. The bipolar transistor (BJT): characteristics in the three configurations (CB, CE, CC) and applications. The field-effect transistors (JFET, MOSFET, MESFET) : characteristics and applications. The basics of Boolean algebra. Logical functions and digital circuits. Fundamental logic families (TTL, ECL, MOS, CMOS). Basic combinational digital circuits : adders, subtractors,

ALU, multipliers, comparators, parity generators and checkers, decoders, demultiplexers, multiplexers, encoders, ROM-PROM, EPROM-EEPROM, PAL, PLA. Basic sequential digital circuits : flip-flops (S-R, J-K, D, T), shift registers, counters. Classification of the integrated circuits : from the standard products to the custom logic. Classification of the PLDs : from the SPLD to the CPLD (FPGA).

The arguments of the practical experiences are:

- 1) First experience: measurement of the I-V characteristics for two semiconductor diodes (Si, Ge) with the best fit method to calculate the inverse saturation current and the ideality factor.
- 2) Second experience: measurement of the output characteristics of a BJT in the common emitter configuration for two values of the base current; use of the best fit method in the active region to calculate the current gain and the output conductance.
- 3) Third experience: analogic and digital applications of the semiconductor diodes; implementation of a two-level clipping circuit with two diodes (Si, Ge).
- 4) Fourth experience: I part - implementation of a Full Adder circuit with integrated circuits TTL-SSI standard and in the open collector configuration with an external pull-up circuit. II part: implementation of a logic OR gate and AND gate with two Si diodes.
- 5) Fifth experience: implementation of a Multiplexer for logic functions using integrated circuits TTL-SSI standard.
- 6) Sixth experience: I part: implementation of a circuit to decode and display a 4-bit code using TTL-IC (Decoder/Driver, 7-Segment LED display, 4-bit Ripple Counter); II part: implementation of a frequency divider with 4 D-Type Flip-Flop connected to be used as T-type Flip-Flop.

## 00691 - Quantum Mechanics

[PDF](#), [ADOC](#).

### Learning outcomes

At the end of the course, the student has the basic knowledge of the foundations, the theory and the main applications of quantum

mechanics. In particular he/she is able to solve problems through the Schroedinger equation and its resolution methods, knows the

algebraic formalism and its main applications, the theory and the

applications of angular momentum and spin, can discuss simple

problems of perturbation theory.

Course contents

Module 1 Theory (Prof. Roberto Zucchini)

## 1) From classical physics to quantum physics

Undulatory theory of light, interference and diffraction

Photoelectric effect and Compton effect

Corpuscular theory of light

Material waves and de Broglie theory

Wave particle duality

Experience of Davisson and Germer

Atomic spectra

Experience of Franck and Hertz

Bohr-Sommerfeld atomic model

Correspondence principle

Experience of Stern and Gerlach

Angular momentum and spin in quantum physics

Spatial quantisation

## 2) The Schroedinger equation

The wave equation and geometric optics

Hamilton-Jacobi equation and its relation to geometric optics

Quasiclassical limit

Derivation of the Schroedinger equation

Wave function and its probabilistic interpretation

Energy eigenfunctions and levels

Time evolution of the wave function

Schroedinger equation for a particle with spin

## 3) Solution of the Schroedinger equation

Schroedinger equation in one dimension

Energy eigenfunctions and levels

Potential boxes and wells

The one-dimensional harmonic oscillator

Schroedinger equation in three dimensions

Schroedinger equation for a central potential

Orbital angular momentum, parity and spherical harmonics

Radial eigenfunctions

Spherical potential boxes and wells

The hydrogen atom

Other examples and applications

4) Collision theory

Collision in quantum physics

Scattering in one dimension

Reflection and transmission coefficients

Potential barriers

Scattering in three dimensions

Differential and total scattering cross section

Scattering in a central potential

Born approximation

Partial waves expansion

Coulomb scattering

Examples and applications

5) Foundations of quantum physics

Basic quantum experiences

States, observables and measurement

Definition and eigenstates

Measurement and state reduction

Probabilistic nature of quantum physics

Spectrum of an observable

Superposition and completeness

Expectation values and uncertainty of an observable

Compatible observables and simultaneous eigenstates

Indetermination principle

6) Formalism of quantum mechanics

Bras, kets and orthonormal bases

Selfadjoint operators and eigenkets and eigenvalues of selfadjoint operators

States and kets

Observables and selfadjoint operators

Schroedinger, momentum and Heisenberg representations

Quantisation and canonical commutation relations

Ehrenfest theorem and quasiclassical limit

7) Elementary applications

Equazione di Schroedinger for a particle in an electromagnetic field

Two-state systems

The harmonic oscillator in the operator formalism

Other examples and applications

8) Angular momentum theory

Angular momentum commutation relations

Angular momentum spectral theory

Sum of angular momenta and Clebsh-Gordan coefficients

Wigner-Eckart theory

The hydrogen atom in the operator formalism

Pauli Theory of the spinning electron

9) Identical particles

Identity and quantum indistinguishability

Spin and statistics, bosons and fermions

Pauli exclusion principle

10) Time independent perturbation theory

Perturbations and lift of degeneracy

Non degenerate and degenerate perturbation theory

Perturbative expansion

Examples and applications

11) Time dependent perturbation theory

Schroedinger equation and evolution operator

Time dependent perturbations

Schroedinger, Heisenberg and Dirac representation

Pulse perturbations

Periodic perturbations

Fermi golden rule

Adiabatic approximation

Examples and applications

No supplementary contents are envisaged for non-attending students.

Module 2 Problem solving (Prof. Ilaria Brivio)

Problem solving in the following topics of the course

One-dimensional potentials

Harmonic oscillator

Central potentials

Hydrogenlike atoms

Angular momentum and spin

Time independent perturbation theory

Time dependent perturbation theory

Readings

# 00056 - Astrophysics

[PDF](#), [ADOC](#).

## Learning outcomes

The aim is to obtain a general understanding of the most important stellar and extra-galactic topics in modern astrophysics. The student will be able to understand and discuss general observational properties of stars, galaxies and clusters of galaxies. An introduction on the modern cosmology will be also given.

### Course contents

Astronomical quantities (measures of distance and magnitude); introduction to the main emission mechanisms (black body, synchrotron, Bremsstrahlung); physical and observational properties of stars and galaxies; introduction to the unified model of active galactic nuclei; clusters of galaxies; the interstellar and intergalactic medium; rotation curves of spiral galaxies and dark matter; the Hubble constant; introduction to cosmology

# B2292 - FISICA DELL'ENERGIA

[PDF](#), [ADOC](#).

## Learning outcomes

Al termine del corso gli studenti acquisiranno le conoscenze di base per avvicinarsi alle complesse questioni energetiche in modo scientifico e rigoroso, ma senza dover seguire corsi avanzati di fisica classica o di meccanica quantistica.

Infatti il profilo flessibile e interdisciplinare del corso consente agli studenti di sviluppare un approccio versatile alla comprensione delle più dibattute questioni nel campo dell'energia.

Lo studente acquisirà le necessarie abilità per capire non solo le basi scientifiche della produzione energetica nelle sue più svariate forme ma di valutarne l'impatto e l'importanza in altri ambiti: sociali, culturali, o più generalmente transdisciplinari alla Fisica.

### Course contents

The three modules will cover the following topics:

Part I: Basic principles of energy (units and scales, different sources of energy: mechanical, heat, electromagnetic, quantum, ...)

Part II: Energy production from fossil and renewable sources

Part III: Energy production from nuclear sources (fission and fusion)

In detail:

Motivations and philosophy of the course, importance of numbers, relative quantities and units of measurement, climate and energy issues, general discourse on environmental sustainability.

Energy units, types and scales. Brief summary of thermodynamics, concepts of entropy and temperature, reversible processes and equilibrium.

Mechanical energy and applications. Brief summary of the fundamental concepts of force, work and moments. Friction and resistive force.

Thermal energy and heat: general principles and transfer. Pressure and work. First and second law of thermodynamics. Thermal capacity. Phase Transitions. Heat conduction (Fourier's law), convection and radiation. Heat equation.

General principles of energy conversion: conversion, Carnot cycle, Stirling cycle, Chillers and heat pumps. Thermal engines, Combustion engines

Energy of electromagnetic origin: storage, conversion, transmission and radiation. Electric engines.

Energy from chemical systems and processes

Energy generation from steam/gas cycles, phase diagram

Fossil fuels. Overview of fossil energy sources.

Solar power. Solar radiation, absorption and thermal utilization. Physics of photovoltaic systems.

Production of energy from biological sources.

Wind. Fluid dynamics and wind power, available technologies. In-depth study of fluids, viscosity, flow dynamics, physics and development of turbines.

Geothermal energy.

Energy sources of a nuclear nature: fission and fusion. Relevant notions to understand the basics of nuclear fission and fusion. Introduction to the definition of cross section. Nuclear forces, energy scales and structure, systematics of nuclear binding energy, reactions and decays. Physics of nuclear fission. Physics of nuclear fusion, brief introduction to plasmas and the most relevant characteristics. Operation diagram of a fission reactor. Four factor formula and fuel enrichment. critical systems. PWR and BWR. Nuclear radiation, fuel cycle, waste management (National and Olkiluoto Depot). magnetic fusion vs. inertial fusion. Models and basic functioning of both concepts. Future of nuclear energy: fourth generation, SMR, ADS.

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## 58358 - Earth Physics

[PDF](#), [ADOC](#).

# Learning outcomes

At the end of the course the student has the basic knowledge of the structure and dynamics of the Earth, the gravitational field and the magnetic field of the Earth.

## Course contents

The course provides the basic knowledge on the shape and dynamics of our planet, in view of the solid Earth and in the context of modern Earth System Physics. In the five parts of the course the structure of the Earth will be described through the study of seismic waves, gravity field, heat flow, rheology and the Earth's magnetic field. Starting from multiple experimental data, the theoretical foundations were laid and the physical models useful for the quantitative analysis of the relevant geodynamic processes are introduced. Pragmatically, case studies and classic examples shall be presented, shedding light on the interconnections between Solid Earth and the various parts of the Earth System. The topics covered in the parts of the course will be seen in the great scenario of Plate Tectonics, which shall be illustrated in its essence.

Part 1: "Seismic waves, internal structure of the Earth and earthquakes" Recall, Motivations, Stress and deformation, Elastic behaviour, Elastic waves, Volume waves, Surface waves, Densities and elastic constants inside the Earth, Seismic velocities, Wave fronts and rays, Energy of seismic waves, Earthquakes.

Part 2: "The shape of the Earth and its gravity field" Background, Motivations, The gravity field, Mass distributions, Multipoles of a mass distribution, Moments of inertia, The gravitational field, The gravity field and the shape of the Earth, Anomalies of gravity, Isostasy, Flexion of the lithosphere.

Part 3: "The thermal structure and rheological behavior of the Earth" Terrestrial heat flux, Conduction and convection, Stationary one-dimensional conduction and continental geothermal, Cooling of a half-space, Subsolar temperatures, Oceanic lithosphere, Topography of ocean floors.

Part 4: "Rheology of the earth" Basics of rheology, Elastic behavior, Newtonian fluid behavior, Plastic and non-Newtonian behavior, Maxwell's visco-elastic model, Stationary and transient rheological models, The Kelvin-Voigt element, Generalized Maxwell bodies.

Part 5: "The Earth's magnetic field" Introductory notes, observations, historical digression and motivations, Elements of the Earth's magnetic field, Magnetostatics and dipolar magnetic field, The magnetosphere, Temporal variations of the Earth's magnetic field, Origin of the Earth's magnetic field.

## 81829 - Introduction to Physics of Condensed Phase

[PDF](#), [ADOC](#).

## Learning outcomes

At the end of the course, the student will acquire some basic concepts of condensed matter physics: Symmetry and order/disorder effects in atoms aggregates; mechanical properties of solids; the concept of length scale and its influence on the properties of condensed matter. How a solid nucleates and grows. Phase diagrams.

Course contents

Requirements/Prior knowledge

Classical mechanics and thermodynamics. Calculus. Elements of quantum mechanics.

The course is focused on experiments and effects. Scientific videos are presented, together with useful images. Technological applications of the presented phenomena are considered.

Contents

Aggregates of atoms and molecules.

Phase transitions with examples such as paramagnetic-ferromagnetic transformation; order-disorder transformation; austenite-martensite transformation.

Second order phase transformations.

Mechanical properties of solids and anelasticity

Nucleation theory. Homogeneous and heterogeneous nucleation

Binary phase diagrams. The cases of steel and salt water.

Surface energy/ surface tension

## 81851 - Introduction to Complex Systems' Physics

[PDF](#), [ADOC](#).

## Learning outcomes

Basic knowledge of physical and mathematical methods to develop dynamic and statistical model for the study of complex systems.

Course contents

Introduction to the Complex Systems Physics and definition of the concept of complexity in science. The role of mathematical models in Physics: concept of predictivity. Construction of a model for a complex system and the role of nonlinear interactions. Introduction to the study of dynamical systems with applications to complex systems models. Methods for the study of stochastic

dynamical systems. Introduction to statistical mechanics: concept of emergent property, critical state and phase transition. Analysis of models both from a theoretical and numerical point of view for the description of complex systems. Applications to physics, physical chemistry, biology, economics and social systems. Analysis of data distributions, comparison of exponential laws and power laws. Examples of study of a complex system model.

## 36564 - Physics Teaching: theoretical and experimental aspects

[PDF](#), [ADOC](#).

### Learning outcomes

The course is devoted to students willing to become formal and/or informal science educators. Conceptual/cultural/professional competences will be developed to allow personal reflexions on basic knowledge in Physics and on teaching/learning processes, aiming at the design of science teaching paths for secondary school education.

#### Course contents

The course concerns introductory physics topics (Kinematics, Mechanics) and on more advanced topic (science of complex systems). About these topics knowledge and abilities introduced and developed in the course concern:

Physics Education research field: history, methods and open problems;

Research on students' difficulties in understanding physics: analysis and discussion of experimental data (from interviews, discussions and questionnaires) and of results from Physics Education research;

The role of history and epistemology of Physics in the teaching/learning processes;

The meaning and role of models and modelling processes in Physics and in teaching/learning Physics;

Interdisciplinarity between mathematics and physics;

Strategies and methods in education (interactive lessons, peer-to-peer interaction, tutorials, cooperative learning, etc.).

Texts of different nature (e.g.: sections from school texts, research articles, historical-epistemological essays) are analysed in order to become familiar with the various aspects of Physics Education: the conceptual/disciplinary, the cognitive, the epistemological, the educational practical ones.

The course includes a module on the topic "thought experiments and simulations ", aimed at:

discussing the role of thought experiments and simulations as scientific tools for research in

physics;

unpacking the role of thought experiments and simulations as educational tools;

analyzing the role of thought experiments and simulations for future-literacy.

The course can be reconsigned as part of the 24 CFU path for FIT (the Italian program of pre-service teacher education): <https://www.unibo.it/it/didattica/formazione-insegnanti/percorso-di-formazione-inserimento-e-tirocinio-fit>

In consideration of the type of activity and the teaching methods adopted, the attendance of this training activity requires the prior participation of all students in the training modules 1 and 2 on safety in the study places, in e-learning mode [<https://elearning-sicurezza.unibo.it/>].

The course participates in the University project of teaching experimentation.

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## 92298 - Applied Optics

[PDF](#), [ADOC](#).

### Learning outcomes

At the end of the course the student knows the fundamentals of geometric, refractive and diffractive optics. He/she also acquires the basis of optical system design for advanced instrumentation in the field of scientific research and industrial applications.

Course contents

Geometrical optics

Reflection, refraction and dispersion

Mirrors, lenses and prisms

Compound optical systems

Geometric aberrations

Wave optic

Fresnel equations

Polarization and polarimetry

Spectroscopy

Interferometry

Fourier optics

Applications

Non imaging optics

Telescopes

Microscopy and refractive optical systems

Adaptive Optics

System engineering approach

Basics of tolerances

No additional content is foreseen for non-attending students.

## 97946 - States, Empires, Nations

[PDF](#), [ADOC](#).

### Learning outcomes

In order to launch a reflection enabling us to present history as an instrument for problematization, some skills and knowledge are to be acquired:

1. Understanding of the nature and quality of sources
2. Capacity of analysing texts and reading sources critically
3. Contextualising the texts
4. Perception of chronology
5. Knowledge of the events necessary to contextualisation
6. Awareness of the historiographical debate within the analysis is to be placed

### Course contents

All classes will take place from 29 september 2023 to 15 December 2023 and will be held every Friday from 3 pm to 5 pm at Department of Biological Science, via Francesco Selmi 3.

“History is a shared commonwealth. The knowledge of is a principle of democracy and equality between citizens. It is a critical, inhomogeneous knowledge, which refuses conformism and thrives in dialogue. Historians have their own political opinions but have to submit them to the evidence of documents and debate, comparing them to others’ ideas and committing to their dissemination.” (Giardina, Camilleri, Segre, Appello. *La storia è un bene comune*). Above all, history is not merely just one discipline amongst many, which explains the meaning of this project, whose intention is to introduce history in those courses that do not provide it in their curricula, as a way to understand the present, the world we live in, by critically comparing it to our past. It is necessary to be aware that all subjects taught in university are rooted, without exception, in a historical flow without which they would no doubt still be able to allow students the acquisition of competence in the field,

but not to enable the latter to acquire a critical understanding of the transformation of knowledge and the societies that express it. It is not always clear to all that history has nothing to do with an antiquarian approach to the past, with the learning of by now bygone events, but it is directly linked to understanding the present, to building a mindful citizenship, to acquiring a critical knowledge, a training ground to 'practice' dealing with the complexity of social and political dynamics otherwise destined to merely shoot before our eyes like mysterious meteors. Further to this point, the strengthening of social and civic competences, which are typical of historical studies, would represent the indispensable, and furthermore winning element of transversality across all specialist fields, within a formative itinerary aiming at both a high professionalization and its cognizant practice.

Structure of the course:

Venerdì 29 settembre 2023, ore 15-17

MARIA ELENA DE LUNA

Guerra e democrazia nell'Atene di V secolo

Venerdì 6 ottobre 2023, ore 15-17

FRANCESCA CENERINI

"Il ruolo delle donne nell'impero romano". Il difficile cammino femminile verso la visibilità

Venerdì 13 ottobre 2023, ore 15-17

TIZIANA LAZZARI

I popoli barbari all'origine degli Stati nazionali? Note di metodo su un pericoloso luogo comune.

Venerdì 20 ottobre 2023, ore 15-17

BERARDO PIO

La Lex regia de imperio. Il popolo come fonte del potere legittimo nella tradizione romana, nel pensiero medievale e nella cultura politica dell'Europa moderna

Venerdì 27 ottobre 2023, ore 15-17

FRANCESCA ROVERSI MONACO

La costruzione della nazione: miti medievali delle origini. La storia come strumento di legittimazione identitaria per individuare nel passato le origini delle nazioni.

Venerdì 3 novembre 2023, ore 15-17

FERNANDA ALFIERI

Non solo social. Media, comunicazione e società di antico regime

Venerdì 10 novembre 2023, ore 15-17

VINCENZO LAVENIA

Religioni e conversioni nella storia degli imperi dell'età moderna

Venerdì 17 novembre 2023, ore 15-17

FRANCESCA SOFIA

L'Antico regime. Nascita postuma di categoria interpretativa

Venerdì 24 novembre 2023, ore 15-17

MATTEO PASETTI

Fascismo / Fascismi: una "malattia" italiana, diversi casi nazionali, o un generico fenomeno internazionale? Lo studio del fascismo, ieri e oggi, tra storia comparata e dinamiche transnazionali

Venerdì 1 dicembre 2023, ore 15-17

LUCA BALDISSARA

Per una genealogia della guerra e della violenza in età contemporanea. Dalle guerre degli stati-nazione alle "nuove" guerre nel tempo presente

Giovedì 7 dicembre 2023, ore 15-17

MARCO FINCARDI

Strategie, tattiche e memoria della guerra aerea nella seconda guerra mondiale.

Venerdì 15 dicembre 2023, ore 15-17

ELENA MUSIANI

Dall'idea di nazione alla formazione degli Stati nazionali nell'Europa del XIX secolo: idee, modelli, principali interpretazioni.

Readings/Bibliography

## **31098 - Elements of Medical and Health Physics**

[PDF](#), [ADOC](#).

## **72566 - Introduction to Quantum Optics**

[PDF](#), [ADOC](#).

## Learning outcomes

The student will learn elementary quantum optics and matter-wave interaction theory in order to understand the recent experimental advances in the field of laser-assisted manipulation of atoms, specifically laser cooling and trapping for both fundamental and applied physics.

Course contents

Matter-wave interaction: A e B di Einstein's A and B.

Two levels atom in a classical field: optical Bloch equations, Bloch's vector, rotating wave approximation, Rabi's oscillations, Ramsey's method.

Two levels atom in a quantized field (Jaynes-Cummings' model): Fock's states and coherent states, spontaneous decay, micromaser.

dressed atom: energy levels, fluorescence spectrum.

Laser cooling: Doppler cooling, Doppler limit, elements of sub-Doppler cooling.

Ion traps: RF traps (Paul), static traps (Penning).

Atom traps: magneto-optical traps, magnetic traps (Quadrupole, Joffe, Time Orbiting Potential), optical traps, optical lattices.

Some special lasers: ultrastable CW lasers, optical combs, measurement of optical frequencies.

Some notions on: evaporative cooling, reaching quantum degeneracy, optical clocks, atom interferometry, quantum computers

## 81827 - Basics of Theory of General Relativity

[PDF](#), [ADOC](#).

## Learning outcomes

The aim of the course is to provide an introduction to the principles of general relativity and some of their main observational consequences (relativistic kinematics, cosmology, black holes).

Course contents

The course is divided into three main parts:

1) After a brief recap of the principle of Special Relativity, the covariant formalism is introduced (Minkowski space-time, Lorentz tensors) in order to write the laws of electrodynamics in a simple form. This part ends with a brief analysis of the Lorentz group and its representations (including spinors).

2) Elements of differential geometry. The student is introduced with the necessary notions and tools to describe geometric spaces independently of the reference frame. Differential manifolds are

defined as well as general tensors and tensorial operations. In particular, the Lie and covariant derivatives are introduced. The role of the metric tensor is studied in details, given its key role in general relativity.

3) Introduction to General Relativity. The principles of general relativity, of equivalence and of general covariance are introduced. We show how geodesics determine the motion of test particles on a given space-time, and how Einstein equations determine the latter from the energy-momentum tensor of a source. The three classical tests are reviewed: Mercury's perihelion precession, light deflection and gravitational redshift. The general formalism is applied to the two most relevant cases:

a) the space outside a compact spherical source, described by the Schwarzschild metric. Radial geodesics are studied and the nature of the Schwarzschild horizon uncovered, thus introducing the notion of black hole.

b) the evolution of the universe is investigated from the cosmological principle of homogeneity and isotropy, leading to simple Friedman-Robertson-Walker models. The course ends with the Hubble law.

## 81828 - Basics of Physics of the Atmosphere and Meteorology

[PDF](#), [ADOC](#).

### Learning outcomes

At the end of the course the student has acquired the basic knowledge of the long term mean properties of the atmosphere and of the basic equations of fluid dynamics. The laws of thermodynamics are applied to a gaseous fluid with phase changes. The equations of atmospheric motion are introduced with applications to some aspects of synoptic meteorology of mid-latitude weather systems with the aid of meteorological chart and satellite imagery. The fundamental radiative processes are introduced to interpret observations from space and to justify the simple planetary energy budget that introduces to the greenhouse effect

Course contents

Module 1

Spatial and temporal scales. Basic concepts of atmospheric fluid dynamics (Knudsen Number, air parcel, eulerian and lagrangian views, total derivative).

Navier-Stokes equation, viscous and inertial forces. Qualitative sketch on transport phenomena. Reynolds number and regimes, linearity and non-linearity, examples. Mass conservation equation with eulerian and lagrangian approach.

Equation of motion on a rotating system: scale analysis.

Simple equilibrium configurations: inertial motion, geostrophic motion (with and without friction),

example of finite difference method.

Gradient wind, role of pressure gradient in the evolution of baric systems. Cyclostrophic wind, Rossby Number.

Isobaric and isentropic coordinates, thermal wind. Barotropicity and baroclinicity. Horizontal divergence and vertical motion

(application to global circulation).

Fronts: pressure, temperature and winds across frontal surfaces. Sketch of extra-tropical cyclone structure. Examples on meteorological charts.

Fronts and cyclones in meteorological satellite imagery: conveyor belt, dry intrusion, warm sector, gust fronts, squall lines.

Basic introduction to weather forecast: nowcasting, NWP, data assimilation, ensemble forecast. Available global products (ERA, NCEP, Globo), and regional (bolam, moloch).

## Module 2

Introduction to atmospheric physics and meteorology. Observational network (in situ and remote sensing). Temporal and spatial mean atmospheric variables. Vertical profile of chemical species and physical quantities.

Equation of state of dry air and adiabatic processes; thermodynamic properties of water. Potential temperature and equivalent potential temperature, moist adiabats, stability and CAPE. Thermodynamic diagrams.

Introduction to radiative processes: emission, diffusion, absorption.

Theory of the general circulation of the atmosphere. Simple energy balance models. The Earth climate systems: definitions and observations.

# **B1046 - GRANDI CONQUISTE E TRAGUARDI DELLA FISICA DELLE PARTICELLE**

[PDF](#), [ADOC](#).

# **99476 - INTRODUZIONE ALLA SCIENZA E TECNOLOGIA QUANTISTICA**

[PDF](#), [ADOC](#).

## **Learning outcomes**

Students will be introduced to the fundamental laws and the innovative technologies that are at the

heart of the new quantum revolution, which is expected to have also a profound impact on culture and society.

At the end of the course, students will know the basics of:

- theory and main applications of quantum information, communication and computation;
- physical realizations of quantum resources and protocols.

At the end of the course students will be able to:

- analyze simple protocols of quantum information processing;
- describe and compare available experimental platforms.

Course contents

Il corso coprirà gli aspetti fondamentali della moderna teoria dell'informazione e computazione quantistica, affrontando le tematiche sia dal punto di vista teorico (prof.ssa Ercolessi) che sperimentale (prof. Minardi), con un approfondimento degli aspetti concettuali e fondazionali (prof.ssa Levrini) e uno sguardo alle applicazioni tecnologiche.

Descrivere un oggetto quantistico

Una nuova logica per una nuova unità di informazione.

Il qubit: stati, evoluzione e misura; stati puri e misti

Sistemi composti: separabilità e entanglement

Il paradosso EPR, il teorema di Bell e gli esperimenti di Aspect

Elementi di teoria della computazione quantistica

Simulare, emulare o computare?

Gates quantistici elementari e circuiti; parallelismo quantistico e algoritmo di Grover; cenni su altri algoritmi

Copiare uno stato: distinguibilità e "fidelity"; teorema di no Cloning e l'implementazione della computazione classica; il protocollo di teletrasporto

Elementi di teoria dell'informazione e comunicazione quantistica

Evoluzione e misure di un sistema aperto.

Canali quantistici. Esempi a un qubit.

Entropia di Shannon e entropia di Von Neumann, informazione mutua

Dense coding e crittografia quantistica (cenni)

Piattaforme sperimentali

Implementazione fisica di qubit

- qubit superconduttivi
- atomi freddi
- sistemi a stato solido (spin)

Implementazione di gates e computer quantistici

Approccio analogico e simulatori quantistici

Vantaggi e problematiche nelle varie realizzazioni

Readings/B

# 94165 - Topics in Mathematical Methods and Models in Theoretical Physics

[PDF](#), [ADOC](#).

## Learning outcomes

The course introduces students to topics and tools of modern theoretical physics.

At the end of the course, students will be able to deal with appropriate mathematical methods and apply theoretical models to the description of some among the most significant problems of physics

Course contents

1. Foundation of Special Relativity
2. Lorentz group
3. Minkowski space time
4. Tensor formalism
5. Rindler coordinates
6. Mandelstam variables
7. Electromagnetism, Lorentz force
8. Maxwell equations, gauge invariance
9. Electromagnetic waves
10. Green functions, retarded potentials
11. Energy momentum tensor
12. Perfect fluids
13. Relativistic field theory