Fisica (2022)

27213 - Mathematical Analysis 2

PDF, ADOC.

Learning outcomes

Students will acquire a mathematical knwledge of informative character using an ample basic instrumentation to describe different physical phenomena. In particular, at the end of the course, students will be able to: solve problems of conditioned extremals, compute simple integrals of functions in many variables; to compute simple integrals of functions defined on surfaces.

Course contents

Differential Calculus in more than one variable Introduction to topology in metric spaces.

Functions from R^n to R^m . Limits and continuity. Bolzano and Weierstrass theorems.

Functions from R^n to R:partial derivatives, directional derivatives,properties of the gradient function, higher order derivatives, Hessian, Schwarz lemma, Taylor formula at second order, tangent plane.

Functions with vector values: the Jacobian, the Jacobian of composite functions.

Applications of differential calculus Local minima and maxima. Fermat theorem. Definition and classification of quadratic forms associated to symmetric matrices, Sylvester theorem, classification of critical points: necessary/sufficient conditions for C^2 functions.

Regular varieties in implicit form. Normal and tangent spaces. Dini theorem and the local parametrization of a variety. Conditioned extrema. Fermat theorem in such case. Lagrange multiplier theorem.

Measure and integration Peano-Jordan measure. Riemann integration for function from R^n to R. Properties of integration: additivity, linearity, monotonicity. The integral average theorem. Reduction theorems for double and triple integrals in normal domains. Cavalieri principle and Cavalieri theorem. The change of variable in the integral. Polar, spherical and cylindrical coordinates.

Curves in parametric form and curvilinear integrals Regular curves. Piecewise regular curves. Orientation. Curvilinear integrals on non oriented curves: length, curvilinear integral of a function (mass, barycenter, inertia moments). Vector fields and differential forms. Curvilinear integral of a differential form and work. Exact differential forms and conservative vector fields. Closed differential forms and irrotational vector fields. Potential of a conservative vector field. Poincarè lemma.

Parametric surfaces and integrals on surfaces. Regular surfaces. Tangent plane and normal vector. Orientation. Area of a surface and integration of scalas functions on non-oriented surfaces (mass, barycenter, inertia momenta). Regular surfaces with boundary. Canonical orientation of the boundary. Piecewise regular surfaces. Stokes theorem. Gauss theorem.

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05844 - Electromagnetism

PDF, ADOC.

Learning outcomes

At the end of the course, the student will have basic knowledge of electromagnetism both in vacuum and in material media, has learned some concepts of vector field analysis and will be able to apply general concepts and fundamental laws of electromagnetism to solving problems.

Course contents

Microscopic origin of the electrostatic phenomena.

Stable elementary constituents of matter, mass and electric charge. Quantization of electric charge.

General information on the electrostatic field in vacuum

Coulomb's law. Definition of the electric field vector and its aspects: the lines of force, field sources, Gauss's law in differential form. The electric field as a conservative field: the electrostatic potential, the closed path integral and the curl. Density of electrostatic energy associated with the electric field.

Dynamic effects of elementary electrostatic fields

Acceleration of a point-like charge subject to the electric field; 'energy conservation. Electric dipole and the corresponding electric field, electric dipole moment, torque acting on the dipole in an external electric field, the potential energy of the dipole in an external electric field. The dipole approximation.

Electrostatics and conductors

Conductors and insulators. Electric field inside a conductor. Electrostatic induction. Conductors in equilibrium, electric field inside an empty conductor, charge distribution on the surface of the conductor. Uniqueness of the solution of Laplace's equation. Electrostatic capacity. Calculations of capacity for different capacitors: plane, cylindrical and spherical capacitors. Capacitors connected in series and in parallel. Electrostatic screen. The method of images.

The energy of the electrostatic field

Energy of a system of point-like charges and of a continuous distribution of charges. Electrostatic energy stored in a charged capacitor. Localization of energy in the electric field.

Dielectric materials

The electric field in non-conducting materials, the dielectric constant. The polarization of a dielectric material (uniform and non-uniform). Equation of electrostatics in dielectric materials. Linear, isotropic and anisotropic dielectric materials. Discontinuity of the electric field components on the surfaces of separation between two dielectric materials. Electric field inside a cavity. Electrostatic energy in dielectric materials.

Electrical currents

Conduction and electrical current. Definition of current intensity and its measurement units. Carrier current density. Law of conservation of charge: continuity equation. The two Ohm's Law: Resistance and resistivity. The Joule effect. Resistors in series and parallel. Electromotive force from a battery. Kirchoff's laws for electrical networks. RC circuits: charging and discharging of a capacitor through a resistor.

The magnetic field in a vacuum in the stationary case

The magnetic interaction. Lines of force of the magnetic field. Gauss' law for the magnetic field. The II Law of Laplace: magnetic force on a current-carrying conductor. Magnetic force on a moving electric charge. Mechanical moments on planar circuits. Hall effect. The magnetic field on the axis of a coil, the magnetic dipole moment of a coil. Potential energy of the coil in an external magnetic field. Equivalence between a coil traversed by the current and a permanent magnet. Intrinsic and atomic magnetic dipole moments of different materials. Non-separability of the magnetic poles.

The I Law of Laplace (or law of Biot-Savart): magnetic field generated by an electrical current. Calculations of magnetic fields produced by elementary circuits. Ampere's law. Magnetic field in a solenoid. Magnetic fluxes between circuits. Properties of the magnetic field in the vacuum. Vector potential. The transformations of the electric and magnetic fields.

Magnetic fields in the matter

Magnetization of matter. Magnetic permeability and magnetic susceptibility. General equations of magnetostatic. The vector field H. Discontinuity of the fields on the surface of separation between two media magnetized. Fields within a cavity. Diamagnetism, paramagnetism, microscopic interpretation. Ferromagnetism, the magnetization curve interpretation of ferromagnetism.

Time dependent Magnetic and electric fields

Electromagnetic induction and Faraday's law. Lenz's Law and conservation of energy. Physical origin of the induced electromotive force. Applications of Faraday's Law. Inductance, Mutual and Self-induction. Oscillating circuits LC and RL. RLC circuits. Magnetic energy. Mutual induction. Displacement current and Maxwell-Ampere's law.

Maxwell's equations

Discussion of the Maxwell's equations. Electromagnetic waves and energetic aspects of the electromagnetic field. The Poynting theorem.

82201 - Physics of Solids and Fluids

PDF, ADOC.

Learning outcomes

During this course, the student will learn the main physical laws governing the mechanical and thermal behavior of continuum media. In particular, he will be able to tackle problems concerning the equilibrium and the dynamics of solid elastic media, of viscid with applications in Physics of the Earth.

Course contents

The mechanics of continuum media provides several applications to the study of natural phenomena occurring in solid and fluid materials, throughout the Universe. Our ability to describe these phenomena requires the introduction of tensors (e.g. strain and stress) and constitutive relations between them, which provide a “complete” system of equations.

The scope of the course is:

to introduce the main concepts and theorems of tensor algebra for the study of stress and strain in solid elastic materials, in viscous and inviscid fluids (with mention to plastic and viscoelastic materials);

to obtain the equations governing the equilibrium and the dynamics of solids and fluids;

to describe the mechanisms of heat transmission by conduction and convection;

to provide a wide range of applications to geophysical phenomena which take place in the in the Earth system.

MOLECULAR FUNDAMENTALS: Continuum model of the matter: Fluid materials: Temperature and thermal agitation, Pressure in a fluid at the equilibrium state: Archimede’s and communicating vessel principle. Microphysical models of viscosity, thermal conduction, osmotic diffusion, surface tension. Heat propagation equation. Solid materials: microphysical models of compressibility, specific heat and thermal expansion.

FLUIDS IN EQUILIBRIUM: Equation of state and specific heat for a generic substance; equilibrium of a compressible medium; adiabatic gradient; latent heat and phase transitions. Applications (adiabatic temperature gradient in the atmosphere, in the ocean, in the Earth mantle; gravitational stability; potential temperature and density. Role of phase transitions).

THERMAL CONDUCTION: the conduction equation (Fourier law), heat flow, Lagrangian and Eulerian description: the material time derivative; the heat transmission equation, radioactive heat production. Applications (geotherms in the continental and in the oceanic lithosphere, seafloor isostatic topography. Solidification of lakes: the Stefan problem).

MECHANICS OF CONTINUUM MEDIA: “zero dimensional” conceptual models of elastic, viscous and viscoelastic materials. Definition of “continuum” medium: the minimum elementary volume.

Definition of a tensor of rank k, the Kronecker delta and the permutation symbol, the e-delta identity: The deformation tensor: geometric interpretations of its components. Strain eigenvalues and eigenvectors; isotropic and deviatoric strain components. Body forces and surface tractions; the stress tensor, the Cauchy relation. Conservation laws for a continuum medium: conservation of mass, equations of motion and angular momentum. Symmetry of the stress tensor: principal stresses and stress axes. Normal stresses and shear stresses, isotropic and deviatoric stress components, mean pressure. The energy equation.

ELASTIC SOLIDS: Constitutive relationships for elastic materials. Isotropic materials: bulk modulus and rigidity, Lamé constants. The inverse constitutive relation, Young and Poisson moduli, their thermodynamic bounds. Elasto-dynamics: The Cauchy-Navier equation, rotational and irrotational elastic waves. Applications (simple stress configurations in the Earth's crust: lithostatic pressure, uniaxial stress and uniaxial strain profiles. Classification of tectonic regimes. Friction and shear failure).

FLUIDS: Constitutive relationship for a Newtonian fluid: dynamic viscosity. Energy and Entropy equations. The Navier-Stokes equation, the Euler equation (inviscid fluids). The Boussinesq approximation. Examples of stationary and transient laminar flows. Poiseuille flow in a cylindrical conduit: the Reynold number and transition to turbulence. The Bernoulli equation: stationary flows and irrotational transient flows.

Readings/Bibl

15745 - Wave-Motion Phenomena

PDF, ADOC.

Learning outcomes

At the end of the course, the student has acquired education to wave phenomena, their generic properties and some essential mathematical tools. He knows mechanical and electromagnetic waves and is able to solve simple problems.

Course contents

Linear oscillations:

Free oscillations. Examples of pendulum, mass and springs systems, and of RLC circuits. Damped and forced harmonic oscillator. The phenomenon of resonance. Oscillation analysis with rotary vectors (phasors); Complex field analysis. Elastic and absorbing amplitudes. Linearity of equations of motion and superposition principle.

Fourier Analysis:

Mathematical tools for analyzing oscillatory phenomena. Fourier series and trigonometric series for periodic signal. Continuous Fourier transformation for non-periodic signals. Fourier series and transform calculations for simple signals.

Mechanical waves:

Introduction to wave phenomena. Propagation of physical perturbations. Progressive and stationary waves, scalar and vector waves, longitudinal and transverse waves, plane and spherical waves. Elastic waves in ropes and solids. D'Alembert's equation. Solution of D'Alembert's equation: progressive and regressive waves. Harmonic waves. Wavelength and frequency. Dispersion relation. Study of a progressive wave. Energy and power in a wave. Wave intensity. Impedance of a medium. Energy, reflection and transmission. Wave superposition. Beats. Phase and group speeds. Stationary waves. Rope with two constrained extremes. Ventrals and knots. Normal and harmonic oscillations. Harmonic frequencies. Stationary waves as harmonic series. Musical notes.

Sound propagation in the air. Sound speed. Power, intensity and energy delivered by sound waves. Decibels and human ear. Stationary waves in a gas column. Superposition principle and beats. Harmonic waves in 3 dimensions. Plane waves. D'Alembert's equation in space. Spherical and cylindrical waves. Group and phase velocity in dispersive media. Sound Doppler Effect.

Electromagnetic waves:

From Maxwell equations to the equation of the electromagnetic waves. Transversal character of electromagnetic waves. Speed of light in the vacuum and in media. Impedance. Representation of an electromagnetic wave. Linear, elliptical and circular polarization. Energy, intensity and impulse: Poynting vector, radiation pressure. Accelerated charges. Irradiation from oscillating charges. Spectrum of electromagnetic waves and visible light. Propagation in a dielectric: dispersion and absorption. Light propagation in transparent media. Reflection and refraction. Complex refractive index. Snell's Law. Total reflection and limit angle, evanescent wave. Fresnel formulas. Brewster's angle. Fermat's Principle and Snell's Law. Dispersion in a prism. Propagation of electromagnetic waves in a metal. Wave equation in a metal and corresponding solution.

Interference and diffraction:

Principle of Huygens-Fresnel. Introduction to interference. Interference of light and electromagnetic waves: Young's experience. Distribution of light intensity on the screen. Optical path. Polarization Conditions. Interference with lenses. Interference on thin glasses and on thin wedges. Interference from N coherent light sources. Primary and Secondary amplitudes. Diffraction phenomena: Fraunhofer and Fresnel diffraction. Intensity on a screen. Diffraction from circular holes and objects. Resolution power. Diffraction pattern. Resolution and dispersion power of a grid. Spectroscopy with diffraction pattern.

Optics:

Introduction to geometric optics. Light rays and laws of Descartes. Mirrors and diopters. Cromatism. Objects and images. Paraxial approximation. Properties of concave and convex mirrors: equation of the spherical diopter. Focus and focal distance. Transverse magnification. Flat mirror. Thin lenses and their properties. Lens Equation. Converging and diverging lenses. Magnification. Aberrations. Optical instruments. The human eye.

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Prerequisites

Wave motion phenomena is a course present in the second semester of the second year in
order to be able to observe an ideal training course path that, when followed closely,
leads to a better overall preparation and a faster achievement of the degree.
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For the content of the course, it is recommended to pass Analysis 1 and Mechanics and
study the topics of Analysis 2, Thermal Phenomena and Electromagnetism before
addressing the Wave motion phenomena exam.

There are several topics in common with the course of Electromagnetism and Optics
Laboratory (same semester, same year) that are presented by the teachers with very
different goals: one on the foundations, the other on laboratory and experimental
aspects. The student will find much benefit in studying the two subjects together.

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moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434316[00686 - Analytical
Mechanics]

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=== Learning outcomes

After the course the student acquires the basic knowledge of the Lagrangian and
Hamiltonian mechanics and on the simple integrable models. In particular the student
will be able to write the Lagrangian and the Hamiltonian function for a mechanical
systems, to study the phase space and the stability of the fixed points, to integrate
the equation of a central field and a rigid body with a rotational simmetry, to use
variational principle and canonical transformations.

Course contents

Dynamical systems: definition of phase space, evolution equations, group properties of
phase flows, fisrt integrals of motion, one dimensional problems, phase portraits,
time law, linear dynamical systems. Definition of Equilibrium and study of its linear
and non-linear stability. Lagrangian mechanics: covariant form of Newton equation,
Minimum Action Principle, properties of LAgrangian equations, properties of Lagrangian
equations, constraints and their realization, constraint forces and constraint
dynamics , geometry of curves and surfaces, D'Alembert's principle, generalized
potentials, Theory of Small Oscillations. Symmetries: Noether's theorem, search for
first integrals of mortion and definition of integral system. Mechanical models:
harmonic oscillators, spherical pendulum, central field with equation of orbits and
Kepler laws, two body problem, double pendulum. Rotation group and rigid body: Euler
angles, velocity field, inertia matrix, principal inertial axis, free motion and
Poinsot cones, Lagrange top. Dynamics in a rotating frame. Hamiltonian mechanics:
variational principles and phase space geometry, canonical transformations, generating
functions, Poisson brackets and Lie series, Maupertuis' Principle, Hamilton Jacobi
equation, elements of perturbation theory and Action-Angle variables.

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moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434323[00709 -
Mathematical Methods Of Physics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].
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=== Learning outcomes

At the end of the course the student acquires the mathematical notions and methods
necessary for the understanding of the modern physics. First, the student studies the
theory of holomorphic functions and is able to calculate the contour integrals in the
complex plane. Then the student learns element of the topology, linear and normed
spaces. Then the student studies the Hilbert spaces and their operators, which permits
to use the mathematical formalism of quantum mechanics.

Course contents

1. Theory of the holomorphic functions.

2. Topological spaces.

3. Linear spaces and normed spaces.

4. Hilbert spaces.

5. Operators in the Hilbert spaces.

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moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434322[54798 - Lab-based
Course on Electromagnetism and Optics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].

=== Learning outcomes

Modules 1, 2 and 5. The students will perform experimental measurements on electrical
circuits in both sinusoidal and transitory regimes, on electromagnetic induction and
on physical optics; they will acquire basic skills in written and oral presentation of
experimental results.

Module 3. The students will have in depth knowledge on programming in C++ and on Monte
Carlo methods for the simulation of physical processes.

Module 4. The student will have an intermediate knowledge of the LabVIEW programming
language, including its use for the development of data acquisition and analysis
applications; moreover, they learn the basics of data acquisition devices including
microcontrollers of the Arduino family.

Course contents

The course is divided in five modules which cover in an integrated fashion different
aspects of data acquisition, analysis and presentation (both in written and oral
form), with reference to the topics covered in the second year of the first level
physics degree.
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Module 3 - Prof. Silvia Arcelli, 1st Semester

Recap on the main concepts of Object Oriented Programming in C++: coding conventions, classes, member functions and data members, encapsulation, aggregation and inheritance, polymorfism.

Applications of the ROOT Data Analysis framework Usage for the data simulation and analysis with examples connected to the laboratory sessions which will be held during Module I:

Further fuctionalities, with examples, of histograms (THx), graphs (TGraph), functions (TFx), ROOT persistency (TFile).Fitting data with ROOT (linear and non linear fits).

the ROOT Monte Carlo utilities for the generation of physics distributions and for the simulation of experimental effects (resolution,efficiency)

Advanced ROOT applications: The ROOT Collection Classes (TList) and ROOT n-tuple type data (TTree)

Module 4 - Prof. Luca Pasquini, 1st semester

The LabVIEW Graphical programming language. Introduction to LabVIEW: Virtual Instruments and dataflow paradigm. Front panel, block diagram, controls, indicators, constants and functions. Data types: numeric, Boolean, string. Arrays, Clusters and Type definitions. Using loops: While loops, For loops, Tunnels and Shift Registers. Decision-making structures: Case Structure, Event Structure. Polling vs Event-drive programming. SubVIs and modularity. Accessing file sin LabVIEW. Sequential and state-machine programming. Local and Global variables, race conditions. Communicating data between parallel loops: queues and notifier functions.

Data acquisition. General architecture of a data acquisition (DAQ) device. The measurement chain. Analog to Digital Converters (ADCs). Communication buses. Signal-device connection. Signal sampling: aliasing and Nyquist theorem. Buffered data acquisition. The DAQ-mx library in LabVIEW.

Introduction to the Arduino Uno microcontroller. Programming of Arduino in C++ and LabVIEW

Module 1 - Prof. Cristian Massimi, 2nd semester

In this module, the main experimental methods used in the electromagnetism, circuits and optics laboratory will be described, with reference to the laboratory sessions. The methods to be used when writing a report and when giving a talk reporting scientific results will be described, with reference to the customary standards of the international scientific community. Finally, some complements necessary to perform the laboratory sessions on electrical circuits in the transient and sinusoidal regime will be given.

Characteristics of laboratory instruments. Function generators. Digital multimeters. Oscilloscopes. Lasers. Light detectors, photodiodes. Reference: Boscherini Strumenti

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Reports. Methods and standards used when writing a laboratory report and when
presenting experimental results in a talk. Linear and non linear fits.

Oscilloscopes. Analogue and digital oscilloscopes. Static and dynamic sensitivity,
band pass. Vertical gain, horizontal deflection and saw tooth time scan. Trigger.
Digital oscilloscopes. Reference: Bava, Galzerano, Norgia, Ottoboni e Svelto

Complements on circuits in the transient and sinusoidal regime. Capacitors and
inductors. First order circuits. Second order circuits. RLC circuits in the sinusoidal
regime and phasors. Frequency response. Low pass, high pass, band pass circuits and
resonant circuits. Reference: Perfetti, chap. 6, 7, 8 and 13 (part). Copy of lecture
slides available on virtuale.unibo.it

Module 2 - Dr. Nicoletta Mauri, 2nd semester

This module consists exclusively in laboratory sessions. The students design a circuit
on ELVIS breadboard, write a data acquisition program in LabVIEW, and perform
measurements and data analysis.

Module 5 - Dr. Matteo Franchini, 2nd semester

This module consists exclusively in laboratory sessions. The students design a
physical optics experiment, write a data acquisition program, and perform measurements
and data analysis.

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moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434327[80327 - Nuclear
and Subnuclear Physics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].

=== Learning outcomes

The student acquires and consolidates the basic concepts on nuclear physics and
aprticle 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
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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 electrodimamics,
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.

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moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434326[43006 - Physics of
Matter]

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=== Learning outcomes

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

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Molecules: Molecular structures. Ionic and covalent bond. The H2+ 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

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selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434328[10801 - Laboratory
of Electronics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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 semiconductors
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
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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.

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moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434329[00691 - Quantum
Mechanics]

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=== 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
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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
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Orbital angular momentum, parity and spherical harmonics

Radial eigenfunctions

Spherical sotential 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
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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

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Readings

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-moocs/insegnamenti/insegnamento/@@multilingual-selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434330[00056 - Astrophysics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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 (parallax, parsec, 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

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-moocs/insegnamenti/insegnamento/@@multilingual-selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434335[58358 - Earth Physics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].

=== Learning outcomes

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

Course contents

Part 1: Structure and dynamics of the Earth

An outline of the formation of the Earth. Structure and composition of the Earth. Thermodynamics of the Earth. Physical properties and dynamics of the Core. Physical properties and dynamics of the Mantle. Volcanic activity. Seismic activity.

Part 2: The Earth's gravity field

The moments of a mass distribution. The Newtonian theory. The roto-gravitational potential of the Earth. Gravity anomalies. The gravity field in the Earth's interior. Orbits and orbital mechanics. The tides. The Earth's free precession. An outline of
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Einstein s theory.

Part 3: The Earth s magnetic field

Phenomenology of the geomagnetic field. The ionosphere and the magnetosphere. Physical
theories. Foundations of magnetohydrodynamics. The geodynamo. Foundations of plasma
physics. Electromagnetic waves in the ionosphere. Magnetic properties of rocks.

It is assumed that the student has a good preliminary knowledge of the basic concepts
of Newtonian mechanics, thermodynamics, electromagnetism, fluid mechanics and theory
of elasticity.

Readin

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434342[81851 -
Introduction to Complex Systems  Physics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].

=== Learning outcomes

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

Course contents

Complex system definition. Role of non-linear interactions.Simple theoretical and
numerical models for complex systems.Examples from Physics, economy and biology.Data
distribution: comparison between exponential and power laws.Agent, neural network and
cellular automata models.

Introduction to the study of dynamical systems with applications to complex systems
models. Methods for the study of stochastic dynamical systems and their applications
to a statistical mechanics approach. Concept of emergent property, critical state and
phase transition. Use of simulations for the study of mathematical physical models.

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434334[36564 - Physics
Teaching: theoretical and experimental aspects]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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.
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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 "simulations of complex systems", aimed at:

discussing the role of simulations as a scientific tool for research in physics (the third "pillar", as well as theory and experiments);

unpacking the role of simulations as educational tools;

analyzing the role of agent 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/].

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-moocs/insegnamenti/insegnamento/@@multilingual-selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/450932[92298 - Applied Optics]

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link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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

Optical design using ZEMAX OpticStudio

Work environment, optimization, tolerances, examples
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No additional content is foreseen for non-attending students.

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-moocs/insegnamenti/insegnamento/@@multilingual-selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/474883[97946 - States, Empires, Nations]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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 30 september 2022 to 19 December 2022 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 submits 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
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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:

30 settembre

MARIA ELENA DE LUNA

Sulla storia delle città greche: guerre, tradizioni culturali ed emozioni politiche

7 ottobre

FRANCESA CENERINI

Il ruolo delle donne nelle città degli uomini nella Roma antica

14 ottobre:

TIZIANA LAZZARI

Diritti e rappresentazioni inattesi: le donne nei regni del primo Medioevo

21 ottobre

BERARDO PIO

I trattati sulla guerra e le origini del diritto internazionale

28 ottobre:

FRANCESCA ROVERSI

L’uso politico del Medioevo nel discorso pubblico contemporaneo

4 novembre:

FERNANDA ALFIERI

Un mondo di parole, immagini e suoni: i media e l'età moderna

11 novembre

VINCENZO LAVENIA

Come si legittima una guerra: l'età moderna

18 novembre

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FRANCESCA SOFIA

L antico regime: nascita postuma di una categoria interpretativa

25 novembre

ALESSANDRO BELLASSAI

Shoah e politiche della memoria

2 dicembre

PAOLO CAPUZZO

La fine degli imperi asburgico, zarista e ottomano e la nascita del mondo
contemporaneo (1917-1923)

16 dicembre

GIULIA GUAZZALOCA

Crisi, legittimazione, consenso

19 dicembre

SALVATORE BOTTA

L'altra faccia del rischio: le emergenze naturali tra storia, istituzioni e politica

Readings/Bibliogra

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434332[31098 - Elements
of Medical and Health Physics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].



== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434337[72566 -
Introduction to Quantum Optics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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
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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

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434339[81827 - Basics of
Theory of General Relativity]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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
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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 re 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.

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434340[81828 - Basics of
Physic of the Atmosphere and Meteorology]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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.
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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, ensamble 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.

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-moocs/insegnamenti/insegnamento/@@multilingual-selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/488694[B1046 - GRANDI CONQUISTE E TRAGUARDI DELLA FISICA DELLE PARTICELLE]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-moocs/insegnamenti/insegnamento/@@multilingual-selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/434341[81829 - Introduction to Physics of Condensed Phase]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[ADOC].

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=== Learning outcomes

At the end of the course, the student will acquire some basic concepts of condensed
matter physics: Simmetry and order/disorder effects in atoms aggregates; mechanical
properties of solids; the concept of lenght 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 thermodinamics. 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. Homogeneus and heterogeneus nucleation

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

Surface energy/ surface tension

== https://www.unibo.it/it/studiare/insegnamenti-competenze-trasversali-
moocs/insegnamenti/insegnamento/@@multilingual-
selector/c49b978e935747049f9cebe759020dc7/en?post_path=/2022/459652[94165 - Topics in
Mathematical Methods and Models in Theoretical Physics]

link:degree-fisica-2022.pdf[PDF], xref:degree-fisica-2022.adoc[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
significative problems of physics

Course contents
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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
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