UNIVERSITY OF L'AQUILA

Department of Physical and Chemical Sciences

1st Cycle Degree in PHYSICS

Laurea in FISICA

Course Catalogue

Academic year starts the last week of September and ends the first week of June.
1st Semester - *Starting date:* last week of September, *end date*: 3rd week of January
2nd Semester - *Starting date:* last week of February, *end date:* 1st week of June
Exams Sessions: I) from last week of January to 3rd week of February, II) from 2nd week of June to end of July, III) from 1st to 3rd week of September

Comprehensive Scheme of the First Cycle Degree in PHYSICS				
YEAR	**CODE**	**COURSE**	**Credits (ECTS)**	**Semester**
I	F0001	Geometry	9	1
	F0002	Mathematical Analysis I	12	1
	F0003	An Introduction to Physics laboratory	6	1
		English	3	1
	F0004	Mechanics and Thermodynamics	12	2
	F0005	Laboratory of Mechanics and Thermodynamics	12	2
	F0006	Chemistry	6	2
II	F0007	Mathematical Analysis II	9	1
	F0008	Electromagnetism	12	1
	F0011	Laboratory of Computational Physics	9	1
	F0010	Classical Mechanics	6	2
	F0009	Laboratory of Electromagnetism and Optics	9	2
	F0012	An Introduction to Modern Physics	9	2
	DF0002	Mathematical Physics I	6	2
III	DF0003	Mathematical Physics II	6	1
	F0014	Introduction to Theoretical Physics	12	1
	F0016	Laboratory of Electronics	6	2
	DF0004	Fundamentals of Condensed Matter Physics	6	2
	DF0005	Fundamentals of Nuclear Physics	6	2
	F0017	Physics of Fluids	6	2
		Free choice Course/Courses	12	1,2
		Thesis	6	2

Programme of "GEOMETRIA" *"GEOMETRY"*		
F0001, Compulsory **First Cycle Degree in PHYSICS, 1st Year, 1st Semester**		
Number of ECTS credits: 9 (Workload is 270 hours, 1 credit=30 hours).		
Teacher: Maria Lucia FANIA		
1	Course objectives	The goal of the course is to make the student familiar with the basic theory of linear algebra and with analytic geometry in the plane and in the 3-dimensional space. The student should also become acquainted with the problem of diagonalization of a matrix and also with quadratic forms and their canonical form. A particular family of plane curves is presented: the conics and their affine and metric classification.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Matrices and systems of linear equations. - Vector spaces and change of bases. - Linear transformations and matrices associated to them. - Eigenvalues, eigenvectors and diagonalization. - Euclidean spaces. Inner product. Cross product. Orthogonal subspaces. Gram-Schmidt orthogonalization. - Eigenvalues and eigenvectors of symmetric matrices. Spectral theorem. - Unitary and Hermitian matrices. Diagonalization of an hermitian matrix. Hermitian product. - Affine and euclidean geometry. - Conics and their affine and metric classification. On successful completion of this module, the student should: - have profound knowledge of basic linear algebra theory and of analytic geometry in the plane and in the 3-dimensional space; - be able to apply the basic results of Linear Algebra and Geometry, being able to use matrix language to describe basic concepts; -be familiar with a variety of geometric ideas and be able to solve a variety of geometric problems; -understand the rudiments of the axiomatic approach to mathematics; - know and understand the basic concepts of linear algebra and how to use linear algebra in problem-solving; - be able to develop and to experiment problem-solving strategies, and to identify the most appropriate method in each situation; - be able to express the basic concepts of the subject and the problem-solving process, using the language of science, both orally and in writing; - demonstrate skills in mathematical reasoning, in operation with vectors, matrices and ability in carrying out proofs; - demonstrate capacity for reading and understand other texts on related topics.
3	Prerequisites and learning activities	No prerequisites are needed.
4	Teaching methods and language	Lectures and exercises. Language: Italian. Ref. Text books, lecture notes. Text book: E. Sernesi *"Geometria 1"* , Bollati Boringhieri
5	Assessment methods and criteria	Written and Oral exam.

Programme of "ANALISI MATEMATICA I" *"MATHEMATICAL ANALYSIS I"*
F0002, Compulsory **First Cycle Degree in PHYSICS, 1st year, 1st semester**
Number of ECTS credits: 12 (Workload : 360 hours, 1 credit = 30 hours)
Teachers: D. De Acutis, C. Pignotti

1	Course objectives	The aim of the course is to provide a knowledge of the differential and integral calculus for functions of a real variable. The basic techniques and theorems are presented in a rigorous way, by pointing out the connections between various arguments. On successful completion of this course the student must be able to solve nontrivial problems by applying the learned concepts.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: -The Real Numbers System; - Numerical sequences; - Functions of a real variable; - Limits and continuity; - Differential Calculus; - Integral Calculus; - Numerical series; - An outline of ordinary differential equations. On successful completion of this module, the student should: - have profound knowledge of basic theory of differential and integral calculus for functions of a real variable; - have knowledge and understanding of differential and integral calculus for functions of a real variable; - understand and explain the meaning of complex statements using mathematical notation and language; - understand the fundamental concepts of the basic theory for functions of a real variable and their connections and be aware of potential applications in other fields; - demonstrate skill in mathematical reasoning and ability to conceive a proof. - demonstrate capacity for reading and understand other texts on related topics.
3	Prerequisites and learning activities	No specific prerequisites are needed. The students are expected to have the basic mathematical notions as provided in the secondary schools.
4	Teaching methods and language	Lectures and exercises. Language: Italian Ref. Text books: Acerbi – Buttazzo *"Primo Corso di Analisi Matematica",* (Pitagora ed.) E. Giusti *"Analisi Matematica I",* (Boringhieri ed.)
5	Assessment methods and criteria	Written and Oral exam

Programme of "INTRODUZIONE ALLA FISICA" ***"AN INTRODUCTION TO PHYSICS LABORATORY"***		
F0003, Compulsory **1st Cycle Degree in PHYSICS, 1st year , 1st semester**		
Number of ECTS credits: 6 (workload is 150; 1 credit = 25 hours)		
Teacher: Michele Nardone		
1	Course objectives	The goal of this course is to introduce the students to basic laboratory practice in physics particularly as far collecting, presenting and analyzing experimental data is concerned. On successful completion of this course, the student should have mastered how to report correctly experimentally measured quantities and their indeterminations, how to make graphs using linear and non-linear scales (particularly lin-log and log-log scales), how to use graphs in order to obtain values and indeterminations of the physical parameters or to use them as calibration graphs. They also should be able to perform a preliminary statistical analysis of a random discrete and continuous variable in terms of averages and mean square deviations.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the lectures of the course are: Measurements of physical quantities: Physical quantities, basic physical dimensions, units, dimensional analysis, absolute and relative errors, significant figures, position (average, mode, median) and dispersion (mean squared deviation, maximum interval) estimators, random errors. Propagation of maximum interval errors on derived quantities, Graphical representation of physical laws: Graphical representation of elementary functions, non-linear scales for exponentials and power laws, interpretation of best slope and intercept. Calibration graphs.

		Discrete and continuous random variables: Frequency distributions ad probability density distributions, histograms, cumulative functions. Sample and parent distributions. Mean and variance, the law of large numbers. The uniform distribution. The theory is supported by an intense practical laboratory activity , performed in small groups of 2 or 3 students. It is based on : data collection with simple direct reading instruments of mechanical quantities – evaluation of the various sources of indeterminations and their propagation – graphical representation of a linearized physical law after appropriate scale choices - determination of the relevant parameters from the slope and the intercept. Experiments yielding uniformly distributed random variables (both discrete and continuous) will also be performed and analyzed in terms of elementary statistical concepts On completion of this course the students are expected to: - have acquired knowledge and understanding of the elementary techniques of experimental data handling as a result of the lecture topics of the course; -be able to apply knowledge and understanding as outcome of the practical laboratory activities; - be able to make informed judgments and choices by practicing critical thinking in the preparation, implementation and evaluation of the goal and the outcome of an experiment, the limits imposed by the available instrumentation and the uncertainties. Have acquired Communicating knowledge and understanding as direct result of theoretical and practical learning activities requiring the ability to report and display the experimental data; - have acquired capacities to continue learning in a complex field for which the course provides knowledge and methodology on a very sophisticated, computer aided, data reduction and error analysis of experimental data in physical sciences enabling them to up-date competences.
3	Prerequisites and learning activities	The student must have a basic knowledge of algebra and trigonometry. Some knowledge of basic calculus could be helpful in the last part of the course
4	Teaching methods and language	Lectures and practical laboratory activities will be both be held in Italian Ref. Text books: besides the lecture notes available on the e-learning site the students may refer to A. Filipponi *"Introduzione alla fisica"*, Zanichelli editore.
5	Assessment methods and criteria	Practical laboratory test followed by oral examination.

Programme of "MECCANICA E TERMODINAMICA"
"MECHANICS AND THERMODYNAMICS"

F0004, Compulsory
1st Cycle Degree in Physics, 1st year , 2st semester

Number of ECTS credits: 12 (workload is 300; 1 credit = 25 hours)

Teacher: Sandro Santucci

1	Course objectives	The main objective of this course is to introduce the fundamental concepts of classical mechanics and thermodynamics aiming to explain daily life phenomena. Through lectures, examples, problems solved, homework assignments, the course introduces the following classical mechanics and thermodynamics topic: space and time; straight line kinematics; motion in a plane; forces and static equilibrium; particle dynamics with force and conservation of momentum; relative inertial frames and noninertial force; work, potential energy and conservation of energy; rigid bodies and rotational dynamics; vibrational motion; conservation of angular momentum; central force motions; kinetic theory and the ideal gas; van der Waals equation of state, blackbody radiation, heat flow and the first law of thermodynamics; MaxwellBoltzmann distribution, random walk and diffusion; Carnot engine, entropy, and the second law of thermodynamics.
2	Course content and Learning outcomes (Dublin descriptors)	The course covers the following basic topics: straight line kinematics, motion in a plane, forces and static equilibrium and the experimental basis of Newton's laws. With the use of results of lab experiments, it applies the concepts of particle dynamics, universal gravitation, collisions and conservation laws, work and potential energy, vibrational motion, conservative forces, rigid bodies and rotational dynamics. At the last stage of the course, some applications of thermodynamics including, kinetic theory and the ideal gas, blackbody radiation, heat flow and the first law of

		thermodynamics, Maxwell Boltzmann distribution will be addressed. The course will conclude with an introduction to Carnot engine, entropy and the second law of thermodynamics. Acquiring knowledge and understanding The students who succeeded in this course; Understand the significance of the essential concepts of momentum and the conservation of momentum, Learn the solution strategies for the problems arising in rotational dynamics, Get acquainted with the concepts of rigid bodies, torque and angular momentum, Apply the conservation of angular momentum in order to deal with more advanced problems of rotational dynamics, Grasp the fundamental concepts in the following areas: thermodynamics, the kinetic theory and the ideal gas, and the basic laws of thermodynamics. Improve their computational skills Employ computer skills to visualize and analyze expermental data Making informed judgments and choices = skills. Learn how theory arises from critically analysis of experiments, collect, analyze and interpret data Understand how to apply the theory they have learned to novel physical situations Demonstrate on examination and through homework assignments, proficiency in solving problems Communicating knowledge and understanding The students will develop capacities to communicate the acquired knowledge using appropriate scientific language Capacities to continue learning The conceptual basis established will enable students to understand related topics in the later years of all programs taking this course.
3	Prerequisites and learning activities	The students must have a basic knowledge of algebra and trigonometry and knowledge of basic calculus
4	Teaching methods and language	Lectures where material will be presented and explained, and the subject will be illustrated with demonstrations and examples; Lectures and examples (problems solution) activities will be both held in Italian A list of homework problems will be posted approximately every week Ref. Text books: besides some lecture notes available on the e-learning site the students may refer to: [1] *P. Mazzoldi, M. Nigro, C. Voci*, "*ELEMENTI DI FISICA - meccanica e termodinamica*- EdiSES [2] *S.Focardi, L.Massa, A. Uguzzoni* , *"FISICA GENERALE – meccanica termodinamica e fluidi"* – CEA [3] R . Duglass GREGORY *CLASSICAL MECHANICS and undergraduate text*- Cambridge University Press
5	Assessment methods and criteria	Three Midterms written Exams, Written(*)and oral final examination. *(*) The midterm written exams might substitute (subjected to a positive teacher's evaluation) the final written exam*

Programme of "LABORATORIO DI MECCANICA E TERMODINAMICA"
"LABORATORY OF MECHANICS AND THERMODYNAMICS"

F0005, Compulsory 1st Cycle Degree in PHYSICS, 1st year , 2nd semester		
Number of ECTS credits: 12 (workload is 300 hours; 1 credit = 25 hours)		
Teacher: Paola Benassi		
1	Course objectives	The goal of this course is to introduce the students to basic laboratory practice on measuring mechanic and thermic quantities. On successful completion of this course the student must be able to design, to install and set up an experiment, align the tools, evaluate the results of measurements, optimize the measurement conditions and to interpret the experimental results using an appropriate statistical analysis.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the lectures of the course are: -Measurements on simple Mechanical systems: Mechanical systems having one degree of freedom (oscillators, inclined plane) and related experiments intended to the verification of the theoretical models. Rigid bodies with high symmetry: Reversible pendulum and the measures of g.

		-Thermodynamics and calorimetry: Measurements of the response time of a thermometer and of the latent heat of fusion of ice. -Probability theory and statistical distribution: Introduction to probability theory and probabilistic models. Chebyshev's inequality and the law of large numbers. Central Limit Theorem. Theory of random errors applied to the processing experimental data: sampling distributions and statistical tests. -Computer literacy: preparation of simple programs written in Fortran. The theory is supported by practical laboratory activity, performed in small groups of 2 or 3 students. It is based on data collection with simple direct reading of instruments or on PC based data acquisition systems. The student must evaluate the various sources of indeterminations and their propagation. The graphical representation of the obtained data may be required. The data analysis in terms of statistical concepts is suggested when appropriate. On successful completion of this Course the student should <u>Have acquired knowledge and understanding</u> on the basic techniques of experimental data acquisition and data handling is an expected result from the lecture topics of the course; <u>Be able to apply knowledge and understanding</u> as direct and immediate result of the practical laboratory activities; <u>Be able to make informed judgments and choices</u> having gained the ability to critically analyze the goal of an experiment, the limits imposed by the available instrumentation and the uncertainties in the outcome; <u>Have acquired Communicating knowledge and understanding</u> as direct result of learning activities requiring the ability to report and display the experimental data by the use of a PC (collateral skills: basic knowledge of Fortran); <u>Demonstrate Capacities to continue learning</u> in a complex field for which the course provides knowledge and methodology on a very sophisticated, computer aided, data reduction and error analysis of experimental data in physical sciences enabling them to up-date competences..
3	Prerequisites and learning activities	The student must have basic knowledge of differential and integral calculus. The student must also have familiarity with exponential, logarithmic and trigonometric functions as well as with basic physics concepts as provided by the course "Introduction to Physics"
4	Teaching methods and language	Both lectures and practical laboratory activities will be held in Italian. Ref. Text books: besides the lecture notes available on the e-learning site the students may refer to: A. Filipponi *"Introduzione alla fisica"*, (Zanichelli editor)
5	Assessment methods and criteria	Practical laboratory test followed by oral examination.

Programme of "CHIMICA"
"*CHEMISTRY*"

F0006, Compulsory **1st Cycle Degree in PHYSICS, 1st Year, 2nd Semester**		
Number of ECTS credits: 6 (Workload:150 hours, 1 credit= 25hours)		
Teacher: Massimiliano Aschi		
1	Course objectives	The goal of this course is to provide the students with the basis of the stoichiometry and general chemistry. On successful completion of this module, the student should be able of solving any simple stoichiometric calculation and should be familiar with the basic concepts of chemical bond and chemical equilibrium.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: Periodic properties and the periodic table, chemical bond and molecular structure, weak interactions, gas, liquids and solids, laws of thermodynamics, chemical equilibrium between pure species and in solution, properties of the solutions, short background in electrochemistry and chemical kinetics. All the basic stoichiometry. On successful completion of this module the student should - be able to predict the structure of any molecule and the hybridization of the related atoms; - be able to provide the name of the most common chemical substances; - have knowledge and understanding of the principles of chemical equilibrium;

		- demonstrate skill in the solution of the stoichiometry problems; - demonstrate capacity to be critical and self-critical.
3	Prerequisites and learning activities	The student must know the basic notions of mathematics and, possibly, of elementary physics.
4	Teaching methods and language	Lectures. Language: Italian Ref. Text books The student can select one of these books: • Peter W. Atkins and Loretta Jones *"Principi di Chimica"* Zanichelli Editore • John Kotz, Paul jr. Treichel, Gabriela C. Weaver *"Chimica"*, Edises • Maurizio Casarin, e altri *"Chimica Generale ed Inorganica"*, EdiErmes
5	Assessment methods and criteria	Written and oral exam.

Programme of "ANALISI MATEMATICA 2" ***"MATHEMATICAL ANALYSIS 2"***		
F0007, Compulsory **First Cycle Degree in PHYSICS, 2nd year, 1st semester**		
Number of ECTS credits: 9 (Workload is 270 hours, 1 credit= 30 hours)		
Teacher: Donatella Donatelli, Marta Nolasco, Bruno Rubino		
1	Course objectives	The goal of this course is to provide the students with the knowledge of the differential and integral calculus for functions of several variables and of the theory of ordinary differential equations. The students will also develop the ability of solving non trivial problems and exercises by applying the techniques learned.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: -Functions of several variables with real and vector values: limits, continuity, and differential calculus. -Taylor expansions and applications. -Implicit functions, local inversion and optimizations of functions, subject to fixed outside conditions or constraints. -Measure and Integration. -Curves, curvilinear integrals and differential forms. -Surfaces and surface integrals. -Gauss-Green, Stokes and Divergence Theorem. -Sequences and Series of Functions. -Ordinary differential Equations. The main concepts are generally presented by showing their links with applications in physics and other sciences, and by providing some background on the main historical references. On successful completion of this module, the student should: - have deep knowledge of basic properties of differential and integral calculus for vector valued functions; - have knowledge and understanding of differential calculus and ordinary differential equations theory; - understand and explain the meaning of complex statements using mathematical notation and language; - understand differential and integral calculus for functions of several variables and of the theory of ordinary differential equations and be aware of their connections and of potential applications in other fields, - demonstrate skill in mathematical reasoning and ability to conceive a proof, - demonstrate capacity for reading and understand other texts on related topics.
3	Prerequisites and learning activities	The student must know the basic notions of numerical sequences and series, functions of one variable and linear algebra contained as provide in "Mathematical Analysis I" and "Geometry"
4	Teaching methods and language	Lectures and exercises. Language: Italian

		Ref. Text books: C.D.Pagani, S.Salsa - *Analisi Matematica* - volumi 1 e 2 – Edizioni Zanichelli
5	Assessment methods and criteria	Written and Oral exam

Programme of "ELETTROMAGNETISMO" ***"ELECTROMAGNETISM"***		
F0008, COMPULSORY **1st Cycle Degree in PHYSICS , 2nd year , 1st semester**		
Number of ECTS credits: 12 (workload is 300 hours; 1 credit = 25 hours)		
TEACHER:Alfonso D'Altorio		
1	Course objectives and Learning outcomes	The goal of this course is to provide the basic principles of classical electromagnetism at a bachelor level. On successful completion of this module, the student should understand the fundamental concepts of electrostatics and magnetostatics in vacuum and in the presence of matter, currents and circuits, electromagnetic induction and its applications, Maxwell's equations and electromagnetic waves. The student should also be familiar with concepts of electrical electromagnetic and able to solve problems in electromagnetism.
2	Dublin descriptors	Topics of the module include: Basic Electrostatics: electric charge, electric force and principle of effect superposition, electric field, Gauss's theorem and its application, electric potential and potential energy. Maxwell's equations in differential and integral form. Electrostatics in the presence of matter: macroscopic description of metals and dielectrics. Electrostatic of conductors, Laplace and Poisson equations. Polarization of dielectric and susceptibility. Polarization charges and polarization vector. The electric displacement vector and the boundary conditions for the electric field. Maxwell equation in presence of dielectrics. Capacitors and circuits with capacitors. Currents and circuits: The electric currents and density. Ohm's laws: local and macroscopic. Charge and discharge of a capacitor in a circuit. Conservation laws and Kirchoff's rules. Transient in RC circuits. Continuity equation. The Thevenin theorem. Magnetostatics: Source of the magnetic field. Lorentz force law and induction magnetic vector. Laplace's equation. The Ampere's law and its applications. Magnetic dipole. Potential magnetic vector. Maxwell's equations in differential and integral form. Magnetic properties of the matter: diamagnetism, paramagnetism and ferromagnetism. Magnetization currents and magnetization vector. Vector field H. The displacement currents and equation of Ampere-Maxwell. Hall effect and non-conservative electric field. Electromagnetic induction: Faraday-Lenz law (phenomenology and formulation). Transient in RL circuits. Phenomenon of self and auto-inductance. Electromagnetic waves: the wave equation, harmonic waves. Transmission Lines: current and tension waves. The electromagnetic wave equations, Poynting vector and Theorem. The laws of geometric optics. Fresnel's equation. Radiation pressure. On successful completion of this module, the student should: - have profound knowledge of the basic concepts in electromagnetism, - have knowledge and understanding of the most common physical phenomena related to electromagnetic effects, - understand and explain the heuristic electric/magnetic properties of metals and dielectrics; - understand the fundamental concepts of classical electromagnetism; - demonstrate skills in physical reasoning and in facing novel problems in basics physics and ability to use the acquired tools and knowledge to solve intermedium problems in electromagnetism; - demonstrate capacity for reading and understanding other texts on these topics.
3	Prerequisites and learning activities	The student must be familiar with the basic notions of mathematic calculus (mainly derivatives and integrals in 1, 2 and 3 dimensions, vector calculus, basics of differential calculus) and the basic concepts of general mechanics (laws of dynamics, gravitational field, conservation laws).
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books: P. Mazzoldi, M. Nigro, C. Voci, *FISICA Elettromagnetismo-Onde*, Vol. II, EdiSES

5	Assessment methods	Written and oral exam.

Programme of "LABORATORIO DI FISICA COMPUTAZIONALE" ***"LABORATORY OF COMPUTATIONAL PHYSICS"***		
F0011, Compulsory **First Cycle Degree in PHYSICS, 2nd year, 2nd semester**		
Number of ECTS credits: 9 (Workload: 225 hours, 1 credit = 25 hours).		
Teacher: Rossella Ferretti		
1	Course objectives	The goal of this course is to introduce the students to languages programming applied to a few simple physics problems. At the end of the course, the student should have developed the ability to solve numerically some calculus problems related to physics, in particular simple ordinary differential equations of second order.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: -Numerical schemes for integrals: linear methods (linear and trapezoidal) and parabolic (Cavalieri-Simpson) scheme -Numerical schemes for solving non linear equations: bisection method, False position method, Newton method -Numerical schemes for solving ordinary differential equations: Eulero, Eulero-Cromer, Verlets schemes and Runge-Kutta of II order On successful completion of the course the students are expected to: -have acquired knowledge and understanding of fundaments of computer programming and of the most important algorithms to solve basic numerical problems (integration, derivation, differential equations); -demonstrate skills in using numerical methods for computing integrals, finding zeros of non linear functions and solving ordinary differential equations of I and II orders; - demonstrate understanding of simple physics problems and have acquired the ability to solve in laboratory numerical problems calculating relevant physical quantities; -demonstrate the ability in making judgments by critically comment the numerical results obtained (as a function of the parameters/approximations used in the calculation), being aware of their dependence on these parameters; -demonstrate capacity to communicate the results of his laboratory exercises with written homework using latex.
3	Prerequisites and learning activities	Students should have a good background in calculus and physics.
4	Teaching methods and language	Lectures, and computer laboratory activity. Lectures are given in English upon request of non-native Italian speakers. Ref. Text books: Lecture notes of the Teacher. Barone L. - Marinari E. - Organtini G. - Ricci Tersenghi F. *"Programmazione Scientifica"*, Pearson Education, 2006
5	Assessment methods and criteria	Computer test followed by an oral exam.

Programme of "MECCANICA CLASSICA E ANALITICA" ***"CLASSICAL AND ANALYTICAL MECHANICS"***		
F0010, Compulsory **1st Cycle Degree in PHYSICS, 2nd year, 2nd semester**		
Number of ECTS credits: 6 (Workload: 180 hours, 1 credit= 30 hours)		
Teachers: Immacolata Merola, Davide Gabrielli		
1	Course objectives	This Course aims to present the Newtonian Mechanic as an axiomatic-deductive theory formulated in a precise mathematical language so that the students will be able 1) to understand the connection between the description of physical phenomena and their

		mathematical formalization, 2) to use different mathematical tools (analysis, geometry, etc) to solve a specific problem 3) to describe concrete phenomenological situations formalizing them into simple, but rigorous mathematical models that allow predictions controllable. 4) to develop a critical understanding of the topics and capacity to use a mathematical language.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: Space-time reference point material and Newton's laws. One-dimensional systems. Central forces, two-body problem, Kepler's laws. Constrained systems and Lagrange equations. Variational principles. Small oscillations, Formulation of the equations of Hamilton. Integrable systems, action-angles variables. All the theoretical concepts are supported by a series of targeted exercises which are essential to achieve the envisaged LO. On successful completion of this module, the student should : - Have acquired knowledge and understanding on classical mechanics and mathematical tools; - have acquired knowledge and understanding of the topics of the course from both mathematical and physical point of view; - Be able to apply knowledge and understanding for solving problems in classical and analytical Mechanics; - have developed skills in facing different novel problems with similar mathematical formalization; - Be able to make informed judgments and choices on the suitability of models and approximations; - Be able to communicate the results of their studies with appropriate language; - Have developed capacities to continue learning autonomously.
3	Prerequisites and learning activities	The students must have familiarity with the basic notions of Analysis, Geometry and Mechanics as provided by the courses: Analysis 1 , Physics 1 and Geometry 1
4	Teaching methods and language	Lectures and exercises. Language is Italian Ref. Text books, (lecture notes can be in English). R. Esposito, *Meccanica Razionale*, ed. Aracne 1998. Handouts related to this course are also available: - A.Teta "Notes of his course"; -E. Presutti "Notes of his course"
5	Assessment methods and criteria	Oral and written (exercises) exam.

Programme of "LABORATORIO DI ELETTROMAGNETISMO E OTTICA" ***"LABORATORY OF ELECTROMAGNETISM AND OPTICS"***		
F0009, Compulsory **1st Cycle Degree in PHYSICS, 2nd year, 2nd semester**		
Number of ECTS credits: 12 (workload is 300 hours; 1 credit = 25 hours)		
Teacher: Vincenzo Rizi (vincenzo.rizi@aquila.infn.it or vincenzo.rizi@univaq.it)		
1	Course objectives	The student, from her/his starting knowledge of electromagnetism and optics, is guided along the preparation and design of the different experiences, which are of various kinds: from those that are more qualitative to the ones that require an accurate quantification of the measurements and their significance. The course objectives: the student will be familiar with simple laboratory equipment, and the experimental methods, namely, the student will know how to analyze and interpret empirical data, apply the basic principles of physics, design simple experiments, analyze the errors of measurement, and communicate the results in a clear and concise manner.
2	Course content and Learning outcomes (Dublin descriptors)	Experimental activities concern the following issues: DC and AC circuit theory: linear and nonlinear elements, filters, resonance, transients. Electromagnetic radiation: lenses, mirrors. Dispersion of light. Diffraction and interference. Reflection, refraction and polarization of light. The experiments: • Measurements of resistances. Verification of Thevenin's theorem. • Frequency dependent analysis of RC, CR, LR, RL, RLC series and parallel circuits. • Measurements of focal lengths of lenses. Building a telescope.

		• Simple spectroscopy with optical prism, and gratings: measures of wavelengths. • Using laser light to study diffraction and interference phenomena. • Use of polarized light to measure the reflection of different surfaces. Qualifications that signify completion of this module, are awarded to students who: • have demonstrated understanding of the basic laboratory activities that builds upon their knowledge of electromagnetism and optics; • can apply their knowledge and understanding to perform simple laboratory experiences; • have the ability to gather and interpret relevant data collected during the laboratory activities; • can communicate the results in a clear and concise manner; • have developed those learning skills that are necessary to design simple experiments.
3	Prerequisites and learning activities	Basics of electromagnetism and optics, familiarity with the laboratory procedures, basics of statistical data analysis.
4	Teaching methods and language	Statements of basic behavior in a laboratory, and safety instructions. Lectures on preparation, description and preliminary design of the experiments. Experiments will be made in a specified time period, and immediately followed by the drafting of the report. Language: Italian. References: • *Teacher notes* (at the moment in Italian); • *Misure ed apparecchi di fisica (elettricità),* G. Cortini, S. Sciuti, Veschi, 1981; • *Electronic instrumentation*, A. M. Portis and H. D. Young, Berkeley Physics Laboratory, 2nd Edition, 1971.
5	Assessment methods and criteria	The individual reports for each group (2 or 3 students), if prepared according the instructions of the teacher, are valued using the following weights: • 5% for the cover page; • 20% for the abstract; • 50% for the part concerning the experimental data and the results; • 25% for discussion. To obtain the exemption from the final experimental test, is required at least 80% of the reports. The overall assessment of the reports constitute 60% of the final assessment, the remaining 40% includes a brief oral exam (20%), and an assessment of the student's presence (10%) and contribution along the laboratory activities (10%).

Programme of "INTRODUZIONE ALLA FISICA MODERNA"
"AN INTRODUCTION TO MODERN PHYSICS"

F0012, Compulsory
1st Cycle Degree in PHYSICS, 2nd year , 2nd semester

Number of ECTS credits: 9 (workload is 225 hours; 1 credit = 25 hours)

Teacher: **Michele Nardone**

1	Course objectives	The goal of this course is to introduce the students to basic concepts of modern physics, namely to special relativity and to the quantum nature of light and energy, emphasizing whenever possible, how classical concepts have shown up to be inadequate in explaining experiments. The experiments which will be analyzed are: a) optical aberration experiments, Michelson-Morley ether wind experiment, Black body radiation experiments in both Planck and Einstein views, temperature dependent specific heats, the photoelectric effect, Rutherford scattering, Compton scattering, optical emission and absorption spectra of atoms, X-ray emission spectra, diffraction of electrons. On successful completion of this module, the student should have not only gained a deep understanding on the motivations that have led in the past century to the relativistic and quantum revolution in physics, but should also have become familiar with relativistic kinematics and mechanics and with the basic formulae describing the quantum nature of light and matter.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course are: Special relativity: Experiments on the nature and the speed of light. Failure of the ether theory. Galileo an Lorentz transforms for coordinates and velocities. Minkowski space and

		space-time 4-vectors. Relativistic Doppler effect. Linear momentum, forces, energy and energy-momentum relation. Energy-momentum 4-vector, rest mass and mass defective reactions. The quantum hypothesis: Black body radiation and Planck's interpretation. Cathode rays, the photoelectric effect and Einstein's light quanta. Light quanta and the black body spectrum. Boltzmann's distribution, the specific heat problem and the quantum hypothesis. Einstein coefficients and Electronic structure of the atom: Failure of the Plum pudding model and the planetary model. Rutherford scattering and the size of the nucleus. Drawbacks of the planetary model and Balmer's formula for the spectral lines of Hydrogen. Stationary states and Born's atomic model. Correspondence principle and the Rydberg constant: reduced mass effect. Many electron atoms: X-ray emission spectra. Matter waves: De Broglie wavelength and the pilot wave. Stationary states and stationary waves. The Davisson-Germer experiment. Single and double slit experiments using waves, classical particles and quantum particles. Particles, wave packets and the basic requirements of the new theory: probability waves and the uncertainty principle. On completion of this course the students are expected to: - have acquired knowledge and understanding of all four topics. Knowledge of the fundamental experiments which have led to the quantum/relativistic revolution and understanding why classical physics was inadequate and how the new theories should be built. - be able to applying knowledge and understanding as far as the solution of problems in the exercise classes is concerned. This is particularly true for topic 1 which is more formal in character. -to be able to make informed judgments and choices upon improvement of the ability to critically analyze the outcome of an experiment in terms of the model adopted for its interpretation. -to have acquired Communicating knowledge and understanding as direct result of theoretical learning activities requiring the ability to report and discuss the experimental data and their theoretical implications to have acquired capacities to continue learning Several topics of the course will strengthen the learning capacities of the students; particularly the one on special relativity as well as the many classical physics calculations encountered in describing the experiments.
3	Prerequisites and learning activities	The student must be familiar with basic calculus and possess a good knowledge of classical physics: mechanics, thermodynamics and electromagnetism.
4	Teaching methods and language	Lectures and numerical exercises will both be held in Italian Ref. Text books: besides the lecture notes available on the e-learning site, the students may refer to: J. J. Brehm, W. J. Mullin *"Introduction to the structure of matter: a course in modern physics"*, and, for a detailed description of many experiments, to B. Cagnac, J. C. Pebay-Peyroula. *"Modern Atomic Physics"* , as well as to two classical books: Max Born, *"Atomic Physics"* and *"Natural philosophy of cause and chance"* which are also available in italian.
5	Assessment methods and criteria	Written and oral exam.

Programme of "METODI MATEMATICI DELLA FISICA"
"MATHEMATICAL PHYSICS I"

DF0002, Compulsory **1st Cycle Degree in PHYSICS, 2nd year , 2nd semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teacher: Alessandro Ciattoni		
1	Course objectives	The course also aims at integrating the real calculus notions, the students are supposed to have at the end of the second year, with an extensive exposition of complex analysis and its applications to a variety of mathematical physics problems.

2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course are: 1- Second order ordinary differential equations: Homogeneous and inhomogeneous equations, local power series solution at both regular and singular-regular points. 2- Complex analysis: Holomorphic functions, Taylor and Laurent series, singular points, analytic continuation, multi-valued functions, residue theory and its application to evaluate real integrals. On successful completion of this module, the student should - acquire knowledge and understanding of second order ordinary differential equations. - acquire knowledge and understanding of complex analysis. - demonstrate skills: Demonstrate on examination and through homework assignments, proficiency in solving problems. - Capacities to continue learning: The conceptual basis established will enable students to face mathematical problems and to handle mathematical formalisms occurring in topics in the later years of all programs taking this course .
3	Prerequisites and learning activities	The student must be familiar with real calculus
4	Teaching methods and language	Lectures will be held in Italian or English according to the audience Ref. text books - F.W. Byron Jr. e R.W. Fuller, *"Mathematics of Classical and Quantum Physics"*, Dover, 1970. - S. Hassani, *"Mathematical Physics"*, Springer, 2002. - A. G. Sveshnikov e A.N.Tikhonov, "*Teoria delle funzioni di una variabile complessa"*, Mir, 1984, same book in English version.
5	Assessment methods and criteria	Final written and oral examination.

Programme of "METODI MATEMATICI DELLA FISICA II" ***"MATHEMATICAL PHYSICS II"***		
DF0003, Compulsory **1st Cycle Degree in PHYSICS, 3rd year , 1st semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teacher: Zurab Berezhiani		
1	Course objectives	The main objective of this course is to provide the students the basic mathematical skills which are essential for both quantum and classical physics, namely the ability to face mathematical problems where finite or infinite dimension vector spaces are involved.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course are: 1- Finite dimension vector spaces: Representation theory, vector spaces equipped with an inner product, matrix theory, operator properties (hermitian, unitary and normal operators) and their spectral problems, functions of operators. 2- Infinite dimension vector spaces: Hilbert spaces, complete orthogonal systems of vectors, the space of square-integrable functions, classical orthogonal polynomials, Fourier series, Fourier integrals, theory of distributions (Dirac delta function), second order differential operators, Liouville theory, Green's functions. On successful completion of this module, the student should - have acquired knowledge and understanding of finite dimension vector spaces. - have acquired knowledge and understanding of Hilbert spaces properties. - demonstrate skills in solving problems. - demonstrate capacities to continue learning: The conceptual basis established will enable students to face mathematical problems and to handle mathematical formalisms occurring in topics in the later years of all programs taking this course .
3	Prerequisites and learning activities	The student must be familiar with real calculus and linear algebra.
4	Teaching methods and language	Lectures will be held in Italian or English according to the audience Ref. text books - F.W. Byron Jr. and R.W. Fuller, *"Mathematics of Classical and Quantum Physics"*, Dover 1970.

		- S. Hassani, *"Mathematical Physics"*, Springer, 2002. - A. G. Sveshnikov e A.N.Tikhonov, *"Teoria delle funzioni di una variabile complessa"*, Mir, 1984, same book in English version.
5	Assessment methods and criteria	Final written and oral examination.

Programme of "ISTITUZIONI DI FISICA TEORICA" ***"INTRODUCTION TO THE THEORETICAL PHYSICS"***		
F0014, Compulsory **1st Cycle Degree in PHYSICS, 3rd year , 1st semester**		
Number of ECTS credits: 12 (workload is 300 hours; 1 credit = 25 hours)		
Teacher: Sergio Ciuchi		
1	Course objectives	The goal of this course is to provide an introduction to the formalism of quantum mechanics and provide some basic notions of statistical mechanics. On successful completion of this course the student should understand the fundamental concepts of quantum mechanics, quantum perturbation theory and basic atomic theory as well as the statistical approach to the equilibrium properties of classical and quantum perfect gases.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course are: 1- Formalism of Quantum mechanics: The Dirac formalism and Hilbert space 2- Schrödinger equation: Schrödinger eq. in one dimension standard problems, current density evolution, harmonic oscillator. 3- Angular momentum: general theory, spherical harmonics, central problems, Hydrogen atom. 4- Symmetries and conservation laws in quantum: momenta and angular momenta as generators, conservation laws in quantum mechanics 5- Time independent perturbation theory. 6- Identical particles. 7- Equilibrium statistical mechanics (basics): classical and quantum perfect gases On successful completion of this module, the student should - have acquired knowledge and understanding of the foundations of quantum mechanics - have acquired knowledge and understanding of the statistical theory of non-interacting classical and quantum gases - know and understand the most common applications of quantum mechanics to the simplest atomic problem (Hydrogen atom) - applicate acquired knowledge in solving problems by applying theoretical knowledge to concrete cases through exercises, homework and exams - demonstrate capacities to continue learning topics related to quantum mechanics and basic statistical mechanics both in later courses and individual self training.
3	Prerequisites and learning activities	The student must be familiar with mechanics, analytical mechanics and electromagnetism.
4	Teaching methods and language	Lectures will be held in Italian or English according to the audience Ref. text books J. J. Sakurai, *Meccanica Quantistica Moderna*, Zanichelli (1996), same book in English version C. Cohen, Tannoudji et al., *Meccanica Quantistica*, Vol I-II, Wiley (1991)), same book in English version P.A.M. Dirac *Principi della Meccanica Quantistica*, Boringhieri (2001),same book in English version K. Huang *Meccanica Statistica*, Zanichelli (1997), same book in English version
5	Assessment methods and criteria	Three optional mid-term exams (exercises) and a final oral examination. Final written and oral examination.

Programme of "LABORATORIO DI ELETTRONICA" *"ELECTRONICS LABORATORY"*		
F0016, Compulsory **1st Cycle Degree in PHYSICS, 3rd year, 2nd semester**		
Number of ECTS credits: 6 (workload is 150; 1 credit = 25 hours)		
Teacher: Giovanni Piano Mortari (*gianni.pianomortari@aquila.infn.it*)		
1	Course objectives	The student, from her/his starting knowledge of basic laws and principles of electricity and electronics, will design and build some simple circuits: data taking and analysis is very qualitative. Course objectives: the student will operate with simple laboratory electronics equipment, apply the basic principles of Electronics Design in the projects of simple devices, analyze the circuits performances and check malfunctioning projects or assembling mistakes.
2	Course content and Learning outcomes (Dublin descriptors)	Experiments on simple circuits concern the following issues: RC/CR filters, Cables and Delay Lines, Diodes, BJT transistor basic circuits, Operational amplifiers and Comparators, Digital Electronics fundamentals. In order to successfully complete this module the student has to: • demonstrate understanding the correct use of basic laboratory electronic equipment; • apply knowledge and understanding of basic Electronics to make projects, analyze and realize simple circuits; • have the ability to understand and interpretate the measurements of circuits parameters, connecting them with the Electronics principles and modeling.
3	Prerequisites and learning activities	Basics of electricity and electromagnetism laws, easy of use of laboratory electronics instruments, basics of measurements and data analysis and interpretation.
4	Teaching methods and language	Lectures and Exerceses. Lessons will be held in Italian, followed by experiments in the Electronics laboratory. Main suggested textbooks are in English: P.Horowitz, *" The Art of Electronics"*, 2nd ed., Cambridge University Press P.Horowitz, *"The Student Manual for The Art of Electronics"*, 2nd ed., Cambridge University Press W.Kleitz, "*Digital Electronics: A Practical Approach"*, 8th ed., Prentice Hall Different lecture notes are also distributed.
5	Assessment methods and criteria	Oral examination with questions on the major topics treated in lectures and discussions on circuits and measurements in the laboratory.

Programme of "ISTITUZIONI DI FISICA DELLA MATERIA" *"FUNDAMENTALS OF CONDENSED MATTER PHYSICS"*		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
DF0004, Compulsory 1st Cycle in PHYSICS, 3rd year , 2nd semester		
Teachers: Carlo Pierleoni		
1	Course objectives and Learning outcomes	The goal of this course is to illustrate how the laws of Quantum Mechanics leads to the present understanding and description of the interaction of light with the matter and of the structure of atoms, molecules and extended crystalline systems. On successful completion of this module, the student should be able to discuss at the qualitative level light-matter interaction, the electronic structure of many electron atoms, the electronic structure and the geometry of simple molecules, the basis of the electronic structure of crystalline solids.
2	Dublin descriptors	Topics of the module include: The variational method in Quantum Mechanics: the use of the variational principle of QM in the approximate solution of interacting quantum systems. Time-dependent perturbation theory and light-matter interaction: perturbation theory for a time-varying external fields and how to use it to describe the interaction of the electromagnetic field with quantum systems, in particular the single electron atom. The fine structure of the hydrogen atom: level slitting and multiplets.

		Many-electrons systems: center of mass reference frame and symmetry of the wave functions. The mass polarization term. Two-electrons atom: spatial and spin part of the wave function, Pauli principle and para-orto symmetric states. Energy spectrum of the two-electrons atom. Central field approximation, perturbation and variational solution for the ground state and for the excited states. Many-electrons atoms: central field approximation, exchange symmetry and Slater determinant. Electronic configurations, shells and subshells. The periodic table of elements. Molecular Physics: relevant energy scales (electronic, vibration and rotation). Born-Oppenheimer approximation. Electronic structure of diatomic molecules: the molecular orbital method in the LCAO approximation for homonuclear diatomic molecules. Energy spectrum and AUFBAU. Electronic configuration of homonuclear molecules of second group. Heteronuclear diatomic molecules in LCAO approximation. Lone-pairs and hybridization. Pair orbitals and the valence bond method. Equivalence of the two approaches. Electronic structure and geometry of polyatomic molecules: localized and bond orbitals. Hybridization of s-p atomic orbitals and molecular geometry. Relevant examples. Benzene rings and delocalized π orbitals. Huckel model for rings and linear chain molecules with π electrons: emergence of energy bands. Introduction to solid state physics: regular lattices and crystalline structures. Bravais lattices, primitive and unitary cell, Wigner-Size cell, basis. Reciprocal lattice, Brillouin zone. X-ray diffraction from a lattice: Bragg and vanLaue descriptions. Electronic structure of crystalline solids: ideal Fermi gas in periodic Boundary conditions. Fermi sphere in the thermodynamic limit. Non-interacting electrons in a periodic potential: Bloch theorem and energy bands. Weak periodic potential, energy gap and first Brillouin zone. The Tight-Binding method for localized orbitals. Classification of solids according to their electronic structure: Metals vs insulators. Covalent crystals, ionic crystals, molecular crystals. Nuclear structure: composition, radius and mass. Alpha, beta and gamma decays. On successful completion of this module, the student should - have qualitative knowledge of the methodology to understand the electronic structure of atoms, simple molecules and simple crystalline solids, - have knowledge and understanding of the most basic physical and chemical properties of matter. - understand the fundamental concepts of quantum physics and their connections/applications to go from simple atoms to the periodic table of the elements, to simple molecules and to some basic concept in solid state physics. - demonstrate skills in physical reasoning and ability in solving problems related to basic concepts of the electronic structure of atomic and condensed matter systems. - demonstrate capacity for reading and understand other texts on related topics.
3	Prerequisites and learning activities	The student must know the basic notions of classical and quantum mechanics and be familiar with the mathematical methods involved.
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books B.H. Bransden, C.J. Joachin: "*Physics of atoms and molecules*", Longman UK (1983). G. Baym: "*Lectures on Quantum Mechanics*", W. A. Benjamin, (1969). R. McWeeny: *"Coulson's Valence"* 3rd edition, OUP (1976). N.W. Ashcroft and N.D. Mermin: *"Solid State Physics"*, Harcourt College Publishers (1976).
5	Assessment methods	Written and oral exam.

Programme of “FISICA NUCLEARE”
“FUNDAMENTAL NUCLEAR PHYSICS”

DF0005, Compulsory
First Cycle Degree in PHYSICS, 3rd year, 2nd semester

Number of ECTS credits: 6 (Workload is 150 Hours, 1 credit = 25 hours)

Teacher: Sergio Petrera

1	Course objectives	The course provides the basic knowledge of the structure of the atomic nucleus, of Nuclear decays, of Nuclear models and of Experimental methods.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - An introduction to experimental methods in nuclear physics. - Nuclear structure: composition, radius and mass. - Nuclear stability and decays: alpha, beta and gamma decays. Fission and fusion. - Nuclear models: liquid drop model, Fermi gas model, shell model. On successful completion of this module, the student should - Acquire knowledge and understanding of the fundamental concepts in nuclear physics. - Acquire knowledge in the use of current theoretical models and basic experimental methods. - Be able to apply such knowledge to the interpretation of data from nuclear experiments. - Be able to make judgments and choices on the suitability of models in comparison with the progressive acquisition of experimental observations. - Be able of communicate the results of their studies in the course with seminars. - Have capacities to continue learning in this field.
3	Prerequisites and learning activities	A good background in electromagnetism and some basic notions of special relativity. Non relativistic quantum mechanics, time depend perturbation theory, interaction picture.
4	Teaching methods and language	Lectures in Italian or in English upon request of non-native Italian speakers. Lecture notes available on specific topics. Text books: W.S.C. Williams, *Nuclear and Particle Physics,* Oxford Science Publications; B. Povh, K. Rith, C. Scholz, K. Zetschke, *Particelle e nuclei,* Bollati Boringhieri; B.R. Martin, Nuclear and Particle Physics, an Introduction, J. Wiley & sons.
5	Assessment methods and criteria	Written partial exams during the course. Oral exam at the end of the class.

Programme of "FISICA DEI FLUIDI"
"PHYSICS OF FLUIDS"

F0017, compulsory
First Cycle Degree in PHYSICS, 3rd year, 2nd semester

Number of ECTS credits: 6 (workload is 150; 1 credit = 25 hours)

Teacher: Guido Visconti

1	Course objectives	Objective of this course is to give to students the basic knowledge of the physics of fluids.
2	Course content and Learning outcomes (Dublin descriptors)	The course content can be summarized as follows: Summary of thermodynamics. Conservation laws. Strain and stress tensor. Navier Stokes equation. Gravity waves. Hydrodynamic Instabilities. Computational fluid dynamics. Turbulence. Magneto hydrodynamics. Geophysical Fluid dynamics. Non linear dynamics. Solitons Expected Learning Outcomes: <u>Acquiring knowledge and understanding</u> is an expected result from all topics. Knowledge of the fundamental of fluid dynamics and some relevant application. <u>Applying knowledge and understanding</u> is an expected result particularly as far as the solution of problems in the exercise classes is concerned. <u>Making informed judgments and choices = skills</u>. On successful completion of this course, the student should have the basis for specific courses in geophysics or solid state physics <u>Communicating knowledge and understanding</u> The student will develop capacities to communicate the acquired knowledge with a proper scientific language <u>Capacities to continue learning</u> Several topics of the course will strengthen the learning capacities of the students; In particular the course will be preparatory for more specific topics.
3	Prerequisites and learning activities	The student must be familiar with basic calculus and possess a good knowledge of classical physics: mechanics, thermodynamics

4	Teaching methods and language	Lectures will be in Italian. Basic textbooks are: Kundu, Cohen, *Fluid mechanics* Drazin, *Hydrodynamic instabilities*
5	Assessment methods and criteria	Oral discussion of a term paper