UNIVERSITY OF L'AQUILA

Department of Physical and Chemical Sciences

2nd Cycle Degree in PHYSICS

Laurea Magistrale in FISICA

Course Catalogue

The student may choose one of the following 4 tracks:

1) Physics of the Environment and Meteorology ,

2) Condensed Matter Physics: Fundamental science and nanotechnology,

3) Space Physics,

4) Physics and astrophysics of elementary particles

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 2nd Cycle Degree in PHYSICS

Track 1): Physics of the Environment and Meteorology

YEAR	CODE	COURSE	Credits (ECTS)	Semester
I	DF0007	Physics of the atmophere and of the ocean	10	1
	F0027	Electrodynamics	6	1
	F0249	Experimental methods in Physical Research	6	1
	DF0015	Advanced physics Laboratory	6	1
	F0271	Statistical Mechanics	6	1
	F0228	Condensed Matter physics	6	1
	DF0012	Radiative transfer in atmosphere	6	2
		Choice Course (group 1)	6	1,2
		Student's Choice Course	8	1,2
II	F0244	Nuclear and subnuclear physics	6	1
	DF0013	Dynamic Meteorology	6	2
		Choice Course (group 2)	6	1,2
		Stages and additional activities	6	1,2
		Thesis	36	

Track 2): Condensed Matter Physics: Fundamental science and nanotechnology

I	F0027	Electrodynamics	6	1
	F0228	Condensed Matter physics	6	1
	F0249	Experimental methods in Physical Research	6	1
	F0271	Statistical Mechanics	6	1
	DF0015	Advanced physics Laboratory	6	1
	DF0008	Solid state physics	10	2
	F0272	Correlation functions in spectroscopy	6	2
		Choice Course (group 1)	6	1,2
		Student's Choiche Course	8	1,2
II	F0244	Nuclear and subnuclear physics	6	1
	DF0011	Physics of the nanostructures	6	2
		Choice Course (group 2)	6	1,2
		Stages and additional activities	6	1,2
		Thesis	36	

Track 3): Space Physics

I	F0244	Nuclear and subnuclear physics	6	1
	F0027	Electrodynamics	6	1
	F0228	Condensed Matter physics	6	1
	DF006	Space physics	10	1
	F0249	Experimental methods in Physical Research	6	1
	F0271	Statistical Mechanics	6	1
	F0234	Physics of Circumterrestrial Space	6	2
		Choice Course (group 1)	6	1,2
		Student's Choiche Course	8	1,2
II	DF0015	Advanced physics Laboratory	6	1
	DF0014	Physics of the magnetosphere	6	2
		Choice Course (group 2)	6	1,2
		Stages and additional activities	6	1,2
		Thesis	36	

Track 4): Physics and Astrophysics of elementary particles				
I	F0244	Nuclear and subnuclear physics	6	1
	F0027	Electrodynamics	6	1
	F0252	Theoretical physics	6	2
	F0271	Statistical Mechanics	6	1
	F0249	Experimental methods in Physical Research	6	1
	DF0010	Particle physics	10	2
	F0240	General Relativity and Cosmology	6	2
		Choice Course (group 1)	6	1,2
		Student's Choiche Course	8	1,2
II	F0228	Condensed Matter physics	6	1
	DF0015	Advanced Physics Laboratory	6	2
	F0331	Gauge theories	6	1
		Choice Course (group 2)	6	1,2
		Stages and additional activities	6	1,2
		Thesis	36	

Optional courses			
Group 1	*Track 2, 4:* F0028-Astrophysics (6 ECTS) DF007- Physics of the Atmosphere and of the ocean (6 ECTS), DF006-Magnetohydrodynamics of Astrophysical Plasmas (i.e. 6 ECTS from Space Physics)	*Track 1:* F0028-Astrophysics, DF007- Magnetohydrodynamics of Astrophysical Plasmas, (i.e. 6 ECTS from Space Physics)	*Track 3:* F0028-Astrophysics (6 ECTS) DF007- Physics of the Atmosphere and of the ocean (6 ECTS)
Group 2	*For all Tracks any course among the followings:* F0252-Theoretical physics, F0027-Electrodynamics, F0271-Statistical Mechanics, DF0010-Particle physics, F0028-Astrophysics, DF007- Physics of the Atmosphere and of the ocean (6 ECTS), DF006-Magnetohydrodynamics of Astrophysical Plasmas (i.e. 6 ECTS from Space Physics), DF0008-Solid state physics, F0272-Correlation functions in spectroscopy, DF0011-Physics of the nanostructures, F0240-General Relativity and Cosmology, F0331-Gauge theories, DF0014-Physics of the magnetosphere, F0329-Nanotechnology Laboratory, DF0012-Radiative transfer in atmosphere, DF0013-Dynamical Meteorology.		

Programme of "FISICA DELL'ATMOSFERA E DELL'OCEANO" *"PHYSICS OF THE ATMOSPHERE AND OF THE OCEAN"*		
DF007, compulsory *for Track 1, , optional for Tracks 2,3,4* **Second Cycle Degree in PHYSICS, 1st year, 1st semester**		
Number of ECTS credits: 10 (Workload: 250 hours, 1 credit=25 hours)		
Teacher: Guido Visconti		
1	Course objectives	Purpose of this course is to introduce student to the physics of the atmosphere and oceans as an application of concept of thermodynamics, radiative transfer and fluid dynamics .
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course are 1. General Characteristics of the atmosphere and oceans 2. Global energy balance 3. Frequency response of simple forcing 4. General circulation of the atmosphere and oceans 5. Waves in the atmosphere and oceans 6. Interactions (ENSO hurricane theory) 7. Non linear phenomena (thermohaline circulation) Expected learning outcomes: Acquiring knowledge of the fundamental of fluid dynamics applied to atmosphere and ocean; Applying knowledge and understanding particularly as far as the solution of problems in the exercise classes is concerned; Making informed judgments and choices = skills the student should have improved the ability to critically analyze the current research literature; Communicating knowledge and understanding as ability to communicate the acquired knowledge with a proper scientific language; Capacities to continue learning 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 and fluid dynamics.
4	Teaching methods and language	Lectures will be in Italian The basic textbooks are: J. Marshall, R.L. Plumb: *Atmosphere, Ocean and Climate dynamics,* Academic Press, 2007. G.K: Vallis: *Atmospheric and Oceanic fluid dynamics,* Cambridge Univ. Press, 2006.
5	Assessment methods and criteria	Term paper and oral discussion

Programme of "ELETTRODINAMICA CLASSICA" *"ELECTRODYNAMICS"*		
F0027, compulsory *for all Tracks* **Second Cycle Degree in PHYSICS, 1st year, 1st semester**		
Number of ECTS credits: 6 (Workload: 150 Hours, 1 credit = 25 hours)		
Teacher: Luigi Pilo		
1	Course objectives	The module aims to develop students' understanding of Maxwell's equations and their applications including some advanced topics. Students will be able to apply the fundamentals of electric and magnetic fields to begin to explore the interaction of electromagnetic radiation with matter.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of this course are: - Maxwell equations and their physical interpretation. Conservation laws. - Electromagnetic waves in vacuum, plane and spherical waves. Polarization. - Special relativity and Geometry of Minkowski space. Vectors and tensors. - Gauge invariance of the Maxwell equations, the 4-potential, the field strength tensor. Maxwell equations in covariant form. -Variation principle for the field and particles. The energy momentum tensor.

		- Radiation from a compact source. Green function, retarded potentials. Multipole expansion. Total power emitted. - Thompson scattering. On successful completion of this module, the student should - acquire knowledge and understanding of: Maxwell equations, geometry of Minkowski space. Electromagnetic radiation; - be able to describe all the fundamental aspects of electromagnetism and explain many aspects of the interaction of electromagnetic radiation with matter; -demonstrate skills: problem solving in the assigned homework; using the basic tools of field theory and special relativity formulated in a geometrical way. - Capacities to continue learning: proceed in the study of the physics of fundamental interactions and many body physics.
3	Prerequisites and learning activities	An elementary knowledge of electromagnetism and some basic notions of special relativity. Calculus.
4	Teaching methods and language	Lectures in Italian or in English. Text books: 1. J. David Jackson, *Classical Electodynamcis*, John Wiley (3rd edition) 1998, 2. L.D. Landau & E.M. Lifshitz, *The classical theory of fields*, Pergamon Press, 1971, 3. A.O. Barut, *Electrodynamics and Classical Theory of Fields and Particles,* Courier Dover Publications, 2012
5	Assessment methods and criteria	Students are supposed to solve assigned set of problems as homework. Oral exam at the end of the class.

Programme of "METODI SPERIMENTALI PER LA RICERCA FISICA" ***"EXPERIMENTAL METHODS IN PHYSICAL RESEARCH"***		
F0249, compulsory *for Track 1, , optional for Tracks 2,3,4* **Second Cycle Degree in PHYSICS, 1st year, 1st semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teachers: Filipponi Adriano & Giovanni Battista Piano Mortari		
1	Course objectives	The objective of this course is to provide a broad fundamental cross-disciplinary knowledge relevant to a number of experimental methods and techniques, including: probability theory and its applications to data analysis, radiation sources, detectors and related electronics, experimental geometries and detection strategies.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the course: 1. Probability theory, characteristic functions and their applications to limit theorems, multi dimensional random variables and Bayesian data analysis. 2. Radiation sources and physical principles: black body, synchrotron radiation, inverse Compton. Emittance conservation and brilliance. 3. Interaction between radiation and matter and detection methods. Photo-multipliers, scintillators and other particle or radiation detectors. Related electronics. Expexted Learning Outcomes: <u>Knowledge and understanding</u> The main objective is to fill the gap in previous student's knowledge showing the relevance of fundamental physical theories for the development and optimization of experimental methods and instrumentation. <u>Applying knowledge and understanding</u> Students are encouraged to apply the fundamental concepts to the solution of problems with an experimental relevance. <u>Making judgments</u> Some of the questions may stimulate individual work that will require independence of judgments. <u>Communication skills</u> Students expand their communication skills in preparation of the final oral exam and possibly associated written reports. <u>Learning skills</u>

		The wide variety of topics forces the student to establish conceptual connections among different pieces of knowledge.
3	Prerequisites and learning activities	The students must possess a good knowledge of classical and quantum physics, mathematical methods for physics and probability theory. Knowledge in analog and digital electronics is useful.
4	Teaching methods and language	Lectures will be held in Italian or English according to the audience. Visits to research laboratories to illustrate experimental equipments and methods are planned. Main suggested textbooks are: W.R. Leo, *"Techniques for Nuclear and Particle Physics Experiments"*, Springer-Verlag, II ed. (1994). G.F. Knoll, *"Radiation Detection and Measurement"*, Wiley, III ed. (2000). Lecture notes in English are also distributed.
5	Assessment methods and criteria	The assessment is based on an oral examination with questions on the major topics treated in the lectures. Ability to apply concepts to problems not fully treated in the lectures is a prerequisite for obtaining higher grades.

Programme of "LABORATORIO DI FISICA MAGISTRALE" ***" ADVANCED PHYSICS LABORATORY"***		
DF0015, Compulsory *for all Tracks* **Second Cycle Degree in PHYSICS, 1st year, 1st semester**		
Number of ECTS credits: 6 (Workload is 150 Hours; 1 credit=25 hours)		
Teachers: Marcello De Lauretis, Adriano Filipponi, Giovanni Pitari, Giovanni Piano Mortari		
1	Course objectives	The course aims to provide the knowledge of the working principle of instruments used in research of any of the following fields: Space Physics (M. De Lauretis), Condensed Matter Physics (A. Filipponi), Earth and Environment Physics (G. Pitari), Nuclear and Astroparticle Physics (G.B. Piano Mortari). The student will have the opportunity to pursue one of the themes proposed. The course aims at providing: Track 1) EARTH and ENVIRONMENTAL PHYSICS the laboratory skills needed to the comprehension of basic experimental methodologies used in the research in atmospheric physics. Track 2) CONDESED MATTER PHYSICS experimental abilities and independence relevant to experimental research in condensed matter physics Track 3) SPACE PHYSICS knowledge of the working principles of instruments geomagnetic field measurements, and the acquisition and processing, in the time and frequency domains, of the related experimental data Track 4) NUCLEAR AND ASTROPARTICLE PHYSICS experimental methods in nuclear and particle physics, investigate main phenomena of radiation interaction with matter (detectors), measure fundamental quantities in particle physics.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course include: 1) EARTH and ENVIRONMENTAL PHYSICS - Methodologies of measurements and data acquisition, main features of instruments. - Methodologies of data analysis and treatment. - Full design and execution of an experiment in atmospheric physics. - Preparation of a detailed written report, with description of instrumentation, methodologies, experimental results and conclusions. - Participation to other experiments in atmospheric and terrestrial physics. 2) CONDESED MATTER PHYSICS The students are introduced to basic equipment relevant to experimental research in condensed matter physics and to specific hardware and software strategies for data acquisition and analysis available in the open-source world. Students are challenged with one or more physical problems that require investigation using an experimental approach 3) SPACE PHYSICS

		- Overview of geomagnetic field instrumentations and in-depth study on the Fluxgate and Search-Coil magnetometers. - Acquisition of experimental data, carried out using “LABVIEW”, a development environment to design and test measurements and control systems. - Analysis of the digitized data, in the time and frequency domains, performed using “MATLAB”, a high level language for numerical computation and programming. - Laboratory Experimental Activity. 4) NUCLEAR AND ASTROPARTICLE PHYSICS - Detectors and electronics in nuclear and particle physics, data acquisition and data analysis. MonteCarlo programs and simulation of detectors and interactions. - Experiments with gamma rays and cosmic radiation (muons): from preparation and mounting of experimental apparata, to data collection and analysis. - Gamma rays: study of energy spectra on different radioactive sources, Compton effect and measurement on electron mass, time concidence and angular correlation in 2-gamma decays, measurement of the speed of light in 2-gamma decays. - Cosmic rays: energy deposition in particle interaction with matter (detectors), lifetime of the muon, electron energy spectrum in muon decay and measurement of muon mass. On successful completion of the course the student are expected to: <u>- have acquired knowledge and understanding</u> of the specific physical issues and of the related experimental techniques. They will learn the working principle of the instruments and techniques that will be assembled/developed during the course. <u>-be able to apply knowledge and understanding</u> as outcome of the laboratory hands-on character of the course, specifically suited to apply all related knowledge (both theoretical and experimental) to the specific problems. The ability to apply the knowledge and understand the experimental results is a prerequisite for a successful outcome. <u>-be able to make judgments</u> in the set-up and optimization of the experimental apparatus and in the critical evaluation of the results. <u>-have acquired communication skills</u> as direct result of theoretical and practical learning activities requires communication skills both as a result of the teamwork experience and for the preparation of the final written report and oral presentation. <u>-have acquired the capacities to continue learning</u> as literature search and physics learning skills are constantly needed to fulfill the laboratory activities: students are stimulated to look for new experimental strategies to pursue and theoretical information to interpret experimental results.
3	Prerequisites and learning activities	Basic knowledge of General Physics, in particular Electromagnetism and Electronics, and be familiar with the use of computing facilities and experimental physics procedures that will be further developed in the course.
4	Teaching methods and language	The method of teaching consists of lectures and laboratory experimentations followed by the drafting of the report. Lectures will be held in Italian or English according to the audience. The students are divided into small groups (typically two/three students each) and challenged with specific experimental physics problems that require to assemble and use a simple experimental apparatus, to develop a suitable acquisition software, to acquire and analyze experimental data and to draw conclusions. The teacher assists the students for about 30/60 hours providing all relevant information for the task. Ref. Text books SPACE PHYSICS: Teacher notes; - D. Halliday, R. Resnick, *FISICA (ELETTROMAGNETISMO)*, Casa Editrice Ambrosiana – Milano (1968, o versioni più recenti); - Richard P. Feynman, Robert B. Leighton, Matthew Sands, *The Feynman lectures on physics,* vol 2, Addison-Wesley. -Julius S. Bendat - Allan G. Piersol, *Random Data*, John Wiley & Sons Inc. Ref. Text books CONDENSED MATTER PHYSICS: Lecture notes. Selected published papers on specific topics. Relevant literature to the particular experiment under study. Ref. Text books EARTH and ENVIRONMENTAL PHYSICS: Lecture notes. Jacobson, M.Z.: *Atmospheric pollution,* (Cambridge University Press, 2002). Selected published papers on specific topics. Ref. Text books NUCLEAR AND ASTROPARTICLE PHYSICS:

		W.R. Leo, *"Techniques for Nuclear and Particle Physics Experiments"*, Springer-Verlag, II ed. (1994). A.C. Melissinos, J. Napolitano, *"Experiments in Modern Physics"*, Academic Press, II ed. (2003). G.F. Knoll, *"Radiation Detection and Measurement"*, Wiley, III ed. (2000). Lecture notes, published papers, instrumentation manuals.
5	Assessment methods and criteria	Individual/team written reports and oral exam.

Programme of "MECCANICA STATISTICA" ***"STATISTICAL MECHANICS"***		
F0271, Compulsory *for all Tracks* **2nd Cycle Degree in PHYSICS, 1st year , 1st semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teacher: Sergio Ciuchi		
1	Course objectives	The goal of this course is to provide elements of basic statistical mechanics i.e. the mechanical description of the thermal equilibrium and how this state is attained. On successful completion of this course the student should understand the fundamental concepts of both quantum and classical statistical mechanics and their applications to the study of phase transitions and critical phenomena.
2	Course content and Learning outcomes (Dublin descriptors)	The topics of the course are: 1. Complements of quantum mechanics: second quantization and thermal S matrix. 2. Thermodynamics: thermodynamics of open systems. thermal fluctuations. 3. The foundations of statistical mechanics: Liouville theorem and evolution of density matrix, evolution of reduced density matrices and probabilities, BBGKY hierarchy, a system in a thermal bath. Boltzmann equation. 4. Classical and Quantum statistical mechanics: ensembles theory and applications. 5. Phase transitions: first and second order phase transitions, mean-field theory, Landau theory of phase transitions. On successful completion of this module, the student should - acquire knowledge and understanding of the foundations of statistical - acquire knowledge and understanding relations between statistical mechanics and calculations of thermodynamic quantities - have knowledge and understanding of the most common applications of both classical and quantum statistical mechanics to the study of phase diagrams of interacting fluids and to the phase transition problem. - demonstrate skills in theoretical modeling a physical problem and solving it using the formalism developed in the course. - demonstrate skills: Demonstrate on examination and through weekly homework assignments, proficiency in solving problems. - demonstrate capacity for reading and understand advanced texts on the subject as well as research papers.
3	Prerequisites and learning activities	The student must be familiar with analytical mechanics and basic quantum mechanics.
4	Teaching methods and language	Lectures will be held in Italian or English according to the audience Ref. text books K. Huang *"Statistical Mechanics"* 2nd edition Wiley (1987) A. Reichl "*A modern course in statistical physics"* 2nd edition Wiley (1998) D. Chandler *"Introduction to modern statistical mechanics"* Oxford (1987) D. Wu and D. Chandler *"Introduction to modern statistical mechanics"* solution manuals D.A.R. Dalvit et al. *"Problems on statistical mechanics*" *Oxford (1987)* P.W. Anderson *"Basic Notions of Condensed Matter Physics"* Benjamin (1984)
5	Assessment methods and criteria	Weekly exercises and oral exam at the end of the course.

Programme of “FISICA DELLA MATERIA” *“CONDENSED MATTER PHYSICS”*		
F0228, Compulsory *for all Tracks* **2nd Cycle Degree in PHYSICS, 1st year , 1st semester**		
Number of ECTS credits: 6 (workload is 180 hours; 1 credit = 30 hours)		
Teacher: Cinzia Casieri, Franco D’Orazio		
1	Course objectives	The goal of this course is to provide a deeper definition and description of the problems inherent to the physics of atoms, molecules, and solids. On successful completion of this module, the student should understand how their knowledge of quantum physics may be applied to describe the structure of matter and explain many of the related physical phenomena which are observed. In particular, the student will become familiar with the electronic states in atoms, molecules, solids and with the dynamics of atoms and ions in molecules and solids. He will also be able to interpret many of the spectroscopic responses of matter.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: -Atomic Physics: fine structure in multi-electron atoms; hyperphine interaction; atoms in magnetic fields, Zeeman and Paschen-Back effect; Schroedinger equation for 2-electron atoms; equivalent and non-equivalent electrons; central field approximation for many-electron atoms. -Physics of Molecules: Born-Oppenheimer approximation; adiabatic approximation and separation of motion for nuclei and electrons. Schroedinger equation for nuclei; rotational, vibrational, and roto-vibrational properties of diatomic and polyatomic molecules; Microwave and IR spectroscopy, light diffusion, elastic and inelastic scattering: Raman Scattering; roto-vibrational and rotational spectra; electronic transitions, fluorescence and phosphorescence. -Solid State Physics: Hamiltonian of the nuclei in a harmonic periodic approximation: lattice dynamics, phonons, lattice specific heat; Hamiltonian of the electrons in a crystal: free-electron approximation for metals, Fermi energy, electronic specific heat. Quasi-free electrons approximation and tight binding approximation; electronic bands, number of states, metals, semiconductors, insulators. On successful completion of this module, the student should - have a general knowledge of the basic electronic properties of atoms, molecules, solids; - know the physical phenomena associated to the motion of nuclei in molecules and solids; - be able to understand and interpret the basic spectroscopic response of atoms and molecules in different spectral ranges; - understand the basic concepts of solids structure and energy band formation; - show problem solving ability in applying her/his knowledge to interpret, demonstrate, explain, obtain physical observations proposed in the written examination; - demonstrate capacity for reading and understanding the different topics from various text books.
3	Prerequisites and learning activities	The student must know the fundaments of quantum mechanics and their application to simpler atomic systems such as the hydrogen atom, and the fundaments of molecular bonding. These arguments are contained in the course “Fundamental of Condensed Matter Physics” in the 1st cycle Degree in PHYSICS.
4	Teaching methods and language	Lectures and exercises. Language: Italian/English Ref. Text books B.H. Bransden and C.J. Joachain *Physics of atoms and molecules* (J. Wiley & Sons) H. Haken and H.C. Wolf *Atomic and Quantum physics* (Springer-Verlag) Rigamonti, P. Carretta *An Introductory Course with Problems and Solutions* (Springer) C. Kittel *Introduzione alla fisica dello stato solido* (Boringhieri) N.W. Ashcroft and M.D. Mermin *Solid State Physics* (McGraw-Hill)
5	Assessment methods and criteria	Written and oral exam

Programme of "METEOROLOGIA DINAMICA" *"DYNAMIC METEOROLOGY"*		
DF0013, Compulsory *for all Tracks* **2nd Cycle Degree in PHYSICS, 1st year , 1st semester**		
Number of ECTS credits: 6 (Workload is 150 hours, 1 credit = 25 hours)		
Teacher: Rossella Ferretti		
1	Course objectives	The course module illustrates the fundamentals of atmospheric motion as solution of fundamental equations of hydrodynamics and thermodynamics. The course provides the scientific basis for the understanding of the physical role of the atmospheric motion in determining the observed weather at all scales.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: Scale analysis to identify the dynamic processes in balanced flows, describe the characteristics of the balanced flow, and use the equations of motion to explain quasi-geostrophy, ageostrophyc and structure and propagation of waves in the atmosphere. Coordinate systems, key components of an NWP model and explain differences between type of models. Strength and weakness of NWP, atmospheric predictability. NWP data assimilation Students are expected to • Have acquired knowledge and understanding of the equation of motion in terms of forces and frame of reference. • Have profound knowledge of atmospheric motion. • Be able to apply knowledge and understanding on characteristics and limitation of numerical weather prediction (NWP) for short, medium and long range forecasting. • Be able to make informed judgments and choices on the suitability of models approximations and on the applications of NWP. • Demonstrate skills for communicating the results of their studies in the course with seminars • Have developed capacities to continue learning in this rapidly growing specific field (keep on track with the scientific literature).
3	Prerequisites and learning activities	A solid background in higher mathematics and physics is required. Knowledge in fluid dynamics will help the students.
4	Teaching methods and language	Lectures, seminars. Lectures are given in English upon request of non-native Italian speakers. Ref. Text book: R.J Holton *"An Introduction to Dynamic Meteorology"*, Academic Press, 1972. E. Kalnay *"Atmospheric Modeling, Data Assimilation and Predictability"* , Cambridge University Press, 2003
5	Assessment methods and criteria	Oral exam and/or a case study chosen by the applicant by using NWP.

Programme of "FISICA DELLO STATO SOLIDO" *"SOLID STATE PHYSICS"*		
DF0008, Compulsory *Track 2 and 3* **2nd Cycle in PHYSICS,** *Track* **2: 1st year , 2nd semester,** *Track 3:* **2nd year, 2nd semester**		
Number of ECTS credits: 10 (workload is 250 hours; 1 credit = 25 hours)		
Teacher: Alessandra Continenza		
1	Course objectives	The goal of this course is to provide the elements of solid state physics, i.e. of the basic understanding of the electrical, optical and magnetic properties of condensed matter. On successful completion of this module, the student should understand the fundamental concepts of condensed matter physics and to apply classical and quantum physics theoretical tools to understand and explain the properties of metals, semiconductors, and insulators. The student should also be familiar with the most common experimental techniques to measure material properties.

2	Dublin descriptors	Topics of the module include: General Physics and Symmetry teory: The basics of crystallography, real and reciprocal space, symmetries. Transport theory: the Drude and Sommerfield theories, Boltzman theory for transport in solids Dynamical properties: Phonons in solids and their implications on the physical properties of the materials (thermal, equilibrium, transport); elastic properties of materials. Electronic properties: Band theory and basic approximations to describe electrons in solids. Electron-electron interactions and basic approximations (Hartree-Fock, RPA, Many-body) Magnetic properties of materials: magnetic properties of condensed matter, diamagnetism, paramagnetism, ferromagnetism. Localized versus itinerant magnetism, various models (Heisenberg Hamiltonian and mean-field theory, Hubbard-Stoner, RKKY-interaction); new materials and applications Superconductivity: phenomenology of superconductors, Landau-Ginzburg theory, BCS-theory, novel high-temperature superconductors. On successful completion of this module, the student should - have profound knowledge of the basic electronic properties of solids, - have knowledge and understanding of the most common physical properties of materials, - understand and explain the physical properties of condensed matter; - understand the fundamental concepts of quantum physics and their connections/applications to condensed matter and be aware of potential applications in other fields, - demonstrate skills in physical reasoning and facing novel problems in solid state physics and ability to use the acquired tools and knowledge to suggest meaningful experiments to probe a given property in a not-previously known material and to critically assess the validity of the procedure proposed. - 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 applied to condensed matter physics and be familiar with the mathematical tools involved.
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books Ashcroft and Mermin, *Solid state Physics*, Saunders College, 1976 Grosso, Pastori Parravicini: *Solid State Physics*, Academic Press (2000)
5	Assessment methods	Written and oral exam.

Programme of "FISICA DELLE NANOSTRUTTURE"
"PHYSICS OF THE NANOSTRUCTURES"

DF0011, Compulsory *Track 2*
Second Cycle Degree in PHYSICS, 2nd year, 2nd semester

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

Teachers: Luca Ottaviano and Sandro Santucci

1	Course objectives	The course module illustrates the fundamentals of physics of nanostructures and low dimensional systems with special emphasis on graphene and two dimensional materials, from this point of view it stands at the forefront of nanotechnology and condensed matter physics.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: General physical (structural and electronic properties) of systems with reduced dimensionality, Graphene, CNT, other 2D materials, scanning probe microscopy/spectroscopy/lithography, other experimental probes for the investigation of nanostructures. On successful completion of this module, the student should: - Acquire knowledge and understanding on one and two dimensional physical systems; - have profound knowledge of structural and electronic properties of graphene, carbon nanotubes, and other two dimensional materials; - have knowledge and understanding of experimental techniques to investigate the physical properties of nanostructures; - understand and explain the physical properties of nanostructures;

		- understand: Why "nano" is different; - be able to apply knowledge and understanding on potential novel nanostructures; - demonstrate skill in facing novel problem at the forefront of 2D condensed matter-physics and ability to stress the differences with the "bulk" properties; -be able to make informed judgments and choices on the suitability of models and approximations at the nanoscale; - demonstrate capacity to read and understand other texts on related topics and to continue learning in this rapidly growing specific fields (keep on track with the scientific literature); - Demonstrate ability in communicating the results of their studies in the course with seminars.
3	Prerequisites and learning activities	A good background in quantum mechanics and solid state physics with specific reference to methods to determine the structural and electronic properties of the condensed matter is a preferable prerequisite of the course.
4	Teaching methods and language	Lectures, seminars of senior students, laboratory demonstrations. Ref. Text books: Lecture notes. Lectures (or summaries) are given in English upon request of non-native Italian speakers. R. Saito, Gene Dresselhaus, Mildred S. Dresselhaus Dresselhaus *"Physical Properties of Carbon Nanotubes ",* Imperial College Press, 1998
5	Assessment methods and criteria	Oral exam and seminar on a topic not dealt with in from lectures and chosen by the applicant.

Programme of "FISICA NUCLEARE E SUBNUCLEARE" ***"NUCLEAR AND SUBNUCLEAR PHYSICS"***		
F0244, Compulsory *all Tracks* **2nd Cycle in PHYSICS,** *Tracks 1,2*: **2nd year , 2nd semester,** *Track 3,4:* **1st year, 2nd semester**		
Number of ECTS credits: 6 (Workload is 150 hours, 1 credit = 25 hours)		
Teacher: Sergio Petrera		
1	Course objectives	Experimental methods in nuclear physics. The nucleus structure. Nuclear decays. Nuclear models. Fundamental interactions. Electromagnetic processes. Hadrons and quarks. Weak interactions and leptons.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - Relativistic kinematics. - Passage of particles through matter. Particle detectors. - Nuclear structure: composition, radius and mass. Alpha, beta and gamma decays. - Liquid drop model. Shell model. - Fundamental interactions and their coupling constants. - Interactions and their mediators. Feynman diagrams. QED, the Yukawa theory, Fermi theory of beta decay. - Hadronic physics. The quark model. Color and QCD. - Leptons. Weak interactions. Electroweak unification. On successful completion of this module, the student should - Acquire knowledge and understanding of the fundamental concepts in nuclear and particle physics. - Acquire knowledge in the use of current theoretical models and experimental methods. - Be able to apply such knowledge to the interpretation of data from nuclear and particle 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 communicating 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 DELLO SPAZIO" ***"SPACE PHYSICS"***		
DF0006, Compulsory *Track 3* **Second Cycle Degree in PHYSICS, 1st year, 1st semester**		
Number of ECTS credits: 10 (Workload is 250 hours, 1 credit = 25 hours)		
Teacher: Umberto Villante		
1	Course objectives	The course in organized in two parts: the first part illustrates basic elements of the physics of astrophysical plasmas and magnetohydrodynamics. The second part illustrates the fundamental aspects of the physics of the heliosphere (mostly, solar wind and interplanetary magnetic field) including basic elements of the physics of the solar atmosphere and solar activity.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the course include: - Basic elements of plasma physics. - Propagation of waves in ionized media. - Magnetohydrodynamic approximation. - Frozen in Fields. - MHD waves and discontinuities. - Physics of the solar atmosphere. - Instruments for Space Physics. - Solar wind and interplanetary magnetic field. On successful completion of this course the student should: -Have acquired a good knowledge and understanding of magnetohydrodynamcs and interplanetary space physics; -Have a good knowledge of the experimental apparatus and techniques for measuring interplanetary plasmas and magnetic field and ability to apply such knowledge to the treatment of space plasmas; -Have acquired good knowledge of the techniques for the data analysis and ability to apply them; -Demonstrate skills in facing novel problems in the field; -be able to make judgments and choices on the suitability of models in comparison with the progressive acquisition of experimental observations from spacecraft; -Demonstrate capacity for reading and understanding texts and papers on related topics and for a continuous learning in this field.
3	Prerequisites and learning activities	Good background in general physic and electromagnetism.
4	Teaching methods and language	Lectures, seminars and jointed data analysis from spacecraft. Lectures can be given in English upon request of non-native Italian speakers. Text books: *Notes and scientific papers.* Ferraro-Plumpton: *An introduction to Magnotofluid Mechanics,* Oxford University Press. Kivelson-Russell: *An Introduction to Space Physics*, Cambridge University Press Kamide-Chian*: Handbook of Solar-Terrestrial Physics*, Springer.
5	Assessment methods and criteria	Oral exam

Programme of "FISICA DELLA MAGNETOSFERA" ***"PHYSICS OF THE MAGNETOSPHERE"***		
DF0014, Compulsory *Track 3* **Second Cycle Degree in PHYSICS, 1st year, 2nd semester**		
Number of ECTS credits: 10 (Workload is 250 hours, 1 credit = 25 hours)		
Teacher: Umberto Villante		
1	Course objectives	The course illustrates basic elements of the geomagnetic field, of its interaction with the solar wind, of the physics of the Earth's (and planetary) magnetosphere, of the current systems in the Earth surrounding space. Attention is also dedicated to aspects of the Space Weather (such as solar and magnetospheric storms).
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the course include: - Basic elements of the geomagnetic field. - The interaction between the solar wind and the geomagnetic field. - Magnetospheric currents and fields. - Geomagnetic instruments and arrays. - Solar and magnetospheric storms and Space Weather On successful completion of this course the student should: -Have a good knowledge of the physics of the Earth's magnetosphere. -Have acquired knowledge and understanding of the physics of the magnetosphere and Space Weather. -Have acquired knowledge in the use of current model representations of the magnetospheric field and ability to apply such knowledge to the use of data from spacecraft and ground-based magnetometer arrays. -Have a good knowledge of the experimental apparatus and techniques for measuring magnetospheric plasmas and magnetic field. -Have a good knowledge of the techniques for the data analysis and ability to apply them. -Demonstrate skills in facing novel problems in the field. -have acquired skills in making judgments and choices on the suitability of models in comparison with the progressive acquisition of experimental observations. -Demonstrate capacities for reading and understanding texts and papers on related topics and to continue learning in this field.
3	Prerequisites and learning activities	Good background in magnetohydrodynamics and physics of the interplanetary space.
4	Teaching methods and language	Lectures, seminars and jointed data analysis from spacecraft and ground-based magnetometer arrays. Lectures can be given in English upon request of non-native Italian speakers. Text books Notes and scientific papers. Kivelson-Russell: *An Introduction to Space Physics*, Cambridge University Press. Kamide-Chian: *Handbook of Solar-Terrestrial Physics*, Springer. Hargreaves, *The Solar-Terrestrial Environment*, Cambridge University Press Gombosi, *Physics of the Space Environment*, Cambridge University Press;
5	Assessment methods and criteria	Oral exam

Programme of "FISICA TEORICA" ***"THEORETICAL PHYSICS"***		
F0252, Compulsory *Track 4* **Second Cycle Degree in PHYSICS, 2nd year, 2nd semester**		
Number of ECTS credits: 6 (Workload is 150 hours, 1 credit = 25 hours)		
Teacher: Luigi Pilo		
1	Course objectives	The course intends to provide the students with the basic knowledge of relativistic quantum field theory enabling them to understand the profound transformation of the interpretation of the physical world during the past century. The student will learn the key mathematical tools needed for it.

2	Course content and Learning outcomes (Dublin descriptors)	Topics of the course: - From quantum mechanics to quantum field theory. - Second quantization, field operators. - Scalar field quantization. - Correlation functions and S matrix. - Perturbative expansion. Feynman propoagator and Feynman rules. - Spinorial representation of the Lorentz group. Weyl, Majorana and Dirac spinors. - Quantization of spinor fields. - Interactions, perturbative S matrix, propagators and Feynman rules. - Quantization of the electromagnetic field in the Coulomb gauge. Photon propagator. - Feynman rules for QED. - Basic process in QED On successful completion of this module, the student should - acquire knowledge and understanding of: elementary quantum field theory, canonical quantization, perturbative expansion of the S matrix. Quantization of the electromagnetic field. Feynman rules for quantum electrodynamics. - demonstrate skills: problem solving in the assigned homework; using basic tools of relativistic quantum field theory, compute the cross section for elementary processes in QED in the oral exam at the end of the course. - acquire capacities to continue learning: proceed in the study of the physics of fundamental interactions and many body physics. - be able to communicate the acquired knowledge with clear and suitable scientific language.
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. Text book: M. Srednicki "*Quantum Field Theory*", Cambridge University Press
5	Assessment methods and criteria	Students are supposed to solve assigned set of problems as homework. Oral exam at the end of the class

Programme of "FISICA DELLE PARTICELLE" ***"PARTICLE PHYSICS"***		
DF0010, Compulsory *Track 4* **Second Cycle Degree in PHYSICS, 1st year, 2nd semester**		
Number of ECTS credits: 10 Workload is the global work. 250 Hours.		
Teacher: Umberto Villante		
1	Course objectives	The course module illustrates the Standard Model of particles and interactions with emphasis on phenomenological aspects of weak and strong interactions. A description of the key experiments for the development of the Standard Model is also provided.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: Elements of quantum field theory: free fields, local and global symmetries, QED. Phenomenological aspects of weak interactions and their description in the Standard Model; Phenomenological aspects of strong interactions and their description in the Standard Model; Evidences for physics beyond the Standard Model (neutrino oscillations, dark matter, etc). On successful completion of this module, the student should: - have knowledge of the phenomenological aspects of the Standard Model; - have knowledge and understanding on the phenomenological aspects of weak and strong interactions; - have knowledge and understanding of the experimental techniques in particle physics; - understand the importance of experiments for the development of the Standard Model - be able to apply knowledge and understanding to calculate quantitatively selected processes in particle physics: - demonstrate skills in calculating processes in particle physics and in making informed

		judgments and choices on the validity of the standard model and on the evidences of possible extensions; - demonstrate ability to communicate the results of their studies in the course; - have capacities for reading and understanding other texts on related topics and to continue learning in this rapidly growing specific field (keep on track with the scientific literature).
3	Prerequisites and learning activities	A good background in quantum mechanics and in quantum field theory
4	Teaching methods and language	Lectures and seminars. Lectures (or summaries) are given in English upon request of non-native Italian speakers. Ref. Text books: Lecture notes. - F. Halzen and A.D. Martin, *"Quarks and Leptons"*, Wiley Ed.; - B.R. Martin and G. Shaw, *"Particle Physics"*, Wiley Ed.; - D.H. Perkins, *"Introduction to High Energy Physics"*, Cambridge Ed.; - R. Cahn and G. Goldhaber, *"The Experimental Foundation of Particle Physics"*, Cambridge Univ. Press
5	Assessment methods and criteria	Oral exam.

Programme of "TEORIE DI GAUGE"
"GAUGE THEORIES"

F0331, compulsory *Track 4*
Second Cycle Degree in PHYSICS, 1st year, 2nd semester

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

Teacher: Luigi Pilo

1	Course objectives	Aims of this course is to provide the key notions of Gauge Theories and their applications to Higgs mechanism interpretation and the construction of the standard model.
2	Course content and Learning outcomes (Dublin descriptors)	The course topics are: - Spontaneous symmetry breaking and the Goldstone Theorem. - Path Integral formulation of quantum field theory. - Abelian and non Abelian gauge theories. Geometrical interpretation. - Quantization of non Abelian gauge theories. - Asymptotic freedom. - Higgs mechanism. - The standard model. On successful completion of this module, the student should - acquire knowledge and understanding of: basic notion of gauge theories, spontaneous symmetry breaking. Path integral formulation. Standard model. - demonstrate skills: problem solving in the assigned homework; basic knowledge of the standard model of interactions. - Capacities to continue learning: proceed in the study of the physics of fundamental interactions and many body physics.
3	Prerequisites and learning activities	Background in elementary quantum field theory and electromagnetism and some basic notions of special relativity.
4	Teaching methods and language	Lectures in Italian or in English. Text book: M. Srednicki *Quantum Field Theory*, Cambridge University Press
5	Assessment methods and criteria	Students are supposed to solve assigned set of problems as homework. Oral exam at the end of the class.

Programme of “TRASFERIMENTO RADIATIVO” *“RADIATIVE TRANSFER”*		
DF0012 , Compulsory *Track 1* **Second Cycle Degree in PHYSICS, 2nd year, 1st semester**		
Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)		
Teacher: Piero Di Carlo		
1	Course objectives and Learning outcomes	The goal of this course is to provide the principles of the interaction between radiation and matter, focusing primarily on solar radiation and Earth’s atmosphere. Beginning with basic concepts of electromagnetic waves and solar radiation, followed by absorption and scattering of the solar radiation. The course introduces the student to the basic concepts of single and multiple scattering. Topics include thermal radiation of the atmosphere, scattering of aerosols and ice crystal, radiative forcing and application of radiative transfer theories to Earth’s atmosphere. On successful completion of this module, the student should understand the fundamental concepts of radiative transfer theories. The student should also be familiar with concepts of radiative transfer applications to Earth’s atmosphere and solve common problems of absorption, emission and scattering of the radiation.
2	Dublin descriptors	Topics of the module include: - Basic electromagnetic waves: The electromagnetic wave equations, black body radiation, absorption and spectral lines formation. - Solar radiation: spectrum and characteristics, absorption and scattering of the Solar radiation in the atmosphere. - Thermal radiation: infrared absorption and emission in the atmosphere. - Scattering of atmospheric particles. - Radiative transfer in the atmosphere: solutions for one-dimensional slab problems with absorption, emission and scattering with various boundary conditions. - Radiation and climate: energy balance and forcing radiative. - Application: basic concepts of remote sensing and atmospheric applications. On successful completion of this module, the student should: - have profound knowledge of the basic concepts in radiative transfer; - have knowledge and understanding of the most common physical phenomena related to radiative transfer; - understand and explain the properties of the interaction between the radiation and the matter; - understand the fundamental concepts of scattering and absorption of the radiation; - demonstrate skills in facing novel problems in basics physics of the atmosphere and ability to use the acquired tools and knowledge to solve radiative problems involving absorption, emission, transmission, and scattering; - demonstrate capacity for reading and understanding other texts on relate topics.
3	Prerequisites and learning activities	The student must be familiar with the basic notions of mathematic calculus (mainly derivatives and integrals, vector calculus, basics of differential calculus) and the basic concepts of mechanics and electromagnetism.
4	Teaching methods and language	Lectures and exercises. Language: Italian / English Ref. Text books: • Liou, Kuo-Nan. *An Introduction to Atmospheric Radiation*. (2nd ed). Academic Press, 2002. • Bohren C. F. and Clothiaux E. E., *Fundamentals of Atmospheric Radiation: An Introduction with 400 Problems.* Wiley-VCH Verlag GmbH & Co, 2006. • Petty G. W. *A First Course in Atmospheric Radiation* (2nd ed.), Sundog Publishing, 2006. • Goody, R., and Y. Yung. *Atmospheric Radiation*. Oxford University Press, 1995.
5	Assessment methods	Oral exam.

<table>
<tr><td colspan="3">Programme of “SPETTROSCOPIA”
“CORRELATION FUNCTION IN SPECTROSCOPY”</td></tr>
<tr><td colspan="3">F0272, Compulsory Track 2
Second Cycle Degree in PHYSICS, 2nd year , 1st semester</td></tr>
<tr><td colspan="3">Number of ECTS credits: 6 (workload is 150 hours; 1 credit = 25 hours)</td></tr>
<tr><td colspan="3">Teacher: Michele Nardone</td></tr>
<tr><td>1</td><td>Course objectives</td><td>The goal of this course is to introduce the students to the use of the language of space-time correlation functions in interpreting a variety of spectroscopic results in condensed matter physics, with particular reference to fluids and disordered systems, and in relating them to susceptibilities as well as to transport coefficients.
On successful completion of this course the student will have a unified view of several scattering and absorption spectroscopies and will become familiar with the most fundamental models used in describing the spectroscopic responses. He will thus be able to access more profitably the recent scientific literature on the dynamical properties of condensed matter, particularly those describing spectroscopic and as computer simulations.</td></tr>
<tr><td>2</td><td>Course content and Learning outcomes (Dublin descriptors)</td><td>The topics of the course are:
1- General theory: Spectra and time correlation functions. Moment and cumulant expansion and continued fraction representation. Susceptibilities and linear response, after effect functions. Correlation times and transport. The fluctuation dissipation theorem. Quantum and classical analogs. The memory function formalism.
2- Specific spectral responses: Absorption spectroscopy: general phenomenological approach, infrared absorption spectroscopy and Einstein coefficients, relation to the complex dielectric susceptibility and complex conductivity. Neutron scattering spectroscopy: inelastic scattering cross section, diffraction in fluids and solids, single particle and collective excitations. Scattering of photons of visible light and X-Rays, Brillouin –Raman spectroscopy, X-Ray diffraction and inelastic scattering.
3- Model systems: Freely recoiling particles. Damped harmonic oscillator and phonons. Vibrational dephasing. Free rotors and rotational diffusion models. Density fluctuations and the hydrodynamics of simple fluids.

Intended Learning Outcomes:
<u>-Acquiring knowledge and understanding</u> is an expected result from all four topics. Knowledge on how the unifying language of space-time correlation functions can be used to compare results obtained from different spectroscopies and understanding the results in terms of simple physical models.
<u>-Applying knowledge and understanding</u> to determine the size distribution profile of small particles and to probe the behavior of complex is an expected key skill from the course.
<u>-Making informed judgments and choices</u> , i.e. the ability to critically analyze the outcome of absorption and scattering experiments performed using different kinds of radiation, is one of the main ability the student should acquire.
<u>-Communicating knowledge and understanding</u> to colleagues and teachers by using appropriate scientific language.
<u>-Capacities to continue learning</u>
Learning capacities will be improved with particular reference to advanced application of modern spectroscopic techniques such as those available at International research facilities.</td></tr>
<tr><td>3</td><td>Prerequisites and learning activities</td><td>The student must be familiar with basic calculus and possess a good knowledge of classical physics: mechanics, thermodynamics and electromagnetism.</td></tr>
<tr><td>4</td><td>Teaching methods and language</td><td>Lectures will be held in Italian or English according to the audience
Ref. Text books: besides the lecture notes available on the e-learning site the students should refer to:
- Wang, ”Spectroscopy of condensed media”, Academic Press
- Sow-Hsin Chen and Michael Kotlarchyk, ”Interaction of photons and neutrons with matter”, World Scientific.
- G. L. Squire, Introduction to the theory of Thermal Neutron Scattering, Dover, 1978
- B.J. Berne and R. Pecora, ”Dynamic Light Scattering: with Applications to Chemistry, Biology and Physics”. Dover, Mineola, N.Y., 2000</td></tr>
<tr><td>5</td><td>Assessment methods and criteria</td><td>Oral exam or seminar on a specific subject only partially covered during the lectures.</td></tr>
</table>

Programme of "FISICA DELLO SPAZIO CIRCUMTERRESTRE" *"PHYSICS OF THE CIRCUMTERRESTRIAL SPACE"*		
F0234, Compulsory *Track 3* **Second Cycle Degree in PHYSICS, 2nd year, 2nd semester**		
Number of ECTS credits: 6 (Workload is 150 hours, 1 credit = 25 hours)		
Teacher: Massimo Vellante		
1	Course objectives	The course is designed to provide basic knowledge on the physics of the upper atmosphere of the Earth (ionosphere and plasmasphere), as well as on diagnostic methods of these regions by ground-detected electromagnetic waves in different frequency regimes.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: -Ionosphere: photoionization, recombination processes, alpha- and beta-Chapman layers, F region, ambipolar plasma diffusion; ionospheric sounding by radio waves, ordinary and extraordinary waves; electric conductivity in the ionosphere, low and middle latitude current systems, their reconstruction by spherical harmonic analysis of the diurnal variation of the geomagnetic field. -Plasmasphere: physical properties, ionosphere-plasmasphere coupling, corotational and solar wind-induced electric fields, plasmapause formation, plasmasphere diagnostics by whistler waves. -ULF waves in the magnetosphere: geomagnetic pulsations, review of MHD waves in a uniform medium, MHD waves in a dipole field, toroidal and poloidal modes, standing oscillations of the geomagnetic field lines, Field Line Resonance (FLR) model, remote sensing of the magnetospheric plasma mass density by FLR ground detection, ionospheric effect on ground transmission of ULF waves; solar wind controlled pulsations: Kelvin-Helmholtz instability at the magnetopause, transmission into the magnetosphere of bowshock associated upstream waves. On successful completion of this module, the student should: - acquire knowledge and understanding of the basic physical processes which lead to the formation of the ionosphere and plasmasphere regions of the Earth's upper atmosphere. - acquire knowledge and understanding of the properties of the more typical waves propagating in the Earth's magnetosphere/ionosphere, and their use for plasma diagnostics. - apply knowledge and understanding of these topics to conduct a research thesis. - demonstrate skills in the use of satellite data and geomagnetic measurements. - demonstrate capacity for reading and understanding other texts and research papers on related topics.
3	Prerequisites and learning activities	A good background in magnetohydrodynamics, and preferably in physics of the magnetosphere, is a prerequisite of the course.
4	Teaching methods and language	Lectures. Language: Italian or English according to the audience. Ref. Text books, lecture notes. Text books: J.K. Hargreaves, *"The solar-terrestrial environment"*, Cambridge University Press, 1992; G.K. Parks *"Physics of space plasmas"* , Addison-Wesley Publishing Company, 1991; W.D. Parkinson *"Introduction to geomagnetism"*, Scottish Academic Press, 1983.
5	Assessment methods	Oral exam.

Programme of "RELATIVITA' GENERALE E COSMOLOGIA" *"GENERAL RELATIVITY AND COSMOLOGY"*		
F0240, Compulsory *Track 4* **Second Cycle Degree in PHYSICS, 2nd year, 1st semester**		
Number of ECTS credits: 6 Workload is the global work. 150 Hours.		
Teacher: Luigi Pilo		
1	Course objectives	Aims of this course are to: - to introduce the student to the challenges which theoretical physics faces today, - to provide an introduction to the general theory of relativity and cosmology which will enable the students to pursue their first steps of independent study in

		this field, - to promote skills in clear, precise, and analytical thinking.
2	Course content and Learning outcomes (Dublin descriptors)	Topics are: - Equivalence principle and its geometrical formulation - Geometric formulation of the equivalence principle. - Riemannian geometry. - Einstein equations, Bianchi identities. - Spherically symmetric solution. - Cosmological principle. - FRW metric and its dynamics. - Cosmology of the early universe. On successful completion of this module, the student should - acquire knowledge and understanding: physical foundation of general relativity. Spherically symmetric solutions. Basic knowledge of early cosmology. - understand the range of validity of Newtonian physics and the basic principles behind the General Theory of Relativity. - be able to perform calculations in tensor algebra and tensor calculus. - be able to derive the basic results in cosmology. -appreciate the experimental status of the theory and derive the classic tests. -understand the key properties of dark matter and cosmological models. - demonstrate capacities to continue learning: proceed in the study of the physics of fundamental interactions and advanced courses in general relativity and cosmology.
3	Prerequisites and learning activities	Electromagnetism, special relativity and calculus
4	Teaching methods and language	Lectures in Italian or in English. Ref. Text Books: -C.W. Misner, K.S. Thorne, J.A. Wheeler "*Gravitation*", W. H. Freeman and Co., 1973 -Carroll *"Spacetime and Geometry: An Introduction to General Relativity"*, Addison-Wesley Longman, Incorporated, 2004
5	Assessment methods and criteria	Students are supposed to solve assigned set of problems as homework. Oral exam at the end of the class

Programme of "ASTROFISICA" ***"ASTROPHYSICS"***		
F0028, Optional **Second Cycle Degree In PHYSICS, 1st year, 2nd semester**		
Number of ECTS credits: 6 (Workload is 150 hours, 1 credit = 25 hours)		
Teacher: Francesco Lorenzo Villante		
1	Course objectives	The course module illustrates basic elements of astrophysics with emphasis on stellar structure and evolution. Special attention is given to physical processes occurring in stellar interiors and to the interconnections between astrophysics and fundamental physics.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: the main astrophysical observables; the main structures of the Universe; the equilibrium equations for stars, the properties of matter and radiation in stellar interiors; the evolutionary properties of stars of different masses and the endpoints of stellar evolution; On successful completion of this module, the student should: - have knowledge of the properties of stars and of their evolution and of the Universe; - have knowledge and understanding of the properties of matter and radiation in the stellar interiors; - understand and explain the endpoints of stellar evolution; - understand: Why stars can be used as laboratories for fundamental physics; - be able to apply knowledge and understanding to predict the main properties of stars from basic principles; - be able to make informed judgments and choices on the possibility to use astrophysical systems as laboratory for fundamental physics;

		- have capacity to communicate the results of their studies in the course; - demonstrate capacity for reading and understand other texts on related topics and to continue learning in this rapidly growing specific field (keep on track with the scientific literature).
3	Prerequisites and learning activities	A good background in classical physics and basic knowledge of quantum mechanics.
4	Teaching methods and language	Lectures and seminars. Lectures (or summaries) are given in English upon request of non-native Italian speakers. Ref. Text books: Lecture notes. "V. Castellani, *"Astrofisica Stellare"*, Zanichelli; Carroll & Ostriker "*An introduction to modern astrophysics*" Addison Wesley Pub. Company; R. Kippenhan & A. Weigert "*Stellar Structure and Evolution*" Springer-Verlag (selected chapters)
5	Assessment methods and criteria	Oral exam.

Programme of "LABORATORIO DI NANOTECNOLOGIE" ***NANOTECHNOLOGY LABORATORY***		
F0329, Optional **Second Cycle Degree in PHYSICS, 2nd year, 1st semester**		
Number of ECTS credits: 6 (Workload is 150 hours, 1 credit = 25 hours)		
Teacher: Maurizio Passacantando		
1	Course objectives	This course gives an introduction to the most widely-used techniques for materials characterization and the growth of nanostructured materials.
2	Course content and Learning outcomes (Dublin descriptors)	Topics of the module include: - An introduction to what is meant by materials characterisation; - The essential elements of the physical basis for x-ray and electron diffraction; - Imaging, optical and electron-optical microscopies; - Scanning probe techniques - physical principles and generic methodologies; - Spectroscopies - techniques, with emphasis on surface and film analysis; - Tactical and practical aspects of materials characterisation; - Electrical characterizations - Growth of nanostructured materials. On successful completion of this module, the student should: - have profound knowledge of structural and electronic properties of materials. - have knowledge and understanding of experimental techniques to investigate the physical properties of materials. - understand and explain the physical properties of materials. - understand: What is the appropriate technique for studying a particular property of a material. - demonstrate skill in facing issues inherent the growth and characterization of materials. - demonstrate capacity for reading and understand other texts on related topics.
3	Prerequisites and learning activities	A background in quantum mechanics and solid state physics.
4	Teaching methods and language	Lectures, seminars and laboratory demonstrations. Lectures are given in English upon request of non-native Italian speakers. Text book: C. Kittel, *Introduction to Solid State Physics*, Wiley, 2004. A. Guinier, *X-ray Diffraction in Crystals, Imperfect Crystals and Amorphous Bodies* , Genral Publishing Company, Canada 1994. Ertl and Küppers, *Low energy electrons and surface chemistry*, VCH (1985). S.M. Sze, K.K. Ng *Physics of Semiconductor Devices,* Wiley 2007.
5	Assessment methods and criteria	Oral exam on topics dealt during the course.