iSAS International Interdisciplinary Intersectoral – UNICAM Università di Camerino 1336 – School of Advanced Studies	**Università degli Studi di Camerino School of Advanced Studies** **Corso di Dottorato di ricerca in** **Physics, Earth and Materials Sciences**

Attività didattiche VERTICALI a.a. 2023/2024

Docente	SSD	Titolo attività formativa	Codice	CFU	CFU modulo	Mutuato parzialmente da:	Valutazione	Ore didattica	Semestre	Curriculum riferimento
Carroll Michael Robert	GEO/07	Applications of radiogenic and stable isotopes to Earth Sciences, Environmental Sciences and Cosmology	DOPE MS012	3		CdL Geo LM	Idoneità	21	II	Earth Science
Rezvani Seyed Javad	FIS/01	Material Science using advanced radiation sources	DOPE MS009	3		-	Idoneità	21	II	Material Science
Perali Andrea	FIS/03	Condensed Matter Theory for PhD		6		CdL in Fisica LM-FI	Idoneità	42	II	Physics
Gabriele Giuli	GEO06	Introduction to crystallography		3			idoneita'	21	II	Earth Science
Danica Jablonska	GEO/07	Carbonate Diagenesis		3		-	Idoneità	21	II	Earth Science
Miller Zambrano	GEO/11	Advanced seismic interpretation		3			Idoneità	21	I	Earth Science

Docente	SSD	Titolo attività formativa	Codice	CFU	CFU modulo	Mutuato parzialmente da:	Valutazione	Ore didattica	Semestre	Curriculum riferimento
Orlando Luongo	FIS/02	Advanced Quantum Field Theory		3			Idoneità	24	II	Physics
Di Cicco Andrea	FIS/01	Advanced Physics Laboratory for PhD		6		CdL in Fisica LM-FI	Idoneità	42	II	Physics
Tatiana Guidi	FIS/03	Solid State Physics for PhD		6		CdL in Fisica LM-FI	Idoneità	42	I	Physics
Roberto Gunnella	FIS/03	Advanced Nanotechnologies for PhD		3		CdL in Fisica LM-FI	Idoneità	21	I	Material Science
Angela Trapananti	FIS/01	Advanced Spectroscopy for PhD		3		CdL in Fisica LM-FI	Idoneità	21	II	Physics
Josephin Giacomini	MAT/08	Computational Fluid Dynamics		3			Idoneità	21	II	Material Science
Luis Aldemar Pena Ardila	FIS/03	Numerical Methods for Many-Body Quantum Systems		3			Idoneità	21	II	Physics
Piangerelli Marco	INF/01	Machine Learning and its applications **	DOCS M013	4	2	PhD in Computer Sciences and Mathematics	Idoneità	28	II	Physics
Pilati Sebastiano	FIS/03				2					
Matassa Roberto	fis/03	A deep look into Micro and/or Nanostructured materials **		3		Synthesis of Functional Materials	Idoneità	21	ii	physics

** corsi interdisciplinari

VERTICAL teaching activities: Contents / Contenuti Attività didattiche VERTICALI

Carroll Michael Robert	GEO/07	Applications of radiogenic and stable isotopes to Earth Siences, Environmental Sciences and Cosmology

Isotope geochemistry - radioactive isotopes and applications
- PHYSICS OF THE NUCLEUS AND THE STRUCTURE OF NUCLEI (basic decay info-not details)
- BASICS OF RADIOGENIC ISOTOPE GEOCHEMISTRY
- DECAY SYSTEMS AND THEIR APPLICATIONS
- Rb-Sr,Sm-Nd, Lu-Hf, Re-Os, La-Ce
- U-Th-Pb
- U and Th Decay Series Isotopes
- Isotopes of He and Other Rare Gases
- 14Carbon, other cosmogenic isotopes

Isotope geochemistry - stable isotopes and applications
- Introduction
- Theoretical Consideration
- Temperature Dependence of the Fractionation Factor
- Composition and Pressure Dependence
- Kinetic Isotope Fractionations
- Isotope Geothermometry
- Isotope Fractionation in Hydrologic Systems
- Isotope Fractionation in Biological Systems (briefly)
- Paleoclimatology
- Hydrothermal Systems and Ore Deposits
- Stable isotopes in the mantle and magmatic systems
- non-traditional stable isotopes

Rezvani Seved Javad	FIS/01	Material Science using advanced radiation sources

Basic knowledge of the advanced radiation sources (synchrotron and Free electron laser) phenomena and their production and characterization. Review of particle accelerators and synchrotron radiation generation and application history. Novel radiation sources scientific and technological applications. Basic knowledge of the methods used in materials science (e.g., Spectroscopic and scattering techniques) exploiting the advanced radiation sources. Frontier of advanced research subjects in the field.

Perali Andrea	FIS/03	Condensed Matter Theory for PhD

The course "Condensed Matter Theory" provides theoretical and phenomenological concepts and tools, in close connections with experiments, for understanding the microscopic properties of quantum systems constituted by a macroscopic number of interacting particles. The focus of the course will be on building a deep knowledge of the microscopic mechanisms and fundamental models for describing the behavior of electrons, ions and excitations in solids and ultracold matter made by atomic gaseous clouds. Key quantum phenomena in Condensed Matter Physics will be considered in detail: superconductivity, superfluidity, ultra-cold gases in traps, BCS-BEC crossover and pseudogap phenomena, electron-hole heterostructures and excitons and their condensation and superfluidity, nanostructured superconductors and resonant phenomena.

Prerequisites: Basic knowledge of quantum and statistical mechanics, structure of matter, atomic and molecular physics.

Syllabus of the course:
1. Hamiltonian in first and second quantization. Non-interacting Fermi and Bose gases; Bose-Einstein condensation.
2. Review of solid state physics: Electronic bands, Fermi surfaces, Density of States; lattice dynamics; phonons.
3. Electron-phonon interaction: perturbative treatment and the Froelich Hamiltonian; deformation potential, the polaron, the Cooper instability.
4. Electron-electron interaction: Hartree-Fock approximation; Coulomb screening and Thomas-Fermi approximation; Landau's theory for the Fermi-liquid; Mott insulator and repulsive Hubbard model and connections with cuprate superconductors.

5. Feynman diagrams and the diagrammatic approach for Condensed Matter Physics. Relevant examples.
6. BCS microscopic theory of superconductivity. The variational approach. Self-consistent gap and Tc equations.
7. BCS-BEC crossover and pseudogap phenomena in solids and ultracold matter: theory and experiments.
8. Superconductivity at the nanoscale. Quantum confinement effects. Systems of sub-bands and Lifshitz transitions. Density of states in different geometries at the nanoscale. Renormalization of the interaction. Equation of gaps and for the Tc at the nanoscale. Superconducting nanofilms and nanostripes. Super-lattices of slabs and stripes: amplification and stabilization of superconductivity. Nanofabrication techniques.
9. Superfluidity of electrons and holes in van der Waals heterostructures of graphene and other two-dimensional semiconductor materials. Theoretical and experimental aspects.

Suggested textbooks:

1) N. Ashcroft, and N. Mermin, Solid-State Physics, Harcourt College Publisher, 1976
2) Superconductivity of Metals and Alloys, P. G. De Gennes, Advanced Book Classics, CRC Press.
3) One-Dimensional Superconductivity in Nanowires, Fabio Altamare, Albert M. Chang, Wiley-VCH

Gabriele Giuli	GEO06	Introduction to crystallography

- Introduction to crystallography (definition of a mineral, differences between crystalline and amorphous matter);
- crystal lattice, simmetry elements compatible with periodic structures;
- point groups, space groups;
- polymorphysm, isomorphism and solid solutions;
- direct lattice and reciprocal lattice;
- X-ray diffraction: basics of X-ray diffraction, Bragg equation, how to read powder X-ray diffractograms;
- Introduction to the Rietveld method

Danica Jablonska	GEO/07	Carbonate Diagenesis

Understanding carbonate diagenesis is a crucial tool for deciphering the paleo- environmental settings during deposition; physical and chemical conditions during burial; and circumstances of subsequent uplift. Moreover, it is possible to define geological processes that impacted the petrophysical properties of the carbonate rocks.

Carbonate diagenesis has a vast application in many disciplines, such as characterization of geofluid reservoirs, CCS reservoir assessment and geothermal potential. This course is divided into 2 main parts: The theoretical part will address: carbonate mineralogy, early diagenesis in different settings; burial diagenesis in various structural settings and telegenesis.

The practical part will be focussed on interpretation of the thin sections and results of analyses.

Miller Zambrano	GEO/11	Advanced seismic interpretation

The course is intended for PhD students and advanced graduate students with experience or some basis in seismic reflection data interpretation. The objective of the course is to provide skills and workflows for the interpretation of 3D seismic data.

The first part of the course will cover the theoretical aspects of the seismic data acquisition and processing. The second part focuses on the practical aspect of the interpretation of seismic data. The main aspect evaluated in the course includes the seismic-well calibration, interpretation of horizons and faults, map generations, construction of velocity models and seismic attributes. During the course the student will have access to advanced seismic interpretation software like Petrel and OpendTect thanks to academic licenses.

The evaluation of the course is continuous due to its immersive characteristics. The final evaluation will be oral in the form of a presentation of a project developed during the practical lessons

Orlando Luongo	FIS/02	Advanced Quantum Field Theory

The functional approach to quantum field theory and instantons. The free Rarita-Schwinger field (4 hours). Quantum Chromodynamics (7 hours). Faddeev-Popov method and BRST symmetry. Quantum Field in Curved Space: Quantization in curved space time (7 hours). Solitons in field theories (2 hours).Bogoliubov transformation. The Hawking effect. The Unruh effect (4 hours).

Di Cicco Andrea	FIS/01	Advanced Physics Laboratory for PhD

Program:

The students will carry out experiments in the laboratory, complemented by classroom lectures on the following topics:
1) X-ray interaction with matter. X-ray fluorescence (XRF). Experimental set-up: x-ray source, optics, detectors. Theory of photoabsorption. Fluorescence yield. Methods for quantitative x-ray fluorescence analysis. X-ray diffraction. Peak-fitting analysis.
2)Conducting measurements by scanning microscopy carried through an AFM and scanning electron microscope. Determination of the properties of an elastic tip interacting with the surface. Frequency spectrum measurements of the elastic cantilever.
Microanalysis by X-ray fluorescence field of SEM.
3) Measurements of the spectrum of vibrations on a sample surface by means of a RAMAN experiment. Characterization of the sample properties, both from the composition and the structure point of view.

Tatiana Guidi	FIS/03	Solid State Physics for PhD

1) Structure of solids and materials and methods of solid state physics. Periodic Table and properties' basic solids. Potential energy and cohesion in typical classes of solids. Crystal structures. Ideal crystal lattice. Primitive cell. Base. Symmetry allowed and forbidden. Classification of Bravais lattices according to the symmetry operations. Miller indices.

2) diffraction of radiation in general: "Scattering" of photons, neutrons, and electrons: similarities and differences.
Atomic form factors.
Diffraction by crystals. Laue equations, equivalence with the Bragg condition. And reciprocal lattice interplanar distances. Symmetries. Structure factor. Examples of calculation of the structure factor of simple solids. Reflections prohibited. Measurements with single crystals and powders.
3) the adiabatic approximation: the separation of the motion of ions and electrons. Conditions for the validity 'of this approximation in solids. Perfect crystals: Bloch theorem for a generic periodic potential. Cyclical conditions to the boundary, counting of states.
Volume of the primitive cell of the reciprocal lattice.
4) Lattice dynamics. Three-dimensional Bravais lattice with basis: the harmonic approximation. Dynamic array. Equations of motion, general characteristics. Acoustic and optical branches. Normal modes in one dimension: dispersion relations for monatomic and diatomic chain. Brillouin zones.
5) Theory of quantum harmonic crystals. Phonons. Internal energy and specific heat of lattice, the classical limit. Quantum corrections and anharmonic. Specific heat at low temperature. Models for intermediate temperatures (Debye, Einstein), the definition and meaning of the Debye temperature. Lattice and electronic contribution. Phonon density of states. Van Howe singularity.
6) "scattering" of neutron scattering cross section. The dynamic structure factor $S(q, \omega)$. Case of crystal structures with thermal disorder. Debye-Waller factor and elastic scattering. Contribution to a phonon. Terms multifononici. Inelastic scattering of X-rays Optical measurements of phonon spectra (Brillouin lines).
7) Property 'electronic equipment. Drude model for metals. Discussion of the approximation of free electron. Density 'of the electronic states. Density 'electronics and the Fermi level. Typical values for metals. Plasmons.
8) Energy and specific heat of an electron gas. Specific heat of metals at low temperature. Conductivity 'electricity in metals. Hall effect and magnetoresistance. Conductivity 'high frequency electric. Property 'optics. Conductivity 'heat in metals. Compressibility '.
9) Limit the model of free electron. Quasi-free electrons. Fermi surface and density 'of the electronic states. Potential approximation "weak" and perturbative approach. Energy levels are close to a Bragg plane. Energy bands and gaps in one-dimensional and three-dimensional systems. Model type "tight-binding". LCAO, linear combinations of atomic orbitals. Application to bands of type s. General characteristics of the levels. Wannier functions. Methods for the calculation of the band structure in the approximation of independent electrons. Method Mobile. Work at APW method. Ortogonalizzate method of plane waves (OPW). Pseudopotentials.
10) Effective mass. Quasi-time. Semiconductors. Statistics of electrons in the bands. Chemical potential and its temperature dependence. Degenerate and non-degenerate systems. Intrinsic semiconductors. Mass action law. Semiconductors doped n-type and p. Semiconductors compensated and partially compensated.

Roberto Gunnella	FIS/03	Advanced Nanotechnologies for PhD

This course has the scope of giving fundamentals of mesoscopic and quantum effects at the boundary of nanometric systems. The course is divided into 4 main main sections: 1) optical properties of nanometric solids and their influences in the plasmonics technologies and in related spectroscopies; 2) effects in conduction devices and correlated problems in integrated electronics and limitations to overcome by using new materials; 3) nanometric materials for optical devices in use for quantum technologies (photonics) and photocatalysis devices for application to environmental technologies.

Angela Trapananti	FIS/01	Advanced Spectroscopy for PhD

Spectroscopic techniques have been crucial in the development of some fundamental theories in physics and still underpin a wide range of research in physics and chemistry as well as serving as valuable analytical tools.
This course will introduce general aspects of spectroscopy, some of the key principles, tools and techniques that govern spectroscopic measurements and the theoretical principles of photon and electron spectroscopy.
Topics include:

- Rotational, vibrational and electronic spectroscopies
- Infrared and Raman spectroscopies
- Auger, X-ray and ultraviolet photoelectron spectroscopies
- X-ray Absorption Spectroscopy
- X-ray Emission Spectroscopy

Josephin Giacomini	MAT/08	Computational Fluid Dynamics

Program:

This course has the scope of giving fundamentals of Fluid Dynamics and showing how to use them in a model of a real-life problem to obtain a reliable approximate solution. In particular, the course will introduce the physical principles and the mathematical modelling of Fluid Dynamics. Then, it will briefly describe some approximation schemes to give the basic tools to understand a CFD simulator. Extensive use of computer simulations will be carried out. In addition, a representative case study will be built and solved by the students.

Luis Aldemar Pena Ardila	FIS/03	Numerical Methods for Many-Body Quantum Systems

Program:

This course introduces fundamental numerical techniques used to tackle many-body problems at zero and finite temperatures. The aim of the course is to provide an overview of different methods as an alternative to analytical techniques that are only applicable under certain limits. Students will learn about various physical systems where these techniques feature strongly and provide powerful tools for solving problems in condensed matter, quantum optics, and atomic/molecular systems. The course covers techniques such as quantum Monte Carlo, non-linear Schrödinger equations, and exact diagonalization

Matassa Roberto	fis/03	A deep look into Micro and/or Nanostructured materials

A Deep look into Micro and/or Nanostructured Materials

Learning Aims

This module aims to introduce students to the basic concepts in optical microscopy to be easily driven to the foundation-level knowledge on the essential setting of the electron microscopy: sources, lens, interaction electron-matter, and imaging-spectroscopy detection. It covers the most essential topics necessary on how to use the optical-electron microscopy correctly to perform imaging, diffraction, and spectroscopy techniques. These are applied to the characterization experiments in which the results can be analysed to investigate the morphology, chemistry, and structure of any matter (Biology, Pharmacy, Medicine, and Chemistry), as well as introducing students to enhancing their future outcomes by quantitative imaging analysis.

Lecture Content:

- Introduction from optical and to the electron microscopy.
- Conventional and advanced electron microscopy techniques
- Specimen preparations: “An essential outcome!” in Biological, Pharmaceutical, Medicine, and Chemistry research fields.
- Morphological, chemical, and structural analyses of micro and nanometric regions.
- Taking advantages from quantitative imaging analysis (QIA).

Contact

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