UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

DIPARTIMENTO INTERUNIVERSITARIO DI FISICA

| **General information** | |
|---|---|
| Academic subject | Solid State Physics |
| Degree course | Physics |
| Academic Year | 2022-2023 |
| European Credit Transfer and Accumulation System (ECTS) | 6 |
| Language | English |
| Academic calendar (starting and ending date) | From March 2023 to June 2023 |
| Attendance | No |

| **Professor/ Lecturer** | |
|---|---|
| Name and Surname | Pietro Patimisco |
| E-mail | pietro.patimisco@uniba.it |
| Telephone | +39 0805442368 |
| Department and address | Physics Department, via Amendola 173 |
| Virtual headquarters (Microsoft Teams code) | *xxxxxxxx* |
| Tutoring (time and day) | Monday, 15:00 – 17:00; Wednesday, 16:00 – 18:00 |

| ***Syllabus*** | |
|---|---|
| Learning Objectives | Crystal Structure. Reciprocal Lattice. Band Structures. Semiconductor Structures. Thermo-electric Transport. Low Dimensional Systems. |
| Course prerequisites | Background knowledge on quantum mechanics, statistical physics and semiconductor physics. |
| Contents | **Crystal Structure.** Periodic Array of Atoms. Lattice Translation Vectors. Primitive Lattice Cell. Fundamental Types of Lattices. Two-Dimensional Lattice Types. Three-Dimensional Lattice Types. Index Systems for Crystal Planes and Directions. Simple Crystal Structures. Sodium Chloride Structures. Cesium Chloride Structures. Diamond Structure. Zinc Blende Structure. Problems.<br><br>**Reciprocal Lattice.** The Bragg Diffraction Law. Reciprocal Lattice. Fourier Analysis of Scattered Wave. Reciprocal Lattice Vectors. Diffraction Conditions. Laue Equations. Brillouin Zones. Reciprocal Lattice to Cubic Lattice. Reciprocal Lattice to Face-Centered Cubic Lattice. Reciprocal Lattice to Body-Centered Cubic Lattice. Fourier Analysis of the Basis. Structure Factor of Body-Centered Cubic Lattice. Structure Factor of Face-Centered Cubic Lattice. Atomic Form Factor. Problems.<br><br>**Band Structures.** Introduction. Free Electron Fermi Gas. Single Electron Model. Fermi Sphere. Density of States. Fermi Distribution Non-Interacting Electrons in a Periodic Potential. Definition of Periodic Potential. Bloch Theorem. Band Index. Fermi Surface. Kronig-Penney Model. Energy Bands in 1D lattice. Nearly Free Electrons in a Weak Periodic Potential. General Approach to Schrodinger Equation. Energy Levels near a single Bragg Plane. Energy Bands in a 1D lattice. Tight-Binding Model. General Approach. Energy Bands in a 1D Lattice. Energy Bands in Three Dimensions. High Symmetry Points. Energy Bands in a Cubic Lattice. Energy Bands in a Body-Centered Cubic Lattice. Energy Bands in a Face-Centered Cubic Lattice. Orthogonalized Plane-Wave. Pseudopotential.<br><br>**Semiconductor Structures.** Introduction. Silicon, Germanium and Gallium Arsenide. Covalent Bonding. Crystal Structure. Energy Bands. Band Gap. Motion of Electron Wave in an Energy band. Semiclassical Equations of Motion. Dynamical Effective Mass. Parabolic Approximation. Carrier Concentration at Thermal Equilibrium. Intrinsic Semiconductor. Donors and Acceptors. Extrinsic Carriers Concentration. Problems.<br><br>**Boltzmann's Transport Equation.** The Electron Distribution Function. Equation of Motion. Steady-state Transport. Relaxation Time Approximation. Electrical and Thermal Transport. Isothermal Electrical Conductivity. Thermo-electric Transport. |

| | |
|---|---|
| | Thermal Conductivity.<br><br>**Low Dimensional Systems.** Introduction. 2D Quantum Heterostructures. Finite Quantum Well. Quantized Energy Levels. Density of States. Influence of Effective Mass. 2D Graphene. Crystal Structure. Brillouin Zones. Energy Bands. Density of States. Quantum Wire. Energy Bands. Density of States. GaAs Nanowire: Subbands and Probability Density. Quantum dot. Density of States. Energy Levels in Spherical Potential Well. Thermal vs Nonthermal Distribution. Population Statistics: Rate Equations vs Random Population. Phosphorene and Black Phosphorus. Crystal Structure. Primitive Cell and Brillouin Zone. Energy Bands and Density of States. Field-Effect Transistors. Photodetectors. |
| Books and bibliography | N. W. Ashcroft and N. D. Mermin – Solid State Physics, Cencage.<br>C. Kittel – Introduction to Solid State Physics, John Wiley & Sons Inc.<br>S. M. Sze – Physics of Semiconductor Devices, Wiley-Interscience. |
| Additional materials | Lecture notes at the website: [http://polysense.poliba.it/index.php/solid-state-physics/](http://polysense.poliba.it/index.php/solid-state-physics/) |

| **Work schedule** | | | |
|---|---|---|---|
| Total | Lectures | Hands on (Laboratory, working groups, seminars, field trips) | Out-of-class study hours/ Self-study hours |
| **Hours** | | | |
| | 40 | 15 | 95 |
| **ECTS** | | | |
| | 5 | 1 | |

| **Teaching strategy** | |
|---|---|
| | Lectures in the teaching room with the aid of a laptop and a projector. |

| **Expected learning outcomes** | |
|---|---|
| Knowledge and understanding on: | ○ crystal structure, electronic and thermal properties of solid-state systems,<br>○ basic properties of metals, insulators, and semiconductors,<br>○ semiconducting elements for the use in electronic devices,<br>○ low-dimensional semiconductors. |
| Applying knowledge and understanding on: | ○ capability to apply quantum mechanics,<br>○ theoretical and numerical calculations in solid state physics,<br>○ solve simple problems concerning different properties that result from the distribution of electrons and regular arrangement of atoms in crystals. |
| Soft skills | • **Making informed judgments and choices**<br>○ Autonomy in the evaluation of descriptions about theoretical models on electronic properties of materials,<br>○ Ability to critically analyse the current research literature.<br>• **Communicating knowledge and understanding**<br>○ Enable transition from theoretical physical subjects towards the understanding of basic properties of solid-state matter and their technological applications,<br>○ Discuss models and mechanics introduced in the course.<br>• **Capacities to continue learning**<br>○ Follow the current progress and further prospects within the areas of solid-state physics,<br>○ Assess the reliability of simple theoretically based relevant problems published in literature and technological documentation |

| **Assessment and feedback** | |
|---|---|
| Methods of assessment | |
| Evaluation criteria | Capability to discuss models and mechanics introduced in the course. Adequate |

| | |
|---|---|
| | comprehension and global knowledge of concepts and arguments described throughout the course. |
| Criteria for assessment and attribution of the final mark | Oral exam (100%) |
| **Additional information** | |
| | |