UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Fisica III - Turno 1

2526-2-E3001Q043-T1

Aims

Illustrations of phenomena that show the inadequacy of classical physics theories for their description and formulation of new models that introduce the students to the first concept leading to quantum physics.

Knowledge and Understanding

By the end of the course, the student will have acquired a solid understanding of the fundamental concepts of modern physics, in particular:
the corpuscular nature of matter and electric charge;
the limitations of classical physics in describing phenomena such as blackbody radiation, the photoelectric effect, and the Compton effect;
historical atomic models (Rutherford, Bohr, Sommerfeld);
the wave-particle duality and the De Broglie relation;
the origin of X-rays and the basic principles of atomic magnetic properties.

Applied Knowledge and Understanding

The student will be able to:
apply theoretical concepts to interpret physical phenomena, recognizing the limitations of classical physics in certain contexts;
analyze data from typical experiments and draw quantitative conclusions;
use models to estimate physical properties of matter.

**Independent Judgment

The student will develop the ability to:
critically evaluate the applicability of physical models (classical or quantum) to different phenomena;
distinguish between classical and quantum approaches in the description of physical reality;
independently interpret the results of key experiments in modern physics.

Communication Skills

The student will be able to:
clearly explain typical experiments in modern physics using precise and appropriate language, both orally and in writing;
concisely present physical models and the experimental evidence supporting them;
critically discuss the transition from classical physics to quantum mechanics

Learning Skills

The student will acquire conceptual and methodological tools useful for:
undertaking the study of advanced physics courses (e.g., quantum mechanics, solid-state physics, atomic physics);
understanding popular science or technical-scientific articles related to modern physics;
applying the knowledge gained to new contexts, both academic and professional, that require physical and quantitative reasoning.

Contents

- **Atomic nature of matter** (Maxwell-Boltzmann distribution) **and of charge** (*e/m* by Thompson, Zeeman, *e* determination for Millikan).
- **Non classical behaviour of e.m. radiation:** Black body and Planck hypothesis about e.m. oscillator quantization. Photoelectric effect and Einstein hypothesis about the photon. Application of Planck oscillator to the specific heat of solids: Einstein and Debye models.
- **Atomic models:** Rutherford coulombian scattering, atomic spectra, Bohr model, Sommerfeld model. Elements of magnetic properties of atoms.
- **E.M. waves or photons?** X rays, Compton effect.
- **Particles or waves?** De Broglie relation, electron diffraction by a crystal.

Detailed program

1. Kinetic theory of gases, equipartition of energy: success and faults. *Cv* of solids and of diatomic gases. Maxwell distribution for the modulus of the molecular velocity. Molecular effusion, Thermal Doppler broadening, Boltzmann factor, notes on classical statistical distribution. Mean free path for gases, transport coefficients: viscosity and thermal conductibility. Brownian motion.
2. Elementary charge: electrolysis (Faraday), *e/m* estimate (Thomson) classical Zeeman effect. Estimate of the elementary charge (Milikan). Thomson parabolas for positive ions, Isotopes.
3. Thermal radiation and Black body. Kirchhoff law. Isotropy of thermal radiation. Law of Stefan-Boltzmann, Black body thermodynamics, radiation pressure. Wien law, Rayleigh-Jeans model for Black body. Planck model and quantization of the harmonic oscillator energy.
4. Specific heat of solids: Einstein model and Debye model.
5. Photoelectric effect: Einstein's theory of the photon.
6. Atomic models: Thomson, scattering of alpha particles, Rutherford model for coulombian scattering. Bohr model: postulates, orbits, energy levels, atomic series. Franck-Hertz experiment, recoil effects. Quantization rules of Wilson-Sommerfeld (particles in a box, 1D, 3D, levels degeneration). Magnetic properties of atoms, Stern and Gerlach experiment.
7. X rays: production, continuum spectrum, Moseley law, Bragg law for diffraction. Thomson cross-section for the electron. Compton effect, pair production.
8. De Broglie hypothesis. Electron diffraction: Davisson and Germer experiment.
9. Heisenberg Uncertainty principle: typical applications and double slit experiment.

Prerequisites

The contents of the math and physics courses of the first three semesters of the Bachelor degree in Physics and Mathematics.

Teaching form

Traditional lessons (DIdattica Ertogativa): Lectures in classroom

Textbook and teaching resource

References
[1] Blundell: Concepts in Thermal Physics
[2] Tipler-Llewellyn: Modern Physics, 6th edition
[3] Serway-Moses-Moyer: Modern Physics, 3rd edition
[4] Eisberg-Resnick: Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles
[5] Feynman lectures
[6] Edge-Wehr-Richard: Introduction to Atomic Physics
[7] Dekker: Solid State Physics
[8] Richtmyer-Kennard-Cooper: Modern Physics
[9] Alonso-Finn: Quantum and Statistical Physics

Bibliography
• Atomic nature of matter: [1] cap. 4, 5, 7, 8, 9, 19, 20, 33.1, [9] cap. 10, [2] cap. 8, [3] cap. 10 ([5-I] cap. 39, 40, 41)
• Atomic nature of charge: [2] cap. 4, [3] cap. 4, [4] cap. 4 ([6] cap. 2)
• Balck Body: [1] cap. 23, [2] cap. 3, [3] cap. 3, [4] cap. 1 ([6] cap. 3)
• Specific Heat of Solids: [1] cap. 24, [3] cap. 10, [4] cap. 11.5 ([7] cap. 2)
• Photoecectric effect: [2] cap. 3, [3] cap. 3, [4] cap. 2
• Atomic models: [2] cap. 4, [3] cap. 4, [4] cap. 4
•X rays: [2] cap. 3, [3] cap. 3, [4] cap. 2 ([8] cap. 7)
• Matter waves : [2] cap. 3, [3] cap. 5, [4] cap. 3 ([5-III] cap. 1, 2, 3)

Semester

II semester.

Assessment method

The assessment is reached through a written exam that last three hours, with open questions (4 to be done out of 5) in which the student is requested to expose a topic of the program with small derivations, graphs and, if needed

some numerical estimates. The use of a scientific calculator is requested. Access to textbooks during the exam is strictly forbidden.
There are no partial tests.
In the written exam, the ability to understand and explain the requested topic is evaluated, both in terms of describing experimental setups or diagrams, and in outlining the modeling aspect.
Regarding the grading: The exam score is expressed in 30 points units. Each exercise is worth a quarter of the maximum score, unless otherwise specified. If an exercise includes multiple parts and requires a numerical estimate, the exercise's contribution to the final grade is distributed so that partial answers can also be assessed.
The optional oral exam, during which gaps identified in the written exam will be addressed and other topics covered in class may be discussed, is intended to improve the score obtained in the written exam.

The student succeeded in a positive written exam (>=18/30) can perform an optional oral exam or keep the rating obtained in the written one.
Those students that have been rated 16/30 and 17/30 in the written exam access the oral exam in order to obtain a final score >=18/30.

For Erasmus students: it is possible to take the exam in English.

Office hours

By appointment.

Sustainable Development Goals

QUALITY EDUCATION | GENDER EQUALITY