

## Quantum metrology

Academic Year: ( 2023 / 2024 )

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Department assigned to the subject: Electronic Technology Department

Coordinating teacher: ACEDO GALLARDO, PABLO

Type: Compulsory ECTS Credits : 3.0

Year : 1 Semester : 2

## REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Sensors and classical measurement instrumentation systems

## OBJECTIVES

Knowledge on the quantum effects that are the basis for SI units definition.

Knowledge of the state of the art on quantum technologies metrological application

Knowledge on quantum technologies for frequency, temperature, voltage and resistance units realization

Practical experience on the laboratory units realization

## DESCRIPTION OF CONTENTS: PROGRAMME

In this subject the state of the art on the quantum application on metrology will be presented. The quantum effects related to frequency, temperature, voltage and resistance units realization and its technologies will be described specifically those that are maintained at CEM facilities where the student will have hands-on activities on their practical realization.

1. Introduction. SI evolution towards quantum physics. The Quantum Flag-ship and metrology. European Quantum metrology network strategy plan. Quantum metrology and standardization.
2. Frequency quantum standards
3. Temperature quantum standards
4. Resistance quantum standards
5. Current quantum standards
6. Voltage quantum standards
7. Laboratory realization of the quantum Hall effect and Josephson and its applications
8. Laboratory realization of the quantum temperature standards
9. Students reports presentations

## LEARNING ACTIVITIES AND METHODOLOGY

Lectures.

Tutoring hours

Group work.

Individual work by the students.

## ASSESSMENT SYSTEM

<b>% end-of-term-examination/test:</b>	60
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<b>% of continuous assessment (assignments, laboratory, practicals...):</b>	40
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Ordinary Call:

The students will prepare two works in groups during the course related to laboratories activities (20% of the grade each). The group works will be presented in class and discussed by all members of the

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course

At the end of the course the students will go through a final exam (60%)

Extraordinary call:

The student may follow the continuous evaluation procedure with the same structure as in the ordinary call, or go for a final exam (100% of the final grade).

## BASIC BIBLIOGRAPHY

- Clark A. Hamilton, Charles Burroughs, and Kao Chieh. Operation of NIST Josephson Array Voltage Standards. , <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4959396/>..
- Klaus von Klitzing 25 Years of Quantum Hall Effect (QHE) A Personal View on the Discovery, Physics and Applications of this Quantum Effect. , <http://www.bourbaphy.fr/klitzing.pdf>..
- Michel Abgrall et al Atomic fountains and optical clocks at SYRTE: Status and perspectives., <https://www.sciencedirect.com/science/article/pii/S1631070515000614>.
- Nobu-Hisa Kaneko, Shuji Nakamura and Yuma Okazaki. A review of the quantum current standard, <https://iopscience.iop.org/article/10.1088/0957-0233/27/3/032001/pdf>..
- Purdy et al., Quantum correlations from a room-temperature optomechanical cavity,, Science 356, 1265¿1268 (2017) 23 June 2017, doi.org/10.1126/science.aag1407.
- Stephan Bauer, Ralf Behr, Jonas Herick, Oliver Kieler, Marco Kraus, Hao Tian, Yoawaret Pimsut and Luis Palafox Josephson voltage standards as toolkit for precision metrological applications at PTB., <https://iopscience.iop.org/article/10.1088/1361-6501/aca5a5>..
- T. Briant, et al Photonic and optomechanical thermometry, MPDI Optics, 2022, 3, 159¿176. <https://doi.org/10.3390/opt3020017>.
- W. Poirier,a) F. Lafont, S. Djordjevic, F. Schopfer, and L. Devoille. A programmable quantum current standard from the Josephson and the quantum Hall effects, <https://arxiv.org/pdf/1310.3172.pdf>..
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- B. Jeckelmann and B. Jeanneret. The Quantum Hall Effect as an Electrical Resistance Standard. , <http://www.bourbaphy.fr/jeanneret.pdf>..