COURSE DESCRIPTION CARD - SYLLABUS

Course name
Metrological systems and standards [S2ETI2>SiWM]

Course

Field of study
Education in Technology and Informatics

Year/Semester
1/2

Area of study (specialization)
–

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
30

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

2,00

Coordinators

dr hab. inż. Przemysław Głowacki
przemyslaw.glowacki@put.poznan.pl

Lecturers

Prerequisites

Knowledge: basic knowledge of physics, electrical engineering, electronics and mathematics Skills: ability to solve elementary problems in the field of general physics, quantum physics, metrology, the ability to acquire information from the indicated sources Social Competencies: understanding the need to expand their competence, readiness to cooperate within the team,

Course objective

1. To provide students with basic knowledge in the field of metrological standards, to the extent determined by the program content 2. Presentation of the theory and technique of taking measurements 3. Explanation of the principles of operation of selected instruments and measuring systems 4. Developing students' ability to solve simple problems based on the acquired knowledge 5. Developing students' self-education skills

Course-related learning outcomes

Knowledge:
Define basic concepts in the field of metrological standards, within the scope of the curriculum. Demonstrates knowledge of measurement theory and techniques, measuring instruments, and knows and understands the main development trends and most important achievements in techniques and

technologies related to metrological systems and standards.
Estimate the accuracy of measuring instruments and determine the operating range of measurement systems and their sensitivity limits. Explains the construction and operating principles of basic research and measurement devices.
Demonstrates detailed knowledge of selected advanced topics in physics, electronics, and automation applicable to modern metrological systems and standards.

Skills:
Use the indicated sources of knowledge (list of primary literature) with understanding and acquire knowledge from other sources (including English-language ones).
Perform simple calculations of parameters describing the measurement object.
Use the acquired knowledge of selected topics in mathematics and physics to formulate and solve complex and unusual metrology problems.
Use appropriate methods and tools, including advanced information and communication technologies, computer science, and scientific studies, to design simple measurement systems, select appropriate sensors and instruments, and determine their lower and upper operating ranges.

Social competences:
understands the need for lifelong learning and deepening one's knowledge, and is able to inspire others to pursue self-education.
is aware of the social role of a technical university graduate, and understands the need to formulate and communicate information and opinions regarding scientific and technological achievements to the public.
is ready to think and act creatively and entrepreneurially, and to initiate activities for the public interest.

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Grade written test
Assessment criteria: in accordance with the study regulations

Programme content

The basics of metrology, classification of measurement methods, and the history and structure of the international SI system of units. The course discusses instruments and measurement systems for various physical quantities and modern quantum standards, such as the Hall effect, the Josephson effect, and SQUID detectors. The course also covers atomic clocks, their operation and stability, as well as interferometry, length measurements, and modern mass standards.

Course topics

1. Basic knowledge about metrology and measurements.
2. The concept of measurement method and classification of methods.
3. The history of measurement systems. The international system of units SI.
4. General information on measuring tools.
- pickups and measuring instruments for electrical quantities.
- analog and digital meters, multimeters,
- recording instruments (recorders, analogue, sampling and digital oscilloscopes).
5. Systems and patterns: length, mass, time, temperature scale,
patterns of electrical quantities and sources of reference signals,
6. Measurements of electrical, magnetic and non-electrical quantities.
7. Quantum metrological triangle.
8. Quantum voltage pattern (superconductivity, Josephson phenomenon, quantum voltage pattern).
9. Magnetic flux detector (rf-SQUID, dc-SQUID detectors).
10. Hall effect quantum and resistance pattern (classical and quantum pattern).
11. Atomic clocks:
- theoretical basics,
- Allan's variance,
- atomic caesium frequency patterns with a beam of caesium atoms,
- caesium fountain,

- hydrogen maser,
- rubidium frequency standard,
- optical frequency patterns (atomic 87Sr, 171Yb, 199Hg, and ionic 27Al +. 40Ca +, 171Yb +, 88Sr +),
- optical frequency comb,
- nuclear frequency pattern (229Th).
12. Fundamentals of the atomic clock system on the example of caesium fountain:
- work cycle of time and frequency pattern,
- signal-to-noise ratio detection,
- short-term stability,
- measurement procedure
13. The process of evaluating disorders affecting the frequency of clock transition in atomic, optical time and frequency patterns:
- Doppler shift
- Stark shift
- Zeeman shift
- black body radiation shift,
- gravitational shift to red
- collision shift,
14. Time scale (GMT, UT, GPST, UTC, TAI,)
15. Distribution of reference frequencies (GPS, TWSTFT, TWIST, TTTOF)
16. Interferometers and length measurements (practical subway implementation, scanning sampling microscopes).
17. Weight standards:
- patterns depending on the Planck constant,
- mass standard with a spherical silicon mass,
- mass standard with ion counting and accumulation)

Teaching methods

Lectures: lecture with multimedia presentation (including drawings, photos, animations, video materials) supplemented with examples given on the board, taking into account various aspects of the issues presented, including: economic, ecological, legal and social issues, presenting a new topic preceded by a reminder of related content, known to students in other subjects.

Bibliography

Basic:
1. W. Nawrocki: Wstęp do metrologii kwantowej. WPP, Poznań 2007
2. A. Chwaleba, M. Poniński, A. Siedlecki: Metrologia Elektryczna. Wydanie 8, WNT Warszawa 2003
3. S. Tumański: Technika pomiarowa. WNT, Warszawa 2007
4. R. Wynands and S. Weyers, Atomic fountain clocks, Metrologia 42 (2005) S64-S79
5. K. Szymaniec, S. E. Park, G. Marra and W. Chałupczak, First accuracy evaluation of the NPL-CsF2 primary frequency standard, Metrologia 47 (2010) 363-376

Additional:
1. Mała encyklopedia metrologii, praca zbiorowa, WNT Warszawa 1989
2. J. Dusza, G. Gortat, A. Leśniewski, Podstawy miernictwa, OWPW Warszawa 2002
3. W. Nawrocki, M. Wawrzyniak, Zjawiska kwantowe w metrologii elektrycznej, WPP, Poznań, 2003.
4. A. Derevianko, H. Katori, Colloquium: Physics of optical lattice clocks, Rev. Mod. Phys. 83, 331, (2011)
5. E. O. Göbel and U. Siegner, Quantum Metrology: Foundation of Units and Measurements, WILEY-VCH Weinheim 2015

Breakdown of average student's workload

	Hours	ECTS
Total workload	50	2,00
Classes requiring direct contact with the teacher	30	1,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	20	1,00