COURSE DESCRIPTION CARD - SYLLABUS

Course name
Metrological systems and standards [S2FT2>SiWM]

Course

Field of study
Technical Physics

Year/Semester
1/1

Area of study (specialization)
–

Profile of study
general academic

Level of study
second-cycle

Course offered in
Polish

Form of study
full-time

Requirements
compulsory

Number of hours

Lecture
30

Laboratory classes
0

Other
0

Tutorials
0

Projects/seminars
15

Number of credit points

3,00

Coordinators

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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 from the field of metrological patterns, to the extent covered by course program content,
has knowledge of the theory and technique of measurements, measuring instruments,

estimate the accuracy of measuring instruments and determine the scope of operation of measurement systems and their limits of sensitivity,
has detailed knowledge of selected, advanced physics topics applicable in modern systems and metrological models.

Skills:
use understanding from the indicated sources of knowledge (list of basic literature) and acquire knowledge from other sources (including English),
perform simple calculations of parameters describing the measuring object,
design simple measuring systems, select appropriate sensors, instruments and determine their lower and upper operating ranges.

Social competences:
understands the need to learn and deepen his knowledge throughout his life, he can inspire other people to the process of self-education,
Is aware of the social role of a technical university graduate, understands the need to formulate and communicate to the public information and opinions on the achievements of science and technology

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

In terms of the methods used to verify the achieved learning outcomes, the following grading thresholds are applied:
50.1-60% - satisfactory;
60.1-70% - satisfactory plus;
70.1-80% - good;
80.1-90% - good plus;
from 90.1% - very good.
The grade is based on an individual written assignment and/or the assessment of an oral response.

Programme content

The lecture will discuss issues related to contemporary metrological systems and standards. The main emphasis will be placed on a detailed explanation of the implementation of the International System of Units SI based on quantum constants. Project classes will include the design of an appropriate metrological system or standard for the implementation of one of the 7 basic quantities in the International System of Units SI

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 provided on the board, taking into account various aspects of the issues presented, including: economic, ecological, legal and social, presenting a new topic preceded by a reminder of related content known to students from other subjects.
Project classes: meetings with the instructor and discussions, work in groups/teams, aimed at designing a system or a unit pattern from the SI System drawn by a team of 2-4 people. Technical aspects of the implementation of the pattern, the technology used for its implementation and the financial budget of the designed system should be presented. Assessment criteria similar to those for lectures.

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	75	3,00
Classes requiring direct contact with the teacher	45	2,00
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	30	1,00