# STUDY MODULE DESCRIPTION FORM

| Name of the module/subject | | Code |
|---|---|---|
| **Quantum Metrology** | | **1010803111010832686** |
| Field of study: **Communications Technologies** | Profile of study (general academic, practical): **general academic** | Year /Semester: **1 / 1** |
| Elective path/specialty: **-** | Subject offered in: **English** | Course (compulsory, elective): **elective** |
| Cycle of study: **Doctoral studies** | Form of study (full-time,part-time): **full-time** | |
| No. of hours: Lecture: **15** Classes: **-** Laboratory: **-** Project/seminars: **-** | | No. of credits: **2** |
| Status of the course in the study program (Basic, major, other): **major** | (university-wide, from another field): **from field** | |
| Education areas and fields of science and art: **technical sciences** | | ECTS distribution (number and %): **2 100%** |

## Responsible for subject / lecturer:

prof. dr hab. inż. Waldemar Nawrocki
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## Prerequisites in terms of knowledge, skills and social competencies:

| | | |
|---|---|---|
| 1 | **Knowledge** | 1. Student has a systematic knowledge of physics, in particular of solid-state physics .<br>2. Sydent has a basic knowledge of electronics and metrology |
| 2 | **Skills** | 1. Is able to extract information from Polish or English language literature, databases and other sources. Is able to synthesize gathered information, draw conclusions, and justify opinions.<br>2. Is capable of studying autonomously.<br>3. Demonstrates the ability to solve basic problems in physics. (K1_08) |
| 3 | **Social competencies** | 1. Is aware of the limitations of his/her current knowledge and skills; is committed to further self-study.<br>2. Is able to participate in collaborative projects. ( |

## Assumptions and objectives of the course:

-To present of the basic definitions and concepts of metrology, measurements in physics and measurement equipment. To introduce students to the analysis and presentation of data and the determination of errors and measurement uncertainty. Practical carrying out laboratory experiments involving the preparation and execution of measurements.

## Study outcomes and reference to the educational results for a field of study

### Knowledge:

1. PhS student has a systematic knowledge, together with necessary mathematical background, of the fundamentals of metrology, which is necessary to measure the signal properties and the parameters of electronic and telecommunication systems components. Has knowledge of measurement methods, measurement equipment. - [SD_W01]

2. Has knowledge of system of units and standards - [SD_W02]

### Skills:

1. PhD student Is able to extract information from Polish or English language literature, databases and other sources. Is able to synthesize gathered information, draw conclusions, and justify opinions. - [SD_U01]

2. Is able to prepare a well-documented study, in English or in Polish, on problems related to metrology - [SD_U02]

3. Is capable of studying autonomously. - [SD_U03]

4. Is able to use information for scientific analyses - [SD_U04]

5. Is able to process of results of research and to prpare a scientific report (paper) - [SD_O06]

### Social competencies:

1. PHD student is critical and self critical to results of scientific research - [SD_K01]

2. Is aware of the main challenges facing metrology and systems of units in the 21st century. - [SD_K02]

## Assessment methods of study outcomes

-Lectures passing based on written test from content of the lectures.

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## Course description

- Basic definitions and terms of metrology, in particular of quantum metrology.
- Systems of units: history, standards of units, system uf units now (SI system) and in the future - proposals.
- Quantum system of units
- Quantum metrological triangle and quantum metrological pyramid.
- Basic terms in quantum metrology, Heisengerg`s uncertaonty principle, quantum noise, energy resolution.
- Superconductivity. Josephson effect and its applications in metrology (voltage standards
- Zjawisko Josephsona.
- Direct current voltage standards.b SAet-up of voltage standards in Warsaw.
- SQUID detectors and their applications.
- Calsical and quantum Hall effect. Electrical resistance standard using quantum Hall effect.
- Quantizarion of electrical conductance in nanostructures.
- Single electron tunneling and a direct current standard.
- Scanning probe microscopy fpr nanoscience and nano technology.
- Frequency standards and atomic clocks.International Time Scale.
- Optical interefrometry for lenght standards.
- Quantum standards of a mass.
- Scale of temperature based on the Boltzmann constant.
- Low noise preamplifiers.

## Basic bibliography:

1. Wstęp do metrologii kwantowej, Nawrocki W., Wydawnictwo PP, Poznań 2007
2. Quantenmasse in der elektrischen Messtechnik, Kose V., Melchert F., WVH Verlag, Weinheim - New York, 1991.
3. Analiza danych w naukach ścisłych i technice, Zięba A., Wydawnictwo Naukowe PWN, Warszawa 2013

## Additional bibliography:

1. Systemy mikroskopii bliskich oddziaływań w badaniach mikro- i nanostruktur, Gotszalk T.P., Oficyna Wyd. Politechniki Wrocławskiej, Wrocław 2004
2. Wzorcowanie aparatury pomiarowej, Piotrowski J. , Kostyrko K., Wydawnictwo Naukowe PWN, Warszawa 2012
3. Practical Data Acquisition for Instromentation and Control Systems, Park J. Mackey S., Elsevier, 2003

## Result of average student's workload

| Activity | Time (working hours) |
|---|---|
| 1. Participation in lectures and discussions | 20 |
| 2. Preparation for exam | 10 |

## Student's workload

| Source of workload | hours | ECTS |
|---|---|---|
| Total workload | 30 | 2 |
| Contact hours | 20 | 2 |
| Practical activities | 0 | 0 |