FACULTY OF PHYSICS AND ASTRONOMY
INSTITUTE OF PHYSICS

ECTS COURSE CATALOGUE

PHYSICS

SECOND DEGREE STUDIES

2013/2014

PHYSICS LABORATORY II

Course code: **13.2-WF-FizD-PrFi2**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr Bartosz Brzostowski**
Name of lecturer: **dr Bartosz Brzostowski**
dr Lidia Najder-Kozdrowska

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					13
Laboratory	120	8	I	Grade	

COURSE AIM:

The goal of the advanced lab is to become familiar with experimental physics research. It is a test run as an experimental physicist with all responsibilities. This includes learning how to conduct meaningful experiments, mastering important experimental instrumentation and methods, analyzing data, drawing meaningful conclusions from them and presenting your results in a succinct manner. For this, you will conduct several experiments and error-analysis exercises.

ENTRY REQUIREMENTS:

- Physics laboratory I (General Physics Lab).
- Calculus.

COURSE CONTENTS:

Experiments at an advanced level:
- Study of natural background radiation.
- Measurement of thermionic electron work function in the metals.
- Current–voltage characteristic of the diodes. Determination of the Boltzmann constant.
- Stefan–Boltzmann law verification.
- Hall effect.
- Study of photoelectric effect, Planck constant.
- Examination of temperature dependence of resistance of various solids.
- Study of converse piezoelectric effect (stress in response to applied electric field) by the static method.
- Electron paramagnetic resonance (EPR) and Nuclear magnetic resonance (NMR) spectroscopy.
- The study of piezoelectric and elastic properties of polycrystalline ferroelectrics.
- Spontaneous and forced birefringence in TGS crystal.
- Malus Law verification. Pockels and Kerr effect investigation.
- Diffraction of laser beam on 2D grating. Reciprocal lattice.

TEACHING METHODS:

Laboratory exercises - exercises in accordance with the instructions and recommendations of the instructor (may increase the number of measurements to be done and recommend to perform additional analyzes on the basis of measurements).

LEARNING OUTCOMES:

As a result of successfully completing this course, students will be familiar with modern methods of research in the field of solid state physics, optics and physics of atoms and molecules and should understand research limitations (K2A_W01, K2A_W03, K2A_W04).

Furthermore student should know the safety rules in science experiments. Moreover student has the ability to plan complex physics experiments including different methods of measurement (K2A_W07, K2A_U02). Student is able to handle complex measurement systems using electronic and information technology tools and has the ability to perform accurate measurements and data analysis and make presentation and interpretation of measurement results (K2A_W5, K2_U04, K2A_U12).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

To pass the laboratory the student should make a reasonable number of exercises in order to get a total of 7.5 points, with the following scores for the exercise:

1,2,3,6 – 1.0 points,

4,7,8,9 – 1.25 points,

5,11,13,14 – 1.5 points,

10,12 – 2.0 points.

The experiments will be conducted in groups of two students. Each student should submit his/her own report. The lab grade consists of two parts: the lab pre-quiz is worth 25% and the lab report is worth 75% of the grade for each lab.

Pre-quiz: Students are expected to prepare for lab by reading the appropriate literature in advance of their lab. The pre-quiz will be taken at the beginning of each lab session and will consist of several questions on material covered in the lab manual.

Lab report: The lab report is a summary of what the student has observed and understood during the lab. Although you will work in twos in the lab, lab reports are to be done individually.

The format is as follows:

<u>Introduction</u>: Briefly give a general overview of the experiment, your expectations (a hypothesis) and the theory behind it. Summarize the main point of doing the lab. Your introduction should be about a 2 pages long.

<u>Results</u>: Present the data in the form of a table or a graph. Usually you will give details of what you observed in the lab. Show any calculations carried out etc. Remember to include units.

<u>Discussion/Conclusion:</u> Discuss in your own words and from your point of view your results.

Example: Looking at your results, tables or graph, can you see any general trend? What is the behaviour of the graph/line? What was the aim of the experiment? Have we achieved anything? If not, how large is the error? Does your result make sense? Can you compare your result to those from the books? What does the book say?

Lab reports are due one week after completion of the last measurement in the experiment.

During the last 3 weeks of the semester the students will have the option to do an extra lab to replace the worst grade and/or to run a make-up lab. At this time, any student who missed a lab, regardless if the absence was excused or unexcused, can make up one lab.

STUDENT WORKLOAD:

- Participation in classes: 15 weeks x 8 hours = 120 hours
- Preparation for classes: 5 x 6 = 30 hours
- Specialized literature-reading: 12 x 5 = 60 hours
- Analysis of performed exercises and writing reports: 6 x 10 = 60 hours
- Participating in consultations: 7 hours

Total: 277 hours, 13 ECTS.

Effort associated with activities that require direct participation of teachers: 127 hours, 6 ECTS.

RECOMMENDED READING:

[1] Each task has its own list of references. The instructor helps the student to choose the most appropriate position, or suggest other items.

OPTIONAL READING:

In Polish:

Poniżej wymienione książki stanowią źródło wiedzy niezbędne w II Pracowni Fizycznej:

[1] R. P. Feynman, R. B. Leighton, M. Sands, *Feynmana wykłady z fizyki*, t. 1-3, Wydawnictwo Naukowe PWN, Warszawa 2001.

[2] David Halliday, Robert Resnick, Jearl Walker. *Podstawy fizyki*, t. 1-5. Wydawnictwo Naukowe PWN, Warszawa 2005/2006.

[3] D. Halliday, R. Resnik, *Fizyka,* PWN, Warszawa 1994.

[4] I. Sawieliew, *Wykłady z fizyki*, PWN, Warszawa 2002.

[5] J. Orear, *Fizyka*, tom 1-2, WNT, Warszawa 2008.

[6] Cz. Bobrowski, *Fizyka - krótki kurs*, WNT, Warszawa 2004.

[7] P.G. Hewitt, *Fizyka wokół nas*, PWN, Warszawa 2008.

Fizyka atomowa i spektroskopia:

[1] Hermann Haken, Hans Christoph Wolf, Atomy i kwanty. Wprowadzenie do współczesnej spektroskopii atomowej, Wydawnictwo Naukowe PWN, Warszawa 1997.

[2] Wolfgang Demtröder, Spektroskopia laserowa, Wydawnictwo Naukowe PWN, Warszawa 1993.

Fizyka ciała stałego:

[1] Neil W. Ashcroft, N. David Termin*, Fizyka ciała stałego*, Państwowe Wydawnictwo Naukowe, Warszawa 1986.

[2] C. Kittel. *Wstęp do fizyki ciała stałego*, Państwowe Wydawnictwo Naukowe, Warszawa 1974.

[3] K. W. Szalimowa, *Fizyka półprzewodników*, Państwowe Wydawnictwo Naukowe, Warszawa 1974.

Optoelektronika i fizyka laserów:

[1] Bernard Ziętek, *Lasery*, Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika, Toruń 2008.

[2] Bernard Ziętek, *Optoelektronika*. Wydawnictwo Uniwersytetu Mikołaja Kopernika, Toruń 2004.

[3] Koichi Shimoda, *Wstęp do fizyki laserów*, Wydawnictwo Naukowe PWN, Warszawa 1993.

Fizyka jądrowa:

[1] Ewa Skrzypczak, Zygmunt Szefliński, *Wstęp do fizyki jądra atomowego i cząstek elementarnych*, Wydawnictwo Naukowe PWN, Warszawa 1995.

[2] Adam Strzałkowski, *Wstęp do fizyki jądra atomowego*, Państwowe Wydawnictwo Naukowe, Warszawa 1979.

[3] Janusz Araminowicz, Krystyna Małuszyńska, Marian Przytuła, *Laboratorium fizyki jądrowej*, Państwowe Wydawnictwo Naukowe, Warszawa 1978.

In English:

For each exercise, the instructor will indicate the literature. However, you may find useful:

General Physics

[1] Richard P. Feynman, Robert B. Leighton and Matthew Sands, *The Feynman Lectures on Physics*, Addison Wesley; 2 edition (August 8, 2005).

[2] David Halliday, Robert Resnick, Jearl Walker, *Fundamentals of Physics*, Wiley; 9 edition (March 16, 2010).

[3] Paul G. Hewitt, *Conceptual Physics*, Addison Wesley; 9th edition (July 2, 2001).

[4] Jay Orear, *Physics*, MacMillan Publishing Company (May 3, 1979).

Atomic Physics and Spectroscopy:

[1] Hermann Haken, Hans Christoph Wolf, W. D. Brewer, *The Physics of Atoms and Quanta*: *Introduction to Experiments and Theory*, pringer; 7th rev. and enlarged ed. 2005 edition (October 19, 2005).

[2] Wolfgang Demtröder, *Laser Spectroscopy*: Vol. 1: *Basic Principles*, Springer; 4th edition (July 29, 2008).

[3] Wolfgang Demtröder, *Laser Spectroscopy*: Vol. 2: *Experimental Techniques*, Springer; 4th edition (September 17, 2008).

Solid State Physics:

[1] Neil W. Ashcroft and N. David Mermin, *Solid State Physics*, Brooks Cole; 1 edition (January 2, 1976).

[2] Charles Kittel, *Introduction to Solid State Physics*, Wiley; 8 edition (November 11, 2004).

[3] Marius Grundmann, *The Physics of Semiconductors: An Introduction Including Nanophysics and Applications*, Springer; 2nd ed. 2010 edition (December 24, 2010).

<u>Optoelectronics and laser physics:</u>

[1] Koichi Shimoda, *Introduction to Laser Physics*, Springer; 2nd edition (September 3, 1986).

[2] Orazio Svelto, *Principles of Lasers*, Springer; 5th ed. 2010 edition (December 28, 2009).

<u>Nuclear physics:</u>

[1] Carlos A. Bertulani, *Nuclear Physics in a Nutshell*, Princeton University Press; 1 edition (April 3, 2007).

[2] Kenneth S. Krane, *Introductory Nuclear Physics*, Wiley; 3 edition (October 22, 1987).

PROGRAM PREPARATION:

Dr Bartosz Brzostowski

THEORETICAL PHYSICS

Course code: **13.2-WF-FizD-FiTeo**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr hab. Krzysztof Urbanowski, prof. UZ**
Name of lecturer: **dr hab. Krzysztof Urbanowski, prof. UZ**
dr Sylwia Kondej, dr Joanna Kalaga

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					11
Lecture	45	3	I SD	Exam	
Class	60	4		Grade	

COURSE AIM:

To familiarize students with the basic concepts of theoretical physics, which are the basis for the development of the whole of modern physics, including a description of the properties of matter, both as a discrete system of points and the continuum, or ensembles made up of large numbers of molecules.

ENTRY REQUIREMENTS:

Knowledge of foundations of physics and mathematics corresponding to educational level undergraduate.

COURSE CONTENTS:

Lectures:

Classical mechanics: *Kinematics and Dynamics of particles and rigid bodies. Galileo transforms. Constrains, D'Alambert's principle, Lagrange equations. Variational principles and conservation laws. Noether theorem. Phase space, Hamilton equations. Invariants of canonical transformations, constants of motion. Relativistic kinematics – Lorentz transformations Minkowski space. Elements of relativistic dynamics. Elements of elastic continuum mechanics.*

Statistical mechanics: *Elements of classical statistical mechanics, Elements of quantum statistical mechanics.*

Classes:

Examples of Newton equations, Kepler problem, two body problem, Euler equation for the rigid body. Lagrange and Hamilton equations, variational principles, phase space, stability of phase trajectories. Elements of relativistic kinematics and dynamics. Elements of classical and quantum statistical mechanics.

TEACHING METHODS:

Conventional lectures and classes

LEARNING OUTCOMES:

Skill of theoretical interpretations known experimental physics facts and using mathematical methods and methods of theoretical physics to solve problems and t to describe the processes occurring in nature (K2A_W03, K2A_W04, K2A_U01). Understanding the role of mathematics in physics (K2A_W02, K2A_K01, K2A_K05).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

LECTURE: The exam

CLASS: Credits of exercises

Before taking the examination the student needs to obtain passing grade in the computational exercises.

The final grade: the weighted average of the examination grade (60%) and the computational exercises grade (40%).

STUDENT WORKLOAD:

- Participation in the lectures: 45 hours
- Participation in the exercises: 60 hours
- Participation in the examination: 2 hours
- Participation in consultation: 5 hours
- Preparation for exam: 45 hours
- Preparation for exercises: 60 hours

Total: 217 hours, 11 ECTS points

Effort associated with activities that require direct participation of teachers: 112 hours, 5,5 ECTS

RECOMMENDED READING:

[1] L. D. Landau, E. M. Lifszic, *Teoria pola*, PWN, Warszawa 1976.

[2] W. Garczyński, *Mechanika teoretyczna*, Wyd. Uniwersytetu Wrocławskiego, Wrocław 1978.

[3] I. I. Olchowski, *Mechanika teoretyczna*, PWN, Warszawa 1978.

[4]J. R. Taylor, *Mechanika klasyczna*, PWN, Warszawa 2006.

[5] K. Huang, *Mechanika statystyczna*, PWN, Warszawa 1987.

OPTIONAL READING:

[1] I. Arnold, *Metody matematyczne mechaniki klasycznej*, PWN, Warszawa 1981.

[2] H. Goldstein, Classical mechanics.

[3] F. Schutz, *Chaos deterministyczn*y PWN, Warszawa 1995.

PROGRAM PREPARATION:

Dr hab. Krzysztof Urbanowski, prof UZ

SCIENTIFIC PROGRAMMING IN PYTHON

Course code: **11.3-WF-FizD-PNwJP**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr Sebastian Żurek**
Name of lecturer: **dr Sebastian Żurek**
dr inż. Artur Barasiński

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					6
Lecture	30	2	I (FK)	Exam	
Laboratory	30	2		Grade	

COURSE AIM:

The course aim is to introduce the Python as the scientific programming tool. Python is a general purpose, high-level and modern programming language and the capabilities of its standard library as well as the external modules to handle the numerical analysis in physics and related fields will be presented.

ENTRY REQUIREMENTS:

Basic knowledge in programming and object oriented programming.

COURSE CONTENTS:

1. General Python introduction
- language syntex and data types
- flow-control and exceptions
- interactive shell
- scripts
- functions
- modules
2. File I/O operations
- writing to and saving files
- data serialization
- typical I/O operations errors
3. Object Oriented Programming
- classes and objects
- inheritance and polymorphism
- abstractions
4. Introduction to software engineering
- version control systems
- Linux as IDE

- introduction to unit-tests
- software efficiency and profiling

5. Numerical analysis and computer simulations introduction

- the math module
- NuPy's arrays
- random numbers
- basic linear algebra operations in NumPy
- differential equations solvers in NumPy
- data visualisations in the matplotlib module
- introduction to parallel computing with mpi4py

6. Visualization, animations and image processing

- the canvas and graphical primitives
- plots
- animations
- image processing with openCV (computer vision) module

TEACHING METHODS:

Lecture and computer lab, discussions, individual students readings of technical documentation

LEARNING OUTCOMES:

- Student is able to use Python and its standard library to implement a simple software that numerically solves a classical physics problem
- Student is able to find out, learn and use the external Python libraries that will help him with the numerical analysis of physical problems
- Student is able to perform graphical data analysis and data visualization using Python and its modules
- Student is able to solve and present (in spoken and printed form) the outcomes of assigned project.

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture: to pass the exam the student will be asked to numerically solve a certain problem of the classical physics or data analysis. The examined knowledge fields and the final exam grade will be evaluated using the following aspects: the problem analysis, presentation of the algorithms used in the problem solution, the presentation of the source code and the validity of the results.

Lab: The final grade will be constructed from the grade related to the report from the project developed during the course (70% of the final grade) and the individual grades obtained during the laboratories (30% of the final grade).

Before taking the examination the student needs to obtain passing grade in the laboratory exercises.

The final grade: the arithmetic average of the examination grade and laboratory exercises grade.

STUDENT WORKLOAD:

- Lecture - 30 h
- Laboratory - 30 h
- Laboratory preparations - 25 h
- Semester project - 25 h
- Examination preparation - 20 h
- Consultations - 3 h
- Examination - 2 h

Total: 135 h, 6 ECTS.

The workload requiring the participation of the teacher: 65 h, 3 ECTS.

RECOMMENDED READING:

[1] Mark Lutz, Learning Python, Fifth Edition, O'Reilly, June 2013.

[2] http://python.org

[3] http://python-ebook.blogspot.com/
[4] http://numpy.scipy.org

PROGRAM PREPARATION:

Dr Sebastian Żurek

QUANTUM PHYSICS I

Course code: **13.2-WF-FizD-FKwa1**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **prof. dr hab. Piotr Rozmej**
Name of lecturer: **prof. dr hab. Piotr Rozmej**
dr Sylwia Kondej

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					8
Lecture	30	2	II	Exam	
Class	45	3		Grade	

AIMS OF THE COURSE

To teach the student advanced methods of quantum mechanics. To teach approximation methods and give foundations for relativisitc quantum mechanics.

ENTRANCE REQUIREMENTS

Knowledge of first course of quantum mechanics

COURSE PROGRAMME

LECTURE:

- Postulates of quantum mechanics – recollection.
- Approximate methods:
  - Perturbation theory (time independent). Non-degenerate case. Interpretation of Stern-Gerlach effect and Zeeman effect. Degenerate case. Stark effect.
  - Variational principle and variational method. Many-body problem of interacting particles. Mean field approach, self-consistent method.
- Symmetries and conservation laws:
  - Unitary transforamations. General formulation.
  - Translations and conservation of momentum.
  - Rotations and conservation of angular momentum.
  - Translations in time and conservation of energy.
  - Space inversion and parity conservation.
- Second quantization, occupation number representation. Creation and anihilation operators for fermions.
- Occupation number representation. Creation and anihilation operators for bosons.
- Elements of relativistic quantum mechanics:
  - Klein-Gordon equation.
  - Dirac equation.
  - Free electron motion in Dirac theory. Negative energy states.
  - Magnetic moment of electron.
  - Spin.
  - Hydrogen atom in Dirac theory.
- Universal properties of wave packet dynamics in bounded systems.

- Fermi and Bose statistics..

CLASS:

Essentially the same topics, but with extension of particular calculations and interpretations on several examples.

TEACHING METHODOLOGY:

Lectures on problems and discussions. Oral practice, in which students solve tasks.

LEARNING OUTCOMES:

Student derives conclusions from particular postulates of quantum mechanics (K2A_W02). Applies several approximate methods (K2A_W02).

Is familiar with different representations of physical operators (K2A_W04).

Student is able to link symmetries of the quantum system with particular conservation laws (K2A_U06).

Is aware of relativistic effects (like spin of fermions) present in quantum systems (K2A_W06).

ASSESSMENT CRITERIA:

LECTURE: A course credit for the lectures is obtained by taking a final exam composed of tasks of varying degrees of difficulty.

CLASS: During the classes the preparation of the students will be checked as well as their understanding of the lecture content at the time of the lectures.

To obtain a course credit for the exercises 50% of the maximum number of points will be required, which can be achieved through two cumulative tests. A student who achieves at least 10% of the maximum points and who does not exceed the class absence limit has the right to a resit test of the entire material before the examination date. The result of the exam is also affected by class participation and preparation for the class.

Entrance to the exam requires prior accreditation of the course exercises.

STUDENT WORKLOAD:

Contact hours:

- Lectures: 30 hours
- Exercises: 45 hours
- Consultation: 10 hours
- Exam; 2 hours

Total: 87 hours, 4 ECTS

Individual workload of student:

- Preparation for lectures and exam: 30 hours
- Preparation for exercises and tests: 45 hours

Total: 162 hours, 8 ECTS.

RECOMMENDED READING:

[1] P. Rozmej, *Lecture Notes,* pdf file, delivered to students.

[2] St. Szpikowski, *Elementy mechaniki kwantowe*j, Wyd. UMCS, 1999.

OPTIONAL READING:

[1] I. Białynicki-Birula, M. Cieplak, J. Kamiński, *Theory of quanta,* PWN, Warszawa 2001.

[2] A. L. Schiff, *Quantum mechanics,* PWN, Warszawa 1987.

PROGRAM PREPARATION:

Prof. dr hab. Piotr Rozmej

INTRODUCTION TO ATOMIC AND MOLECULAR PHYSICS

Course code: **13.2-WF-FizD-WdFAC**

Type of course: **compulsory**

Language of instruction: **Polish**

Director of studies: **dr hab. Anatol Nowicki, prof. UZ**

Name of lecturer: **dr hab. Anatol Nowicki, prof. UZ**
dr Piotr Jachimowicz

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					7
Lecture	30	2	II	Exam	
Class	30	2		Grade	

COURSE AIM:

The aim of the course is to teach the students methods and applications of quantum mechanics in description of matter-matter interactions; at the scale of one or a few atoms and energy scales around several electron volts. In particular we present the approximated methods, method of self consistent field and variational methods in atomic physics.

ENTRY REQUIREMENTS:

Quantum mechanics and Classical electrodynamics courses.

COURSE CONTENTS:

LECTURE: One-electron atoms. Eigenvalues, quantum numbers, degeneracy, Zeeman effect, spin. The orbit-spin interaction. Identical particles, Pauli rule Multielectron atoms. Hartree-Fock theory, the self consistent field. The periodic table. Optical excitations, atomic spectra. Molecules, Born-Oppenheimer theory, LCAO MO theory. Molecular spectra, rotation, vibration-rotation and electron spectra. Raman effect.

CLASS: A hydrogen atom, quantum numbers, atom orbitals, spin. Multielectron atoms, the periodic table. The orbit-spin interaction, atomic spectra. Molecules spectra.

TEACHING METHODS:

Conventional lectures, calculate class.

LEARNING OUTCOMES:

The basic aim of the course is a presentation of approximated methods in description of atoms and molecules. The course is devoted to increasing the students working knowledge of physics principles and problem solving skills.

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

LECTURE: The exam

CLASS: Credits of exercises

Before taking the examination the student needs to obtain passing grade in the computational exercises.

The final grade: the weighted average of the examination grade (60%) and computational exercises grade (40%).

STUDENT WORKLOAD:

- Participation in the lectures: 30 hours

- Participation in the exercises: 30 hours

- Participation in the examination: 2 hours

- Participation in consultation: 5 hours

- Preparation for exam: 30 hours

- Preparation for exercises: 40 hours

Total: 137 hours, 7 ECTS points.

Effort associated with activities that require direct participation of teachers: 67 hours, 3,5 ECTS.

RECOMMENDED READING:

[1] 1] W. Kołos, J. Sadlej, *Atom i cząsteczka*, WNT, Warszawa 2007.

[2] J. Ginter, *Wstęp do fizyki atomu, cząsteczki i ciała stałego*, PWN, Warszawa 1986.

[3] I. Białynicki-Birula, M. Cieplak, J. Kamiński, *Teoria kwantów*, PWN, Warszawa 1991.

[4] W. Kołos, *Chemia kwantowa*, PWN, Warszawa 1980.

[5] L. Schiff, *Mechanika kwantowa*, PWN, Warszawa 1977.

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr hab. Anatol Nowicki, prof. UZ

APPLICATIONS OF COMPUTER SIMULATIONS

Course code: **11.3-WF-FizD-SKwZa**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr Marcin Kośmider**
Name of lecturer: **dr Marcin Kośmider**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					6
Lecture	30	2	II (FK)	Exam	
Laboratory	30	2		Grade	

COURSE AIM:

The aim of the course is to gain a knowledge of computer simulation methods, their applications, strong and weak sides. Students should acquire skills in implementation of this knowledge by designing the proper algorithms and then interpreting the results of computer simulations.

ENTRY REQUIREMENTS:

Object oriented programming in Java or Python or C++, introduction to computer simulations, basics of MD and MC algorithms and techniques.

COURSE CONTENTS:

- Random walk – lattice and off-lattice, lattice gas model
- Percolation
- MC simulations of spin system with interactions
- Queue systems
- Computer simulations of polymers
- Basics of Molecular Dynamic – revision
- System with two atom interactions
- Molecular mechanics and force field
- NVE, NPT, NVT ensemble – MD simulations

TEACHING METHODS:

Lectures and laboratory exercises, discussions, independent work with a specialized scientific literature in Polish and English, and work with the technical documentation and search for information on the Internet.

LEARNING OUTCOMES:

Students expand their ability to acquire knowledge in different ways using a variety of sources (K2A_U10). They have practical knowledge on modeling using pseudo-random number generator and deterministic methods (K2A_W02, K2A_W02). Students have an extended knowledge of classical physics of interacting systems (K2A_W01). They know numerical error analysis, numerical methods of solving differential equations, they can use molecular dynamics methods, methods of Monte Carlo (K2A_W05). They have skills in data analysis (K2A_U05), they posses knowledge which is acquired during studies of the scientific literature (K2A_U03, K2A_U10). Characteristic feature is the expanding awareness of the need to update the technical knowledge on the available techniques and simulation results (K2A_K01) as well as awareness of the impact of research on the development of computer technology, including in particular nanotechnology (K2A_K05).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture: positive evaluation of the practical exam.

Laboratory: evaluation of laboratories of 30%, the assessment of the project 70%.

Before taking the examination the student needs to obtain passing grade in the laboratory exercises.

The final grade: the arithmetic average of the examination grade and laboratory exercises grade.

STUDENT WORKLOAD:

- Participation in lectures: 30 hours
- Participation in exercises: 30 hours
- Preparation for the exercises: 20 hours
- Project preparation: 30 hours
- Consulting for the lectures and exercises: 5 hours
- Preparation for the completion of the lecture: 10 hours
- Exam: 2 hours

TOTAL: 127 hours, 6 ECTS.

Contact hours: 67 hours, 3 ECTS.

RECOMMENDED READING:

[1] D. Frenkel, B. Smit, *Understanding Molecular Simulation. From Algorithms to Applications,* Academic Press 2002.

[2] M. P. Allen, D. J. Tildesley *Computer Simulation of Liquids*, Oxford University Press 1990.

[3] D. P. Landau, K. Binder *A guide to Monte Carlo Simulations in Statisticsl Physics,* Cambridge University Press 2005.

[4] K. Binder, D. W. Heerman, *Monte Carlo Smulation in Statistical Physics*, Springer 2010.(5th ed)

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr Marcin Kośmider

UNIX OS PROGRAMMING

Course code: **11.3-WF-FizD-UNIX**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr Krzysztof Krzeszowski**
Name of lecturer: **dr Krzysztof Krzeszowski**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Laboratory	30	2	II (FK)	Grade	

COURSE AIM:

To teach students how to use advanced programmer tools available in *UNIX operating system with the emphasis on the tools often used in supercomputing-clusters

ENTRY REQUIREMENTS:

Ability to program in one of the following programming languages: C/C++/Java/Python, ability to use the *UNIX based systems in the user level

COURSE CONTENTS:

- GNU toolchain: a programmer toolset provided with *UNIX systems by the GNU project (gcc, automake, autoconf, binutils)
- GNU Emacs as IDE
- shared and static libraries
- low-level streaming (vector) instructions (SSE programming)
- parallel programming with OpenMPI
- OpenMPI interfaces (bindings) to high-level scripting languages: examples in Pyhon programming language

TEACHING METHODS:

Computer lab, discussions, individual students readings of technical documentation

LEARNING OUTCOMES:

Ability to write efficient programs using GNU toolchain, basic knowledge in high-performance computing with SIMD streaming instructions and/or parallel programming with MPI interface

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Two laboratory projects implemented during the course are marked positively:

- the Ising model Monte-Carlo simulation implemented in parallel technique with the scientific rapport created in LaTex system (50% of final grade)

- development of helping-tools enhancing the scientific work in supercomputing-cluster: running scripts in queue systems, automated e-mail reporting on broken or finished calculation tasks, programs re-running , etc. (50% of final grade)

STUDENT WORKLOAD:

- Laboratory: 30 h
- Laboratory preparation: 20 h
- Individual projects workload: 20 h
- Consultations: 5 h

Total: 75 h, 3 ETCS.

The workload requiring the participation of the teacher: 35 h, 1,5 ECTS.

RECOMMENDED READING:

[1] Peteresn Arbenz*, Introduction to Parallel Computing*, Oxford University Press, 2004

[2] Intel(R) 64 and IA-32 Architectures Optimization Reference Manual (http://developer.intel.com/assets/pdf/manual/248966.pdf)

OPTIONAL READING:

[1] Papers on MPI applications: http://www.open-mpi.org/papers/

[2] GNU Emacs Manual (http://www.gnu.org/software/emacs/manual/emacs.pdf)

SYMBOLIC PROGRAMMING IN PHYSICAL PROCESSES SIMULATIONS

Course code: **11.3-WF-FizD-PSSPF**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr Tomasz Masłowski**
Name of lecturer: **dr Tomasz Masłowski**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Laboratory	30	2	II (FK)	Grade	

COURSE AIM:

Students can use a Computer Algebra Systems (Mathematica, Sage, Maxima as examples) in symbolic problem solving in physics and verification of analytical calculations.

ENTRY REQUIREMENTS:

Knowledge of calculus and linear algebra and the basis of classical mechanics, classical electrodynamics and quantum mechanics. Programming in C or Fortran.

COURSE CONTENTS:

1. Introduction to computer algebra (wxMaxima, Mathematica):
   - Sessions, evaluation of expressions, environment variables,
   - Differentiation and integration,
   - Systems of linear equations,
   - 2D and 3D plots and data visualization,
   - Differential equations.
2. Classical Mechanics:
   - Harmonic oscillator,
   - Coupled harmonic oscillators,
   - Two-body problem.
3. Electrodynamics:
   - Discrete distribution of charges,
   - Poisson equation,
   - Charged particle in an electromagnetic field.
4. Quantum Mechanics:
   - Potential barrier,
   - Potential well,
   - Harmonic oscillator,
   - Hydrogen atom.

TEACHING METHODS:

Laboratory classes in the computer lab. Working in groups. Joint solvining more complex or laborious examples.

LEARNING OUTCOMES:

Student:

- can present a problem in terms of the physical laws and principles to propose its mathematical model (K2A_W02, K2A_U03)

- can use the CAS system to analyze the experimental data and for graphical representations of data; is able to analyze the results, present and discuss conclusions (K2A_W05, K2A_U03, K2A_U04, K2A_U05)

- can use symbolic and numerical calculations in the CAS to solve physical problems; is able to analyze the obtained solution and perform its verification by comparison with known analytical solution (if it exists) (K2A_W02, K2A_W05, K2A_U04, K2A_U06).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

The condition of positive assessment is accomplishment of all programming exercises.

Final assessment: the weighted average of the final test (50%) and programming exercises (50%).

STUDENT WORKLOAD:

- Laboratory classes: 30 h
- Self-learning on homework tasks: 30 h
- Consultations: 2 h

Total: 62 h, 3 ECTS.

Workload directly involving teacher: 32 h, 1,5 ECTS.

RECOMMENDED READING:

[1] L. D. Landau, E. M. Lifszyc, *Mechanics*, Vol. 1, (3rd ed.), Butterworth–Heinemann 1976.

[2] D. J. Griffiths, *Introduction to Electrodynamics*, (3rd ed.), Addison Wesley 1999.

[3] L. Piela, *Ideas of Quantum Chemistry*, (1st ed.), Elsevier 2006.

[4] S. Wolfram, *The mathematica book*, 5-th ed., Wolfram Media 2003.

[5] http://maxima.sourceforge.net/docs/tutorial/en/gaertner-tutorial-revision/Contents.htm

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr Tomasz Masłowski

SCRIPTING LANGUAGES IN DATA ANALYSIS

Course code: **11.3-WF-FizD-JSwAD**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **dr Krzysztof Krzeszowski**
Name of lecturer: **dr Krzysztof Krzeszowski**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Laboratory	30	2	II (FK)	Grade	

COURSE AIM:
The primary language is the Python programming language and by using it students should acquire the ability to analyze data on examples of specific tasks. Students should familiarize themselves with the available Python libraries, data analysis methods and they should be able to use them in practical tasks.

ENTRY REQUIREMENTS:
It is assumed elementary programming skills in any programming language, and knowledge of basic mathematical methods of data analysis.

COURSE CONTENTS:
- Introduction to programming in Python
- Python libraries: NumPy, pandas, matplotlib, SciPy
- Basics of NumPy (data processing using arrays, mathematical and statistical methods, read and write data to disk in binary or text)
- Pandas basics: read and write data to disk in various formats (CSV, Microsoft Excel), multi-dimensional data.
- Basics of Matplotlib: data plots, visualization
- Time series (methods of analysis)

TEACHING METHODS:
Laboratory exercises, individual work and group work, exchange of ideas, work with documentation, self-knowledge acquisition, project.

LEARNING OUTCOMES:
Student knows the information technology used to solve common problems in the field of physical sciences and understands their limitations (K2A_W05). Student understands the complexity of the issues relating to access to the data, the appropriate analysis of data and data storage. Based on empirical data, student can build simple mathematical models adequate to physical problems (K2A_U03). Student is able to work effectively in a group assuming different roles according to the situation (K2A_K03).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Score: average grades achieved during the activity and short tests advances in science (50% of the final mark) and the assessment of the semester project (50% of the final mark). To pass the semester project is its preparation and commitment within the prescribed period of the project report as well as its presentation.

STUDENT WORKLOAD:

- Participation in laboratory: 30 h
- Preparation for the laboratory: 20 h
- Project preparation: 20 h
- Preparation for the completion of the lecture: 15 h
- Consulting: 3 h

Total: 73 h, 3 ECTS.

Contact hours: 33 h, 1,5 ECTS.

RECOMMENDED READING:

[1] Allen Downey, *Think Python. How to Think Like a Computer Scientist*, 2013. Green Tea Press, Needham, Massachusetts.

[2] Wes McKinney, *Python for Data Analysis*, O'Reilly Media Inc. (2013).

OPTIONAL READING:

[1] Internet

REMARKS: -

SOLID STATE PHYSICS

Course code: **13.2-WF-FizD-FFaSk**

Type of course: **compulsory**

Language of instruction: **Polish**

Director of studies: **The academic teacher giving the lecture**

Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					8
Lecture	30	2	III	Exam	
Class	45	3		Grade	

COURSE AIM:

The aim of the course is to provide students with basic knowledge of solid state physics and the corresponding research methods with the learning outcomes in the area of science. Students should know the basics of crystallography, the concept of reciprocal lattice, diffraction methods for determining the crystal structure, they should be familiar with the issue of an electron in a periodic potential, the question of the formation of the band structure in solids, the harmonic crystal approximation, they should know in detail the selected problems of condensed phase in the quantum description, including superconductivity.

ENTRY REQUIREMENTS:

It is assumed that students know subjects of general physics and they have got basic course of mathematical analysis (knowledge and skills that meet the criteria K2A_W01).

COURSE CONTENTS:

- Crystal lattices, the classification of Bravais lattices and crystal structures.
- Reciprocal lattice, diffraction methods to determine the crystal structure (Laue condition, Bragg equation, Brillouin zones, geometric structural factor).
- An electron in a periodic potential, the Bloch theorem, Kronig-Penney Model.
- Band theory of solids: metals, semiconductors and dielectrics, examples of band structures.
- Crystal in the harmonic approximation (classical and quantum theory), dispersion relations, normal modes in 1D monatomic Bravais lattices, one-dimensional chain with basis, acoustic and optical branches at Brillouin zone boundary.
- Selected issues: continuum linear elastic theory, wave propagation, specific heat, Debye model.
- Superconductivity.

TEACHING METHODS:

Teaching methods have two forms: lecture and exercises.
During the lecture both theory and selected examples are presented. Next, the examples are recommended to

be extended at exercises. Students increase their computational skills by solving these examples in detail. In addition, they discuss selected problems.

LEARNING OUTCOMES:

Students have a basic knowledge of the methods of condensed matter physics. General knowledge (K2A_W01) is supported by a detailed skills in computing for selected models such as one-dimensional model Kröning-Penney'go one-dimensional chain of atoms - unions dispersion, specific heat, which allow broader understanding of the more general theoretical frameworks. They can explain and describe particular phenomena (K2A_W01, K2A_W04).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

The course ends with an exam grade. Examination is a written test of theoretical knowledge and practical skills in accounting. The effects of exercise training are reviewed by partial reviews on completed tasks, evaluation of written tests and assessment of accounting skills and understanding of selected topics of condensed matter physics.
Overall rating: arithmetic mean score of the exam and exercises.

STUDENT WORKLOAD:

- Participation in lectures: 30 hours
- Participation in exercises: 45 hours
- Preparation for the exercises: 45 hours
- Consulting for the lecturees and exercises: 5 hours
- Preparation for the completion of the lecture: 40 hours

TOTAL: 165 hours, 8 ECTS.

Contact hours: 60 hours, 2,5 ECTS.

RECOMMENDED READING:

[1] Neil W. Ashcroft, N. David Mermin, *Solid State Physics*, Harcourt College Publishers 1976

[2] C. Kittel, *Introduction to solid state physics*, John Wiley& Sons Inc, 1996.

[3] L. E. Reichl, *A Modern Course in Statistical Physics*, E. Arnold (Publishers) LTD, University of Texas Press 1980.

OPTIONAL READING:

[1] Donald A. MCQuarrie, The Kroning-Penney Model: A Single Lecture Illustrating the Band Structure of Solids, in The Chemical Educator VOL. 1. 1996 Springer-Vellag New York, inc.

[2] F. Reif, *Fundamentals of Statistical and Thermal Physics*, Mc Graw-Hill, Singapore 1985.

PROGRAM PREPARATION:

Dr hab. Miroslaw Dudek, prof. UZ

NUCLEAR AND HIGH ENERGY PHYSICS

Course code: **13.2-WF-FizD-FJFWE**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher giving the lecture**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					6
Lecture	30	2	III	Exam	
Class	30	2		Grade	

COURSE AIM:

Introduction to fundaments of nuclear physics and high energy physics.

ENTRY REQUIREMENTS:

Basic knowledge of classical and quantum mechanics.

COURSE CONTENTS:

LECTURE:

- Subjects of nuclear physics and high energy physics
- Physical quantities characterizing nuclei and elementary particles; mass, charge, life-time, barion and lepton numbers, spin, magnetic moment, isospin, parity.
- Nucleon-nucleon interaction. Theory of deuteron.
- Nuclear models: Liquid Drop Model, Fermi gas model, shell model, self-consistent model.
- Mean field theory. Nuclear potentials.
- Residual interactions, quasi-spin model, BCS theory.
- Collective motion. Rotational and vibrational excitations.
- Spontaneous decay of nuclei; α, β, γ, fission.
- Nuclear reactions, Collisions with low, medium and high energies.
- Elements of the standard model and high energy physics.

ECERCISES:

Subject basically the same as lecture. Explicit calculations for particular problems.

TEACHING METHODS:

Lectures on problems and discussions. Oral practice, in which students solve tasks.

LEARNING OUTCOMES:

- The student knows and understands the fundamental properties of atomic nuclei (K2A_W01, K2A_U01).
- The student knows mean field approach to many body problem (K2A_W06).
- The student understands several models applicable in nuclear physics: liquid drop model, Fermi gas model. The student is able to estimate basic nuclear propertis on the ground of those models (K2A_U03).
- The student knows general mechanisms of nuclear reactions (K2A_W03) and recognizes collective excitations (K2A_U11).
- The student knows elementary particles according to the standard model (K2A_W05).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

A course credit for the lectures is obtained by taking a final exam composed of tasks of varying degrees of difficulty.

During the classes the preparation of the students will be checked as well as their understanding of the lecture content at the time of the lectures. To obtain a course credit for the exercises 50% of the maximum number of points will be required, which can be achieved through two cumulative tests. A student who achieves at least 10% of the maximum points and who does not exceed the class absence limit has the right to a resit test of the entire material before the examination date. The result of the exam is also affected by class participation and preparation for the class.

STUDENT WORKLOAD:

Contact hours:

- Lectures: 30 hours
- Exercises: 30 hours
- Consultation: 2 hours
- Exam; 2 hours

Total: 64 hours, 3 ECTS.

Individual workload of student:

- Preparation for lectures: 8 hours
- Preparation for exercises: 20 hours
- Preparation for tests: 15 hours
- Preparation for exam: 15 hours

Total: 58 hours, 3 ECTS.

Final total: 122 hours, 6 ECTS.

RECOMMENDED READING:

[1] P. Rozmej*, Lecture Notes,* plik pdf.

[2] B. Nerlo-Pomorska, K. Pomorski, *Zarys teorii jądra atomowego,* PWN, Warszawa 1999.

OPTIONAL READING:

[1] E. Skrzypczak, Z. Szefliński, *Wstęp do fizyki jądra atomowego i cząstek elementarnych*, PWN, Warszawa 1995.

[2] W. S. C. Williams, *Nuclear and particle physics*, Oxford: Clarendon Press, 1997.

PROGRAM PREPARATION:

Prof. dr hab. Piotr Rozmej

INTERNET APPLICATIONS PROGRAMMING

Course code: **11.3-WF-FizD-PrApl**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher giving the lecture**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					4
Lecture	15	1	III (FK)	Exam	
Laboratory	30	2		Grade	

COURSE AIM:

The aim of this course is to introduce the programming techniques required to develop and create internet applications – how to design and code frontend in css and html, hot to store and analyse data (relational databases). Open source software is important part of this course.

ENTRY REQUIREMENTS:

basic programming in python (with OOP)
relational databases on the basic level

COURSE CONTENTS:

1) HTML
- document structure
- blok and „in-line" elements
- data presentation
- links
- graphics
- lists
- tables
- forms
- HTML 5

2) CSS
- selectors
- data formating
- box model
- positioning
- layouts
- menu

3) JQuery
   - JavaScript – introduction
   - JQuery – introduction
   - Jquery UI
   - Plugins
   - Ajax
4) Django framework
   - Python – OOP techniques
   - Django installation and configuration
   - view and urls
   - models and relational databases
   - admin panel
   - forms

TEACHING METHODS:

Lecture:

Convencional lecture, work with problems, discusiion, workshop

Laboratory:

Laboratory exercise, project, work in group, presentation, work with documentation, independed work, brain storm

LEARNING OUTCOMES:

- Student can find, choose and use external libraries, frameworks and other solutions according to the licences and the law. Student can describe what OpenSource means and discuss why Open Source Software is a good alternative to commercial software and why is worth to use. (K2A_W09, K2A_U09, K2A_U10, K2A_K04).
- Student can prepare web page according to the W3C standards. Student can discuss why data and presentation layer should be separated. (K2A_W09, K2A_U09, K2A_U10, K2A_K04).
- Student can design database based internet service and create it in Django framework. Student can discuss role of the database web services in modern world. (K2A_U09, K2A_U10, K2A_K04).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Lecture:

final procject – 40% (Html + CSS + Jquery), 40% design, quality of code, 20% presentation and discussion.

Laboratory:

20% - tests during laboratories

40% - frontend project

40% - Django project

Before taking the examination the student needs to obtain passing grade in the laboratory exercises.

The final grade: the weighted average of the examination grade (60%) and laboratory exercises grade (40%).

STUDENT WORKLOAD:

- Lectures: 15 h
- Laboratories: 30 h
- Preparation for laboratory: 20 h
- Project preparation: 25 h
- Consultation: 3 h
- Exam: 1 h

Sum: 94 h, 4 ECTS.

Lecturer direct participation: 49 h, 2 ECTS.

RECOMMENDED READING:

[1] http://www.w3.org/Style/Examples/011/firstcss

[2] http://www.w3schools.com/

[3] http://docs.jquery.com/Tutorials

[4] http://www.djangobook.com/

[5] https://docs.djangoproject.com/en/1.3/

OPTIONAL READING:

[1] http://www.smashingmagazine.com/

[2] internet

PROGRAM PREPARATION:

Dr Marcin Kośmider

GRADUATE SEMINAR I

Course code: **13.2-WF-FizD-SMgr1**

Type of course: **compulsory**

Language of instruction: **Polish**

Director of studies: **The academic teacher directing the seminar**

Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Seminar	30	2	III	Grade	

COURSE AIM:

To teach students how to prepare and show the presentation involving results discussed in MSc thesis. Preparation for writing MSc thesis.

ENTRY REQUIREMENTS:

Skills and knowledge gained during completed courses.

COURSE CONTENTS:

Elements of topics in the field of contemporary physics (with special emphasis on those discussed in students' MSc theses).

TEACHING METHODS:

Preparation of talks related to MSc thesis. Joint discussion concerning the merit and form of the presentations.

LEARNING OUTCOMES:

The student gains a general knowledge in the field of current developments and latest discoveries in the physical sciences (**K2A_W06**). He can adapt the his presentation to the level of recipient's knowledge (**K2A_U01**), acquire by oneself his knowledge and to develop skills using a variety of sources (in Polish and foreign language) and modern technology (**K2A_U10**). Student gains the ability to prepare oral presentations, in Polish and foreign language in the fields typical for both theoretical and experimental physics (**K2A_U13**). He understands the role of active and passive dissemination of the knowledge (**K2A_K02**).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Preparation and presentation at least two talks related to the topis discussed in classes. Participation in discussions concerning presented talks.

STUDENT WORKLOAD:

- Participation in classes: 30 hours
- Preparing presentations: 35 hours

- Consultations: 5 hours

Total: 70 hours, 3 ECTS.

Effort related to activities requiring direct participation of teachers 35 hours - equivalent to 1,5 ECTS.

RECOMMENDED READING:

[1] Articles recommended by lecturer, published in scientific and popular journals

[2] Scientific articles downloaded from the server: lanl.arxiv.org.

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr hab. Wiesław Leoński, prof. UZ

GENERAL SEMINAR I

Course code: **13.2-WF-FizD-SPrz1**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher directing the seminar**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Seminar	30	2	III	Grade	

COURSE AIM:

The purpose of this course is to acquaint the participants with the requirements of MA Exam. Students prepare and present presentations on the basic concepts of physics. At the same time, students learn to prepare and present a presentation in various forms.

ENTRY REQUIREMENTS:

Passed all previous lectures.

COURSE CONTENTS:

Topics are divided into two groups. The first group is refereed by students "at the blackboard", whereas the secondin the form of multimedia presentations.

Group A

- the principles of conservation
- the principle of least action
- the postulates of classical mechanics
- the postulates of classical statistical mechanics
- electromgnetic waves and spectroscopy
- electrical properties of matter , Maxwell's equations
- special theory of relativity, relativistic mechanics
- electrostatics, capacitors, dielectrics
- magnetostatic
- electromagnetic induction
- geometrical optics, reflection and refraction of light
- interference and diffraction of light
- the experimental basis of quantum mechanics
- postulates of quantum mechanics, the essence of quantization
- the dynamics of the quantum system
- eigenvalue problems in quantum mechanics
- systems of indistinguishable particles, the Pauli exclusion principle, quantum statistics
- properties of solids in quantum theory
- atomic structure and the periodic table

Group B

- the dilema of Einstein, Podolsky and Rosen
- Bohm and Aharonov refolmulation of EPR paradox in terms of spins
- the Bells inequalities
- quantum computation
- uses of entanglement

TEACHING METHODS:

Students choose topics and form of presentation at least one week in advance. The teacher and other participants in the seminar, listen to the presentation. If necessary the teacher corrects or completes the statement.

LEARNING OUTCOMES:

Student completes and organizes knowledge in physics from previous years of study (K2A_W01, K2A_W02, K2A_U01). Student is able to provide various branches of physics, both theoretical and experimental (K2A_W03, K2A_K02) and to specify and describe their application in the modern world (K2A_U07, K2A_U10). If necessary, the teacher completes information on student presentations on the latest scientific achievements (K2A_W06, K2A_U08). Student can demonstrate their knowledge in different ways (K2A_U01, K2A_U10, K2A_U13).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

The basis of assessment of the students is their activity. The final assessment is based on the criterion thresholds granted by the teacher in the classroom.

STUDENT WORKLOAD:

- Participation in seminars 15 x 2 = 30 h

- Participation in consultations: 6 h

- Preparation for seminars: 30 h

Total: 66 h, 3 ECTS.

Direct participation of the teacher: 36 h, 1,5 ECTS.

RECOMMENDED READING:

[1] D. Halliday, R. Resnick, J. Walker, *Podstawy fizyki* tomy 1 - 5, Wydawnictwo Naukowe PWN, Warszawa 2005.

[2] S. Szpikowski, *Podstawy mechaniki kwantowej*, Wydawnictwo UMCS, Lublin 2006.

[3] C. Kittel, *Wstęp do fizyki ciała stałego*, PWN, Warszawa 1999.

[4] H. Kerson, *Podstawy fizyki statystycznej*, PWN, Warszawa 2006.

OPTIONAL READING:

[1] S. Weinberg, *Lectures on Quantum Mechanics*, Cambridge Univ. Press 2013.

PROGRAM PREPARATION:

Dr hab. Anatol Nowicki, prof. UZ

SPECIALIZATION SEMINAR I

Course code: **13.2-WF-FizD-PrSp1**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher directing the laboratory exercises**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Laboratory	30	2	III	Pass/Fail	

COURSE AIM:

Student finds a complex knowledge of research methodology in physics, in particular in the choice of problems and method to solve them, in the proper choice of literature and use it properly. He will able to write scientific articles using several editorial tools, in particular in Latex as the best editor language for the mathematical and physical texts. Moreover he will obtain information about recent achievements in physics and technology, then he will be good prepared to professional work or further studies.

ENTRY REQUIREMENTS:

Knowledge of physics and mathematics from previous years of study

COURSE CONTENTS:

- *Methodology of scientific researches. Difference between theoretical and experimental work.*
- *Typical scheme of a scientific paper*
  - *The content of the paper*
  - *How one can publish the paper in a good scientific journal*
- *Editor programs*
  - *Microsoft Word*
  - *Latex and its advantages*
- *New achievements in physics*
  - *Quantum information theory and quantum computers. Entangled states and teleportation*
  - *Nonlinear optics of photons and atoms, solitons*
  - *Higgs bosons and their meaning in particle physics and cosmology*

TEACHING METHODS:

Presentation of the participant about his progresses in writing Master thesis.
Conventional lectures given by lecturer with the application of multimedia devices.

LEARNING OUTCOMES:

Knowledge:

Student possesses a general knowledge concerning fundamental concepts of physics, in particular quantum field theory on the level appropriate to the knowledge obtained in the previous period of studies. Some presentations contain the short introduction to the fundamental problems of the scientific domains which develop very fast in the last time, namely the quantum field theory, the quantum information theory. They applications are also considered (K2A_W02, K2A_W06). Thus the problems presented on the seminar expend the physical horizon of MsC students and will be very helpful for them even after their defense of Master thesis. Moreover participants of the seminar will obtain useful hints in writing Master thesis (K2A_W05, K2A_W09).

Ability:
Student can analyze and solve some simple problems in modern physics, in particular in quantum theory. Using the knowledge and information obtained from the literature, data bases, internet resources in both polish and English, he can talk about different new difficult physical problems by a simple comprehensible language (K2A_U01). He will able to perform the analysis of results for some useful quantum algorithms (e.g. teleportation protocol, Shor's algorithm…), and basing on this he can formulate proper conclusions for usefulness of quantum theory (K1A_U01, K2A_U06).

Social competences:
Student has an awareness about his knowledge and abilities, understand the need and know the possibilities of continuous gain own qualifications (studies of second and third degree, postgraduate studies) – raising the personal, professional and social qualifications (K2A_K01).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Presentations of the project of own Master thesis and its progresses (at least two times). Regular presence on the seminar.

STUDENT WORKLOAD:

Participation in the seminar: 30 hours

Independent work: 30 hours

In sum: 60 hours (3 ECTS)

RECOMMENDED READING:

[1] D. R. Bes, *Quantum Mechanics – A Modern and Concise Introductory Course*, Springer-Verlag 2005.

[2] J. Audretsch, *Entangled Systems – New Directions in Quantum Physics*, Wiley-VCH Verlag GmbH & Co. KGaA 2007 p. 23.

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr hab. Van Cao Long, prof. UZ

MONOGRAPHIC LECTURE I – INTRODUCTION TO QUANTUM INFORMATION THEORY

Course code: **13.2-WF-FizD-WyMo1**
Type of course: **compulsory**
Language of instruction: **Polish or English (to be chosen)**
Director of studies: **dr hab. Van Cao Long, prof. UZ**
Name of lecturer: **dr hab. Van Cao Long, prof. UZ**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					3
Lecture	30	2	III	Exam	

COURSE AIM:

Acquaint students with foundations of Quantum Information Theory: Mathematical tools of this Theory and possible physical realizations of quantum computers.

ENTRY REQUIREMENTS:

Knowledge of mathematics and quantum mechanics found from the previous period of study.

COURSE CONTENTS:

- Mathematical foundations of quantum calculations
  - Vectors and operators in Hilbert space
  - Postulates of quantum mechanics
  - Two paradoxes of quantum mechanics: Schroedinger's cats and Einstein-Podosky-Rosen pairs
  - Qubits and quantum registers. Entangled states
  - Quantum gates
  - Quantum algorithms. Teleportation. Shor's algorithm
- What is the quantum computer?
  - Two-level atom as a qubit
  - Optical Bloch equations, quantum gates as rotations on Bloch Sphere
  - Photon as a qubit
  - How quantum computer works
  - Quantum addition and multiplication
- Quantum cryptography
  - Fundamental concepts of cryptography
  - Quantum key distribution by polarized photons
  - Attack on the Rivest-Shamir-Adleman cryptosystem
- Conclusions

TEACHING METHODS:

Conventional lecture with the application of multimedia devices.

LEARNING OUTCOMES:

Knowledge:
Student possesses a general knowledge concerning quantum information on the both mathematical and physical levels appropriate to the knowledge obtained in the previous period of studies. Lecture is a short introduction to the fundamental problems of the scientific domain which develops very fast in the last time, namely the quantum information theory. Its applications are also considered, in particular quantum cryptography. (K2A_W02, K2A_W06).

Ability:
Student can analyze and solve some simple problems in quantum information theory, in particular in quantum cryptography, based on the knowledge and information obtained from the literature, data bases, internet resources in both polish and English, he can present different physical realizations of quantum computers by a simple comprehensible language (K2A_U01). He will able to perform the analysis of results for some algorithms (e.g. teleportation protocol, Shor's algorithm…), and based on this he can formulate proper conclusions (K1A_U01, K2A_U06). He could also find himself a necessary knowledge and develop his abilities in this new domain using different sources of information (K2A_U10).

Social competences:
Student has an awareness about his knowledge and abilities, understand the need and know the possibilities of continuous gain own qualifications (studies of second and third degree, postgraduate studies) – raising the personal, professional and social qualifications (K2A_K01).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

The condition for credit is a positive grade of the final exam. This grade is also the final grade.

STUDENT WORKLOAD:

- Participation on the lecture: 30 hours
- Independent work: 30 hours
- Consultations: 2 hours
- Participation in the exam: 2 hours

In sum: 64 hours, 3 ECTS.

Contact hours: 32 hours, 1,5 ECTS.

RECOMMENDED READING:

[1] M. A, Nielsen, I. L. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, Cambridge, UK 2000.

[2] K. Giara, M. Kamiński M, *Wprowadzenie do algorytmów kwantowych*, Akademicka Oficyna Wydawnicza EXIT, Warszawa 2003.

OPTIONAL READING:

[1] D. Bouwmeeste, A. Ekert, A. Zeilinger (red.), *The Physics of Quantum Information*, Springer-Verlag, Heidenberg 2000.

PROGRAM PREPARATION:

Dr hab. Van Cao Long, prof. UZ

QUANTUM SYSTEMS SIMULATIONS

Course code: **11.3-WF-FizD-SyUKw**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher giving the lecture**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					6
Lecture	15	1	IV (FK)	Exam	
Laboratory	30	2		Grade	

COURSE AIM:

Students should know the methods of numerical simulation of quantum systems and how to applie them to selected problems of quantum mechanics and quantum computing.

ENTRY REQUIREMENTS:

Knowledge of quantum mechanics, knowledge of mathematical methods of physics, knowledge of programming languages - the knowledge and skills that meet the criteria K2A_W01.

COURSE CONTENTS:

1. Quantum Mechanics:
- Wavepackets (Gaussian wavepacket, diffraction, tunneling),
- Simulation using quantum chemistry methods (orbitals, Slater determinant, Hartree-Fock equations, DFT method),
- Simulations using quantum Monte Carlo.
2. Selected aspects of quantum information (qubit concept, arithmetic operations on qubits, quantum algorithms).

TEACHING METHODS:

Teaching methods take the form of lecture, computer lab and excersises. The lecture is is for theoretical introduction. It wshould be enriched with examples of computer simulations and indications of how and when to use quantum methods. The laboratory should have a practical nature, where students are discussing the lecture material, prepare simulations of simple quantum systems, become familiar with the available libraries to conduct simulations of quantum systems. The suggested programming language - Python.

LEARNING OUTCOMES:

Students have a basic knowledge of the methods of computer simulation of quantum systems. General knowledge (K2A_W01) is supported by the ability to implement a detailed quantum model simulations. They can explain the quantum of phenomena under consideration (K2A_W01, K2A_W04) and justify the methods to be used. They have elementary knowledge of quantum computing.

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

The lecture ends with an examination to be assessed. Form of a check is a written theoretical problem and practical skills in its implementing. The effects of exercise training are verified by partial rankings on completed tasks, evaluation of written tests and assessment of skills in computer simulation for a specific issue of quantum problem.

Overall rating: arithmetic average exam grade and credit.

STUDENT WORKLOAD:

- Participation in lectures: 15 hours
- Participation in exercises: 30 hours
- Preparation for the exercises: 40 hours
- Preparation to exam: 20 hours
- Consulting for the lecturees and exercises: 8 hours
- Exam: 2 hours

TOTAL: 115 hours, 6 ECTS.

Contact hours: 55 hours, 3 ECTS.

RECOMMENDED READING:

[1] W. M. C. Foulkes, L. Mitas, R. J. Needs , G. Rajagopal, *Reviews of Modern Physics*, Vol. 73, No. 1, January 2001

[2] Leonard I. Schiff, *Quantum Mechanics*, McGrawHill Book Company (1968)

OPTIONAL READING:

[1] Internet, python libraries.

PROGRAM PREPARATION:

Dr hab. Mirosław Dudek, prof. UZ

GRADUATE SEMINAR II

Course code: **13.2-WF-FizD-SMgr2**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher directing the seminar**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					4
Seminar	30	2	IV	Grade	

COURSE AIM:
To teach students how to prepare and show the presentation involving results discussed in MSc thesis. Preparation for writing MSc thesis.

ENTRY REQUIREMENTS:
Skills and knowledge gained during completed courses.

COURSE CONTENTS:
Elements of topics in the field of contemporary physics (with special emphasis on those discussed in students' MSc theses).

TEACHING METHODS:
Preparation of talks related to MSc thesis. Joint discussion concerning the merit and form of the presentations.

LEARNING OUTCOMES:
The student gains a general knowledge in the field of current developments and latest discoveries in the physical sciences (**K2A_W06**). He can adapt the his presentation to the level of recipient's knowledge (**K2A_U01**), acquire by oneself his knowledge and to develop skills using a variety of sources (in Polish and foreign language) and modern technology (**K2A_U10**). Student gains the ability to prepare oral presentations, in Polish and foreign language in the fields typical for both theoretical and experimental physics (**K2A_U13**). He understands the role of active and passive dissemination of the knowledge (**K2A_K02**).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:
Preparation and presentation at least two talks related to the topis discussed in classes. Participation in discussions concerning presented talks.

STUDENT WORKLOAD:
- Participation in classes: 30 hours.

- Preparing presentations: 40 hours.
- Consultations: 10 hours.

Total: 90 hours, 4 ECTS.

Effort related to activities requiring direct participation of teachers 40 hours - equivalent to 2 ECTS.

RECOMMENDED READING:

[1] Articles recommended by lecturer, published in scientific and popular journals

[2] Scientific articles downloaded from the server: lanl.arxiv.org.

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr hab. Krzysztof Urbanowski, prof. UZ

GENERAL SEMINAR II

Course code: **13.2-WF-FizD-SPrz2**
Type of course: **compulsory**
Language of instruction: **Polish**
Director of studies: **The academic teacher directing the seminar**
Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					4
Seminar	30	2	IV SD	Grade	

COURSE AIM:
To teach students how to prepare speeches and papers in the field of modern physics and how to prepare by oneself to refer their speeches.

ENTRY REQUIREMENTS:
Skills and knowledge gained during completed courses.

COURSE CONTENTS:
Elements of topics in the field of contemporary physics (with special emphasis of topics related to quantum optics and quantum information theory).

TEACHING METHODS:
Preparation of talks related to MSc thesis. Joint discussion concerning the merit and form of the presentations.

LEARNING OUTCOMES:
The student gains a general knowledge in the field of current developments and latest discoveries in the physical sciences (**K2A_W06**). He can adapt the his presentation to the level of recipient's knowledge (**K2A_U01**), acquire by oneself his knowledge and to develop skills using a variety of sources (in Polish and foreign language) and modern technology (**K2A_U10**). Student gains the ability to prepare oral presentations, in Polish and foreign language in the fields typical for both theoretical and experimental physics (**K2A_U13**). He understands the role of active and passive dissemination of the knowledge (**K2A_K02**).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:
Preparation and presentation at least two talks related to the topis discussed in classes. Participation in discussions concerning presented talks.

STUDENT WORKLOAD:
- Participation in classes - 30 hours
- Preparing presentations - 50 hours
- Consultations - 5 hours

Total: 85 hours, 4 ECTS.

Effort related to activities requiring direct participation of teachers 35 hours - equivalent to 1,5 ECTS.

RECOMMENDED READING:

[1] Articles recommended by lecturer, published in scientific and popular journals

[2] Scientific articles downloaded from the server: lanl.arxiv.org.

OPTIONAL READING: -

PROGRAM PREPARATION:

Dr hab. Wiesław Leoński, prof. UZ

SPECIALIZATION SEMINAR II

Course code: **13.2-WF-FizD-PrSp2**

Type of course: **compulsory**

Language of instruction: **Polish**

Director of studies: **The academic teacher directing the laboratory exercises**

Name of lecturer: **Academic teacher from the Faculty of Physics and Astronomy**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					4
Laboratory	30	2	IV	Pass/Fail	

COURSE AIM:

Knowledge of modern experimental methods and techniques of electron paramagnetic resonance (EPR) and optical spectroscopy and their applications to the study of electron and local structure of the paramagnetic and luminescence centres in solids with ordered (crystals) and disordered (glasses) structure.

ENTRY REQUIREMENTS:

Basic knowledge of modern physics, including foundations of electrodynamics, atomic and nuclear physics, quantum mechanics, solid state physics in the framework of university courses as well as methods of modern experimental physics, in particular, magnetic resonances and optical spectroscopy.

COURSE CONTENTS:

Registration, treatment and analysis of the EPR spectra $3d^n$ - ions (iron group) in crystals and glasses.
Registration, treatment and analysis of the EPR spectra $4f^n$ - ions (rare-earth group) in crystals and glasses.
Registration, treatment and analysis of the luminescence spectra (excitation and emission) and the kinetics of luminescence $3d^n$ - ions in crystals and glasses.
Registration, treatment and analysis of the luminescence spectra (excitation and emission) and the kinetics of luminescence $4f^n$ - ions in crystals and glasses.
Registration, treatment and analysis of EPR spectra of the radiation-induced point defects in crystals and glasses.

TEACHING METHODS:

Laboratory works. Measurements of EPR and luminescence spectra as well as luminescence decay times in crystals and glasses, treatment and interpretation of the obtained results.

LEARNING OUTCOMES:

He knows the theoretical basis for the operation of scientific instruments in the field of scientific fields and disciplines relevant to physics (K2A_W04).
It has a general knowledge of current developments and latest discoveries in the physical sciences (K2A_W06).
Able to critically assess the results of experiments, observations and theoretical considerations, including the measurement errors discussed (K2A_U04).

Can understand the problems of areas of knowledge common to physics and science related to it as chemistry and biology (K2A_U07).
Has some research on the labour market for the physics graduate (K2A_K04).
Is aware of the social impact of research typical of physics (K2A_K05).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Attendance in the laboratory and prepare to perform lab works. Measurements, treatment, presentation and interpretation of the experimental results. Passing grade on time.

STUDENT WORKLOAD:

Participation in the lab works: 30 h
Preparation for lab works: 30 h
Preparation for grade: 20 h
Consultations and grade: 10 h
Total: 90 h, 4 ECTS.
Efforts associated with activities that require direct participation of teacher: 40 h, 2 ECTS.

RECOMMENDED READING:

[1] J. A. Weil, J. A. Bolton. J. E. Wertz, *Electron Spin Resonance. Elementary Theory and Practical Applications*, John Wiley & Sons, New York 1994.

[2] B. Padlyak, Foundations of the Electron Paramagnetic Resonance Spectroscopy of Ions of the Transition Groups, Lviv National University, Lviv 1996 (in Ukrainian).

[3] B. Henderson, G. F. Imbush, *Optical Spectroscopy of Inorganic* Solids, Clarendon Press, Oxford 1989.

OPTIONAL READING:

[1] Hyperfine Interaction, Selected review articles, Edited by A. J. Freeman, R.B. Frankel, Academic Press, New York – London, 1967.

[2] S. Sugano, T. Tanabe, and H. Kamimura, *Multiplets of Transition-Metal Ions in Crystals*, Academic Press, New York 1993.

[3] J. R. Pilbrow, Transition Ions Electron Paramagnetic Resonance, Clarendon Press, Oxford 1990.

[4]Special literature (monographs and original articles) on investigations of different substances by modern methods of the magnetic resonance and optical spectroscopy.

PROGRAM PREPARATION:

Dr hab. Bohdan Padlyak, prof. UZ

MONOGRAPHIC LECTURE II – AN INTRODUCTION TO THE CLASSICAL AND QUANTUM FIELD THEORY

Course code: **13.2-WF-FizD-WyMo2**

Type of course: **compulsory**

Language of instruction: **Polish**

Director of studies: **dr hab. Anatol Nowicki, prof. UZ**

Name of lecturer: **dr hab. Anatol Nowicki, prof. UZ**

Form of instruction	Number of teaching hours per semester	Number of teaching hours per week	Semester	Form of receiving a credit for a course	Number of ECTS credits allocated
PHYSICS – second degree studies					4
Lecture	30	2	IV	Exam	

COURSE AIM:

Presentation of basic problems and ideas of classical and quantum field theory for students and their role in description of theory of elementary particles and their interactions.

ENTRY REQUIREMENTS:

Knowledge of Electrodynamics and Quantum Mechanics and elementary notions of functional analysis.

COURSE CONTENTS:

Classical field theory: cannonical formalism, canonical transformations and symmetry transformations. Noether Theorem. Scalar field, electromagnetic field and massive vector field. Fields interacting with electromagnetic field.

Quantum theory of free fields: quantum fields. Commutation relations for unequal times. Jordan-Pauli function. Notion of locality. Fourier representation of the field, the creation and annihilation operators. Normal product. The construction of the Fock Hilbert space.

Symmetry properties: translational and Lorentz covariance. Energy-momentum tensor. Noether theorem fo quantum fields.

Scalar field in interaction with an external sources: asymptotic space in description of interacting particles, scattering matrix S.

TEACHING METHODS:

Conventional lecture and work with original scientific papers.

LEARNING OUTCOMES:

Student understands physical methods of description of phenomena of elementary particle creation and annihilation in high energy physics. He is able to interpret known ealier experimental facts (K2A_W03, K2A_W04), and learns processes in microworld physics (K2A_U01). The important aim of the lecture is presentation of the role of mathematics in physical description (K2A_W02).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

Oral and written examination of the full range of material. Passing the exam for a passing grade.

STUDENT WORKLOAD:

- Participation in lectures: 30 h
- Preparing for exam: 25 h
- Work with original scientific papers: 20 h
- Consultations: 6 h
- Participation in the exam: 2 h

Total: 83 hours, 4 ECTS.

Effort associated with activities that require direct participation of teacher – 38 hours, 2 ECTS.

RECOMMENDED READING:

[1] I. Białynicki-Birula, *Wstęp do teorii pól kwantowych*, PWN Warszawa 1971.

[2] J. T. Łopuszański, *An Introduction to the Conventional Quantum Field Theory*, Wrocł. Univ. Press, 1976.

[3] Z. Jacyna-Onyszkiewicz, *Piętnaście wykładów z kwantowej teorii pola,* Wyd. Naukowe UAM, Poznań 2009.

OPTIONAL READING:

[1] J. T. Łopuszański, *An Introduction to Symmetry and Supersymmetry in Quantum Field Theory,* World Scientific Publ. Co. 1991.

[2] S. Weinberg, *Teoria pól kwantowych*, Tom I, PWN Warszawa 1999.

PROGRAM PREPARATION:

Dr hab. Anatol Nowicki, prof. UZ