



## I. DESCRIPTION OF STUDY PROGRAMME FORM

| BASIC INFORMATION  |  |
|--|--|
| <b>Title of study programme</b>                                      | Graduate study programme PHYSICS             |
| <b>study programme coordinator</b>                                   | University of Rijeka - Department of Physics |
| <b>Study programme implementor</b>                                   | University of Rijeka - Department of Physics |
| <b>Type of study programme</b>                                       | university                                   |
| <b>Level of study programme</b>                                      | graduate                                     |
| <b>Academic/professional degree awarded upon completion of study</b> | Master of physics                            |

### 1. INTRODUCTION

#### 1.1 Reasons for launching the study programme

When the Department of Physics at the University of Rijeka was founded, one of the principal strategic goals was to initiate and organize graduate study in research physics. After employing outstanding scientists from the country and abroad, the Department of Physics has developed significantly its scientific and research capacities and increased its output in the past few years. A Center for micro- and nano-science and technologies (CMNZT) was founded at the University of Rijeka. Due to the common researchers, it cooperates tightly with the Department of Physics. At the Center, the students have a great opportunity to work with the cutting-edge modern equipment and take part directly in experimental research. When the Department moved to the new building at the University Campus in Rijeka in September 2012, the last necessary condition to finally launch and organize the new graduate study of research physics was fulfilled.

This kind of study is of greatest and utmost importance, primarily to satisfy requirements of local and national economy, but also to satisfy the needs for physics specialists in the local community of the city of Rijeka and at the University of Rijeka.

The development of high-tech industries is of greatest and primary importance for countries like Croatia, which lacks the natural resources (such as minerals, oil or gas), but still aims to achieve the substantial living standard for their citizens. In order to meet this goal, the country must follow the recent scientific progress and must have a substantial number of highly educated and skilled citizens as a labour force, which will be able to introduce new technologies and scientific achievements in our economy. According to some estimates, 60% of the world industry is based or tightly connected with technologies coming from application of quantum physics, so a sufficient number of trained and highly-educated physicists is of key importance for the Croatian economy. The proposed graduate study programme is intended to educate and provide skills and qualifications needed to meet such demands. Few technologies and know-how's can be mentioned for which well-educated physicists are essential: micro- and nano-technologies, environment protection, appliances for diagnostics and therapy in medicine, research, development and application in chemical industries, research and application in the fields of biomedicine, biotechnology, genetics, etc.

Beside the mentioned arguments, there are other specific reasons for the initiation of the proposed study programme. The city of Rijeka and the Primorsko-goranska county plan to launch and invest in large economic projects where environment protection plays an important role. Thus the particular curriculum *Physics and environmental science* in the proposed study programme is the direct response to such needs. It is very important to educate students in this field in order to enable them to actively participate in development, research and application of new technologies in environment protection from the standpoint of natural sciences. Climate changes, drinking water and air susceptibility and exposure to industrial pollutants, construction of new roads and development of transport infrastructure, are just a few of the reasons why environmental protection has become one of the leading world problems and subject to scientific research and debates.

It should be emphasized that Croatia, aware that conservation of natural and especially water resources is one of the most



important conditions for our survival, is one of the countries which has declared environment protection as its top scientific priority.

A large part of the Primorsko-goranska county is geologically a karst region which is highly susceptible and exposed to pollution. Besides, the climate changes represent a major problem which can and will affect the future development of tourism as leading economy in our region. Particular curriculum *Physics and environmental science* as a part of the proposed graduate study will enable students to take part in solving the exposed problems. The strategic plan for development of Primorsko-goranska county defines environment protection as one of its four top priorities, so highly-educated environmental physicists will be needed to meet the EU environmental protection standards in the county. Note that a new Center for medical physics and radiation protection was founded this year at the Clinical hospital center Rijeka, which will also require qualified physicists. A strong research group of experimental astroparticle physicists at the Department of Physics is linked to the medical application of physics. Namely, this group takes part in the development and application of gamma detectors and cameras, all of them being the key elements of sophisticated devices for medical diagnostics (i.e. PET-scanners).

Through this graduate study programme, University of Rijeka will receive a vigorous impetus in development and growth of scientific research in natural sciences. It would also enable our researchers to become more competitive on the national and international level. Foundation of such a graduate study logically leads to introduction of doctoral postgraduate studies, which would significantly boost the scientific and research potentials at the Department of Physics. This study programme also requires and simultaneously enables strong synergy and integration with other university departments (Mathematics, Informatics, Biotechnology) and with the Faculty of Medicine. It will educate research physicists for multi- and interdisciplinary research conducted at the mentioned institutions. Besides, some of the study programme lecturers belong to the staff of the mentioned institutions.

One of the important problems in Croatia is a persistent brain drain of the most perspective students, whose only possibility is to search for university education in physics in other cities or abroad, as this kind of graduate study (or a similar one) does not exist neither in Rijeka nor in larger region. Despite the progress in mobility, most of them do not return back to Rijeka, especially the most successful ones. As physicists are at present among the most needed employees in all developed countries with a highly developed educational system, it is almost impossible to compensate brain drain with 'brain gain'. We expect to reduce brain drain by initiating this study programme.

### *1.2. Evaluation of purposefulness in respect to the market needs in public and private sector*

The labour market will strongly benefit from launching of the proposed graduate study programme. According to data from the National employment office, there is a persistent and continuous lack of physicists on the labour market, not only in Croatia but also in the European union. On the other hand, according to the document entitled „*Network of high-education institutions and study programmes in Republic of Croatia*“ (AZVO, September 2011), under the section „*Recommendations for educational enrolment politics and scholarship politics*“, at least 10 regional administrative units have declared a need for the increase of the number of students attending the university programmes in physics. In the same document, environment protection is declared as one of the four top priorities. The particular curriculum *Physics and environmental science* is designed for education of highly skilled specialists needed to meet these demands.

The importance of graduated physicists educated in the proposed study programme, goes much further than the above stated needs. In fact, such studies provide a number of different competences and skills, mainly focused on analytical reasoning and problem-solving approach for which advanced skills in mathematics and/or computing are needed. As a consequence, the physicists are highly demanded in developed economies in fields which are not originally directly linked to physics, but its methods and analytical thinking are used, for example in finances and financial markets. Condition for the development of economies based on high technologies is the availability of highly educated and trained specialists on the labour market. Note that education of at least 5 years is necessary to produce such profiles. It should be also emphasized that many top students who finish such studies, due to their ability of analytical and problem-solving approach, launch their own successful start-up companies, which adds a new value to the private economic sector and opens new working places.

#### *1.2.1. Connection with the local community (economy, entrepreneurship, civil society)*



The need for physicists has been declared by the local region, the University of Rijeka being its scientific and education center. A strong support is expected for the proposed study programme by the fact that the Primorsko-goranska county has expressed a strong interest for the founding of Analytical center for environment research at the University of Rijeka. This center is meant to provide a precise detection and analysis of all important parameters needed for the decision on strategy of environmental management in the county and farther. In cooperation with the Department of Physics, the Department laboratories (*Laboratory for elemental microanalysis* and *Laboratory for environmental physics* which will become part of the Department in 2013) will be in charge of a detailed sample analysis in order to detect the sources of possible pollution. Another contribution will be provided by the Center for micro- and nano-science and technologies already in function, with more equipment planned to be acquired from EU structural funds through the project for laboratory equipment on university campus. This project, declared as top priority of the University of Rijeka, stands as well on the priority list of the Ministry of science, education and sport.

The Clinical hospital center Rijeka has recently founded the Center for medical physics and radiation protection. The Department is establishing cooperation with this Center. The Center is expected to be highly interested in the proposed study programme which would provide highly-educated physicists working for the Center.

#### 1.2.2. Compliance with professional association's requirements (recommendations)

The proposed programme of the graduate study in Physics is fully compatible and compliant with the requirements, recommendations and strategy of the *Croatian physical society* and of *European physical society*.

#### 1.2.3. Name possible partners outside higher education system that showed interest in the study programme

Primorsko-goranska county, City of Rijeka, Clinical hospital center Rijeka.

#### 1.3 Comparability of the study programme with similar programmes of accredited higher education institutions in the Republic of Croatia and the EU (name and explain comparability of the proposed programme with two programmes, whereas at least one of which should be from the EU (provide their web sites))

During the creation of the proposed study programme, special care was taken to assure its equivalence and compliance with similar study programmes in the leading European universities. The following study programmes were consulted and followed:

1. Master in Physics, Faculty of Physics (Ludvig-Maximilians-University, Munich, Germany);  
[http://www.en.physik.lmu.de/programs/degrees/msc\\_physics/index.html](http://www.en.physik.lmu.de/programs/degrees/msc_physics/index.html)
2. Master of Physics and Applications, UPMC (Sorbonne Universities, Paris, France);  
[http://www.upmc.fr/en/education/diplomas/sciences\\_and\\_technologies/masters/master\\_of\\_physics\\_and\\_applications.html](http://www.upmc.fr/en/education/diplomas/sciences_and_technologies/masters/master_of_physics_and_applications.html)

It can be seen that the basic structure and contents of the quoted study programmes are very similar and compliant with the structure of the proposed study programme: the first year of the study consists of courses in theoretical physics and experimental methods and of the laboratory exercises, which will provide the basis for elective more specialized courses in the second semester. The second year of study consists almost entirely of the specialized courses which lead to research activities and diploma thesis. The differences that arise between the study programmes are mainly influenced by differences in the national higher education systems and presence of particular fields of physics on institutions.

#### 1.4. Openness of the study programme towards horizontal and vertical mobility of students within national and international higher education area

The proposed study programme is fully compatible and compliant with main ideas and baseline of the Bologna treaty and Bologna reforms, which includes a high level of students' mobility. Bachelor of a university of adequate quality level can enrol in this graduate study. It is expected that the graduates in this study programme will gain a sufficient knowledge to be able to apply to appropriate postgraduate study/doctoral school in any country. The ECTS system enhances students' mobility between different universities in Croatia and abroad. Transfers between study programmes inside and between universities are also possible.



*1.5. Alignment with the Mission and the Strategy of the University of Rijeka*

This study is in complete agreement with the University of Rijeka Mission and Strategy. One of the main goals is formation of flexible academic profiles in all three university levels (undergraduate, graduate and postgraduate), in accordance with the needs of the community, economy and development of the society. With its interdisciplinary and multidisciplinary character, the proposed study fulfils the requirements of the University strategy. This study is a follow up of the Undergraduate study Physics (accredited in 2011) and fills, up to now empty, second academic level necessary to start the postgraduate doctoral study in physics as a third academic level. Besides, it represents the necessary basis needed to achieve the scientific mission of the University, all this in order to help further development of natural sciences at the University. It is expected that it will help integration of University in the local economy and social development.

*1.6 .Institutional strategy for study programmes development*

Introduction of a new graduate study in research physics will significantly enhance the quality of scientific and research activities and outputs in the Department, which is one of its primary goals.

*1.7. Other important data – according to the coordinator's opinion*

The compulsory literature for some courses which is not present in the University library in the required number, will be acquired before the beginning of the academic year when the particular course enters into realization for the first time.



## 2. GENERAL PART

### 2.1. Title of study programme

Graduate study programme PHYSICS

#### 2.1.1. Type of study programme

university

#### 2.1.2. Level of study programme

graduate

#### 2.1.3. Area of study programme (scientific/artistic) – indicate the title

Area-Natural sciences, Fields- Physics

### 2.2. Study programme coordinator

University of Rijeka - Department of Physics

### 2.3. Implementor/s of study programme

University of Rijeka - Department of Physics

### 2.4. Duration of study programme (indicate possibilities of part-time study, long distance study)

Two academic years, i.e. four semesters.

#### 2.4.1. ECTS credits – minimal number of credits required for completion of study programme

120 ECTS credits

### 2.5. Enrolment requirements and selection procedure

The candidates should obtain adequate undergraduate university degree (B.Sc.) in natural or technical sciences. Applicants who do not have an adequate undergraduate university degree in physics (B.Sc. in physics) have to pass an obligatory qualifying exam in which the knowledge and skills needed to follow the 1st year courses will be tested.

### 2.6. Study programme learning outcomes

#### 2.6.1. Competences which student gains upon completion of study (according to CROQF ( HKO): knowledge, skills and competences in a restricted sense –independence and responsibility)

The general competences which student gains upon completion of the study programme include:

- advanced knowledge of physics adequate to join scientific research groups,
- capability of analytical reasoning and autonomous problem solving, regardless of their nature and field, which includes application of advanced mathematical, statistical and/or computational methods,
- developed scientific reasoning and approach by active participation in scientific research during the study,
- practical skills (methodology, preparation and execution of an experiment) acquired by work with modern equipment during exercises and laboratory courses,

By concluding one of the following four particular curricula in the graduate study, the student gains specific knowledge, skills and competences:



#### **(A) Solid state physics**

The solid state physics investigates and analyses structures built from bonding of atoms or molecules in stable configurations. It involves research of matter properties from nano and micro structures including specific phenomena connected with material surfaces, up to specific properties typical for the behaviour of infinite crystals. In this particular curriculum, students gain fundamental knowledge on solid state physics from both theoretical and experimental standpoint. They are expected to understand and predict the behaviour of materials in more complex structures. Students gain skills and competences needed to solve more complex experimental and theoretical problems. They are able to actively answer the challenges of the fast technological development in the modern society.

#### **(B) Astrophysics and physics of elementary particles**

Accelerated growth of astrophysics and particle physics in the last two decades has resulted in their strong mutual interweaving, though, traditionally, these two fields of physics were well separated, the former dealing mainly with the largest, and the latter with the smallest scale in nature. The interconnection of these two fields has led to astroparticle physics as a new field. Consequently, the proposed particular curriculum is based on modern approach which enables students to understand the two fields through their mutual interconnection. The curriculum remains flexible to leave the student the choice to specialize in different combinations of fields (such as astrophysics + atomic and molecular physics, astrophysics + nuclear physics, elementary particle physics + nuclear physics). Students gain basic and advanced knowledge and skills on the recent understanding of the fundamental forces in the universe and on the structure of the universe from the smallest to the largest scales. By attending laboratory and experimental courses, the students also gain important experimental and practical skills and competences that can be used even outside the fundamental scientific research. This enables students to get acquainted with experimental equipment, devices and methods based on the most advanced technologies which have wide application in industry and medicine.

#### **(C) Atomic and molecular physics**

Atomic and molecular physics deals with the research of matter properties from the smallest atoms to the extremely complex molecules, their mutual interaction as well as interaction between matter and radiation. Student gain knowledge and understanding in atomic and molecular physics which are essential in chemical, biological, and biotechnological laboratories in the public and private sectors. They gain advanced knowledge and skills in atomic and molecular physics, including theory and application of absorption and emission, scattering of electromagnetic radiation on excited atoms and molecules, spectroscopic methods, lasers and optical properties of matter. After the graduation in this particular curriculum, students are expected to have developed skills and competences needed in further education in the frame of postgraduate/doctoral studies in this or related fields. The students are prepared to work in health institutions as well as in private enterprises in which lasers and laser or other type of spectroscopy are applied.

#### **(D) Physics and environmental science**

Students gain knowledge and skills needed to understand relevant concepts in theoretical physics which are essential in solving environment-related problems. They are expected to:

- be able to interconnect and apply skills and knowledge from different fields of physics in order to solve environmental problems
- become acquainted with experimental methods in physics with special emphasis on their application in environmental science
- gain knowledge and understanding of physical processes and phenomena in the water, atmosphere and soil and their influence on specific ecosystems
- gain understanding of the recent global environmental problems,
- gain understanding and knowledge of the concepts of the biochemical circulation of elements in the nature,
- gain knowledge of statistical and computing methods and their application in environmental monitoring and modelling,
- gain knowledge of different anthropogenic and natural factors contributing to environmental pollution and be able to assess their environmental impact.

#### *2.6.2. Employment possibility (list of possible employers and compliance with professional association's requirements)*

There are vast employment possibilities for students graduating in this study programme. For example, research and development departments, sections and laboratories in high-tech and/or advanced technology companies (such as



Ericsson-Nikola Tesla), companies in chemical (INA) or IT sector, laboratories for monitoring and analyses of environmental samples (public health department, private enterprises), private and public research institutions, various government agencies at all levels (mostly in the field of environmental protection). Furthermore, employment could be found in the financial sector (banks, insurance and investment funds), as well as in hospitals and other related institutions that use advanced diagnostic and therapeutic equipment. Other possible jobs are the ones where radioactive substances are handled or radiation protection is needed. The proposed study develops broader competences including advanced knowledge and skills in mathematics, statistics and computing, as well as analytical reasoning and problem-solving approach. The latter ensures the variety of employing possibilities in a developed economy.

*2.6.3. Possibility of continuation of study on higher level*

After the graduation, students will be able to enrol to all postgraduate studies of physics in Croatia (e.g. Faculty of Science at the University of Zagreb) and abroad. According to the ideas of Bologna treaty and Bologna reforms, the student is expected to be allowed to apply for postgraduate studies in other fields of natural and other sciences.

*2.7. Upon applying for graduate studies list proposer's or other Croatian institution's undergraduate study programmes which enable enrolment to the proposed study programme*

Undergraduate study Physics (University of Rijeka – Department of Physics),  
Undergraduate study Physics (Faculty of mathematics and natural sciences at University of Split),  
Undergraduate study Physics (J.J. Strossmayer University of Osijek – Department of Physics).

The bachelors from other study programmes related to natural or technical sciences can apply for this graduate study assuming that they have passes the qualifying exam.

*2.8. Upon application of integrated studies - name reasons for integration of undergraduate and graduate level of study programme*

The proposed study is not integrated.



### 3. PROGRAMME DESCRIPTION

3.1. List of compulsory and elective subjects and/or modules (if existing) with the number of active teaching hours required for their implementation and number of ECTS-credits (Table 1)

Table 1: 3.1. List of compulsory and elective courses and/or modules with teaching hours required and ECTS credits allocated (pages 10-25)

3.2. Description of each subject (Appendix 1)

Appendix 1: Course description (page 26, all courses in alphabetical order)

3.3. Structure of study programme, dynamic of study and students' obligations

The dynamics of the study and students' obligations are regulated by the Rules of studies issued by the University of Rijeka and by the programme of each study course. The whole study programme is divided into four semesters, while each study course is a one-semester course. At the beginning of the graduate study (1<sup>st</sup> year), students can choose on of the four particular curricula:

- (A) Solid state physics
- (B) Astrophysics and physics of elementary particles
- (C) Atomic and molecular physics
- (D) Physics and environmental science

Student's Supervisor from the faculty staff is assigned to each student at the beginning of the study. The Supervisor helps the student during his progress through the study, helps him to decide for the elective courses in the frame of enrolled particular curriculum, guides the student in accordance to his potential and abilities, and takes care of the timing regarding the introduction of the student to the scientific research and selection of thesis supervisor. The student's Supervisor guides and helps the student in agreement with the Head of the graduate study. In order to increase flexibility and mobility of the students, in agreement with the student's Supervisor and Head of the graduate study, they are allowed to attend courses from different particular curricula.

3.3.1. Enrolment requirements for the next semester or trimester (course title)

The enrolment requirements are aligned with the Rules of studies issued by the University of Rijeka. The rules related to the enrolment of a specific course, if existing, are given in the description of that particular course.

3.4. List of courses and/or modules student can choose from other study programmes

The following courses are available on other graduate study programmes at the Department of Physics:

- Semiconductors and applications (graduate study *Engineering and material physics*)
- Micro and nano sciences and technologies (graduate study *Engineering and material physics*)
- Electrodynamics (graduate study *Physics and mathematics*)

3.5. List of courses and/or modules that can be implemented in a foreign language (specify the language)

All the courses offered by the faculty of the Department of Physics of the University of Rijeka can be delivered and implemented in English language.

3.6. Allocated ECTS credits that enable national and international mobility

ECTS credits achieved during the study programme (30 ECTS per semester, 120 in total) allow students to transfer to other (equivalent) study programmes at universities in Croatia or abroad.



### 3.7. *Multidisciplinarity/interdisciplinarity of study programme*

Multidisciplinarity of the proposed study programme is achieved through the wide choice of courses and lecturers who are researchers coming from various fields of different scientific areas (natural, technical, biomedical and biotechnological sciences). The particular curriculum *Physics and environmental science* has pronounced interdisciplinarity.

### 3.8. *Mode of study programme completion*

The graduate study programme is completed by a final exam consisting of a public defence of the Master Thesis, previously written on the basis of the performed scientific research.

#### 3.8.1. *Conditions of approval of final work /thesis and/or final/thesis exam application*

The topic of the Master Thesis can be approved only to students who have accomplished all 1<sup>st</sup> year courses of the study programme (i.e. 60 ECTS credits are a required minimum). Student must have completed all courses of the graduate study in order to submit the written form of the Master Thesis for review and evaluation.

#### 3.8.2. *Composing and furnishing of final work/thesis*

The written form of the Master Thesis is regulated by the Set of Rules for writing the Master Thesis, issued by the Department of Physics.

#### 3.8.3. *Final work/thesis assessment procedure and evaluation and defense of final work/thesis*

The Master Thesis is reviewed and evaluated by a three-member committee consisting of supervisor and two others lecturers in the graduate study programme. In the case of negative evaluation, the student must choose a new supervisor and topic of the thesis, and pass the whole procedure from the start. Positive evaluation of the written Master Thesis allows the student to apply for the public defence. The whole procedure for the public defence of the Master Thesis is regulated by the Set of Rules for Master Thesis, issued by the Department of Physics.



**TABLE 1**

**3.1. List of compulsory and elective courses and/or modules with teaching hours required and ECTS credits allocated**

**(A) GRADUATE STUDY PROGRAMME PHYSICS**

**MODULE: Solid State Physics**

| LIST OF MODULES/COURSES – COMPULSORY COURSES |   |                    |   |   |   |      |                     |
|--|---|--------------------|---|---|---|------|---------------------|
| Year of study: 1.                            |   |                    |   |   |   |      |                     |
| Semester: 1.                                 |   |                    |   |   |   |      |                     |
| MODULE                                       | COURSE                                      | COURSE COORDINATOR | L | E | S | ECTS | STATUS <sup>1</sup> |
| Solid state physics                          | Advanced Quantum Physics                    | Z. Lenac           | 3 | 2 | 1 | 8    | C                   |
|  | Advanced Electrodynamics                    | M. Karuza          | 3 | 1 | 1 | 8    | C                   |
|  | Statistical Mechanics                       | Ž. Bošnjak         | 3 | 1 | 1 | 8    | C                   |
|  | Semiconductors: Principles and Applications | M. Petravić        | 2 | 1 | 1 | 6    | C                   |

<sup>1</sup> IMPORTANT: Insert C for compulsory course or E for elective course.



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 1.</b> |                                   |                    |   |   |   |      |        |  |
|--------------------------|-----------------------------------|--------------------|---|---|---|------|--------|--|
| <b>Semester: 2.</b>      |                                   |                    |   |   |   |      |        |  |
| MODULE                   | COURSE                            | COURSE COORDINATOR | L | E | S | ECTS | STATUS |  |
| Solid state physics      | Experimental Methods in Physics I | M. Karuza          | 2 | 1 | 1 | 6    | C      |  |
|                          | Atomic and Molecular Physics      | N. Orlić           | 3 | 2 | 1 | 8    | C      |  |
|                          | Solid State Physics I             | Z. Lenac           | 3 | 2 | 1 | 8    | C      |  |
|                          | Elective courses II               |                    |   |   |   | 6    | E      |  |
|                          | Seminar in Physics on English     | Ž. Bošnjak         | 0 | 0 | 1 | 2    | C      |  |

**LIST OF MODULES/COURSES – ELECTIVE COURSES II**

Students are required to take 1 course with a total of 6 ECTS credits.

| <b>Year of study: 1.</b> |                                |                    |   |   |   |      |        |  |
|--------------------------|--------------------------------|--------------------|---|---|---|------|--------|--|
| <b>Semester: 2.</b>      |                                |                    |   |   |   |      |        |  |
| MODULE                   | COURSE                         | COURSE COORDINATOR | L | E | S | ECTS | STATUS |  |
| Solid state physics      | Advanced Computational Physics | D. Dominis Prester | 2 | 1 | 1 | 6    | E      |  |
|                          | Electronics                    | D. Kotnik Karuza   | 2 | 1 | 1 | 6    | E      |  |
|                          | Quantum Field Theory           | P. Dominis Prester | 2 | 1 | 1 | 6    | E      |  |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 2.</b> |  |                    |   |   |   |      |        |
|--------------------------|--|--------------------|---|---|---|------|--------|
| <b>Semester: 3.</b>      |  |                    |   |   |   |      |        |
| MODULE                   | COURSE                                   | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Solid state physics      | Experimental Methods in Physics II       | I. Orlić           | 2 | 1 | 1 | 6    | C      |
|                          | Structure of Matter Lab                  | N. Orlić           | 0 | 0 | 4 | 6    | C      |
|                          | Solid State Physics II                   | Z. Lenac           | 2 | 1 | 1 | 6    | C      |
|                          | Micro and Nano Sciences and Technologies | S. Zelenika        | 2 | 1 | 1 | 6    | C      |
|                          | Elective courses III                     |                    |   |   |   | 6    | E      |

**LIST OF MODULES/COURSES – ELECTIVE COURSES III**

Students are required to take 1 course with a total of 6 ECTS credits.

| <b>Year of study: 2.</b> |  |                    |   |   |   |      |        |
|--------------------------|--|--------------------|---|---|---|------|--------|
| <b>Semester: 3.</b>      |  |                    |   |   |   |      |        |
| MODULE                   | COURSE   | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Solid state physics      | Electronics Laboratory                               | D. Kotnik Karuza   | 0 | 0 | 4 | 6    | E      |
|                          | Selected topics of Atomic and Molecular Spectroscopy | N. Orlić           | 2 | 1 | 1 | 6    | E      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 2.</b> |                       |                    |   |    |   |      |        |
|--------------------------|-----------------------|--------------------|---|----|---|------|--------|
| <b>Semester: 4.</b>      |                       |                    |   |    |   |      |        |
| MODULE                   | COURSE                | COURSE COORDINATOR | L | E  | S | ECTS | STATUS |
| Solid state physics      | Master Thesis Seminar | D. Kotnik-Karuza   | 0 | 0  | 4 | 6    | C      |
|                          | Master Thesis         |                    | 0 | 12 | 0 | 18   | C      |
|                          | Elective courses IV   |                    |   |    |   | 6    | E      |
|                          |                       |                    |   |    |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES IV**

Students are required to take 1 course with a total of 6 ECTS credits.

| <b>Year of study: 2.</b> |                                  |                    |   |   |   |      |        |
|--------------------------|----------------------------------|--------------------|---|---|---|------|--------|
| <b>Semester: 4.</b>      |                                  |                    |   |   |   |      |        |
| MODULE                   | COURSE                           | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Solid state physics      | Advanced Experimental Laboratory | M. Petravić        | 0 | 0 | 4 | 6    | E      |
|                          | Quantum Field Theory             | P. Dominis Prester | 2 | 1 | 1 | 6    | E      |
|                          | Electron Spin Resonance          | S. Valić           | 3 | 0 | 1 | 6    | E      |
|                          |                                  |                    |   |   |   |      |        |



**(B) GRADUATE STUDY PROGRAMME PHYSICS**  
**MODULE: Astrophysics and Elementary Particle Physics**

**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| LIST OF MODULES/COURSES – COMPULSORY COURSES             |                          |                    |   |   |   |      |        |
|--|--------------------------|--------------------|---|---|---|------|--------|
| Year of study: 1.  |                          |                    |   |   |   |      |        |
| Semester: 1.   |                          |                    |   |   |   |      |        |
| MODULE   | COURSE                   | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics<br>and<br>elementary<br>particle<br>physics | Advanced Quantum Physics | Z. Lenac           | 3 | 2 | 1 | 8    | C      |
|  | Advanced Electrodynamics | M. Karuza          | 3 | 1 | 1 | 8    | C      |
|  | Statistical Mechanics    | Ž. Bošnjak         | 3 | 1 | 1 | 8    | C      |
|  | General Relativity       | P. Dominis Prester | 2 | 1 | 1 | 6    | C      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| Year of study: 1.                            |                                   |                    |   |   |   |      |        |
|--|-----------------------------------|--------------------|---|---|---|------|--------|
| Semester: 2.                                 |                                   |                    |   |   |   |      |        |
| MODULE                                       | COURSE                            | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics and elementary particle physics | Experimental Methods in Physics I | M. Karuza          | 2 | 1 | 1 | 6    | C      |
|  | Elective courses II-A             |                    |   |   |   | 16   | E      |
|  | Elective courses II-B             |                    |   |   |   | 6    | E      |
|  | Seminar in Physics on English     | Ž. Bošnjak         | 0 | 0 | 1 | 2    | C      |

**LIST OF MODULES/COURSES – ELECTIVE COURSES II-A**

| Students are required to take 2-3 courses with a total of 16 ECTS credits.<br>At least one of following courses is required: " Astronomy and Astrophysics I ", " Elementary Particle Physics I " |                               |                    |   |   |   |      |        |
|--|-------------------------------|--------------------|---|---|---|------|--------|
| Year of study: 1.  |                               |                    |   |   |   |      |        |
| Semester: 2.   |                               |                    |   |   |   |      |        |
| MODULE   | COURSE                        | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics and elementary particle physics   | Astronomy and Astrophysics I  | D. Kotnik Karuza   | 3 | 2 | 1 | 8    | E      |
|  | Elementary Particle Physics I | P. Dominis Prester | 3 | 2 | 1 | 8    | E      |
|  | Nuclear Physics               | I. Orlić           | 3 | 1 | 0 | 6    | E      |
|  | Practicals in Nuclear Physics | I. Orlić           | 0 | 0 | 2 | 2    | E      |
|  | Atomic and Molecular Physics  | N. Orlić           | 3 | 2 | 1 | 8    | E      |

**LIST OF MODULES/COURSES – ELECTIVE COURSES II-B**

| Students are required to take 1 course with a total of 6 ECTS credits. |                                |                    |   |   |   |      |        |
|--|--------------------------------|--------------------|---|---|---|------|--------|
| Year of study: 1.  |                                |                    |   |   |   |      |        |
| Semester: 2.   |                                |                    |   |   |   |      |        |
| MODULE   | COURSE                         | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics and elementary particle physics                           | Quantum Field Theory           | P. Dominis Prester | 2 | 1 | 1 | 6    | E      |
|  | Advanced Computational Physics | D. Dominis Prester | 2 | 1 | 1 | 6    | E      |
|  | Electronics                    | D. Kotnik Karuza   | 2 | 1 | 1 | 6    | E      |
|  |                                |                    |   |   |   |      |        |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| Year of study: 2.  |                                    |                    |   |   |   |      |        |
|--|------------------------------------|--------------------|---|---|---|------|--------|
| Semester: 3.   |                                    |                    |   |   |   |      |        |
| MODULE   | COURSE                             | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics<br>and<br>elementary<br>particle<br>physics | Experimental Methods in Physics II | I. Orlić           | 2 | 1 | 1 | 6    | C      |
|  | Elective courses III-A             |                    |   |   |   | 6    | E      |
|  | Elective courses III-B ili III-A   |                    |   |   |   | 12   | E      |
|  | Structure of Matter Lab            | N. Orlić           | 0 | 0 | 4 | 6    | C      |

**LIST OF MODULES/COURSES – ELECTIVE COURSES III-A**

Students are required to take 1(2) course(s) with a total of 6(12) ECTS credits.

| Year of study: 2.  |                                |                    |   |   |   |      |        |
|--|--------------------------------|--------------------|---|---|---|------|--------|
| Semester: 3.   |                                |                    |   |   |   |      |        |
| MODULE   | COURSE                         | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics<br>and<br>elementary<br>particle<br>physics | Observational Astrophysics     | D. Dominis Prester | 2 | 1 | 1 | 6    | E      |
|  | Elementary Particle Physics II | B. Melić           | 2 | 1 | 1 | 6    | E      |
|  |                                |                    |   |   |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES III-B**

Students are required to take 2(1) courses with a total of 12(6) ECTS credits.

| Year of study: 2.  |                              |                    |   |   |   |      |        |
|--|------------------------------|--------------------|---|---|---|------|--------|
| Semester: 3.   |                              |                    |   |   |   |      |        |
| MODULE   | COURSE                       | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics<br>and<br>elementary<br>particle<br>physics | Astroparticle Physics        | Ž. Bošnjak         | 2 | 1 | 1 | 6    | E      |
|  | Astronomija i astrofizika II | D. Kotnik Karuza   | 2 | 1 | 1 | 6    | E      |
|  | Electronics Laboratory       | D. Kotnik Karuza   | 0 | 0 | 4 | 6    | E      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| Year of study: 2.  |                       |                    |   |    |   |      |        |
|--|-----------------------|--------------------|---|----|---|------|--------|
| Semester: 4.   |                       |                    |   |    |   |      |        |
| MODULE   | COURSE                | COURSE COORDINATOR | L | E  | S | ECTS | STATUS |
| Astrophysics<br>and<br>elementary<br>particle<br>physics | Master Thesis Seminar | D. Kotnik-Karuza   | 0 | 0  | 4 | 6    | C      |
|  | Master Thesis         |                    | 0 | 12 | 0 | 18   | C      |
|  | Elective courses IV   |                    |   |    |   | 6    | E      |
|  |                       |                    |   |    |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES IV**

| Students are required to take 1 course with a total of 6 ECTS credits. |                    |                    |   |   |   |      |        |
|--|--------------------|--------------------|---|---|---|------|--------|
| Year of study: 2.  |                    |                    |   |   |   |      |        |
| Semester: 4.   |                    |                    |   |   |   |      |        |
| MODULE   | COURSE             | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Astrophysics<br>and<br>elementary<br>particle<br>physics               | Physical Cosmology | H. Štefancić       | 2 | 1 | 1 | 6    | E      |
|  | Astrophysics Lab   | D. Dominis Prester | 0 | 0 | 4 | 6    | E      |
|  |                    |                    |   |   |   |      |        |



**(C) DIPLOMSKI STUDIJ FIZIKA**  
**MODULE: Atomic and Molecular Physics**

**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| Year of study: 1.            |                                       |                    |   |   |   |      |        |
|------------------------------|---------------------------------------|--------------------|---|---|---|------|--------|
| Semester: 1.                 |                                       |                    |   |   |   |      |        |
| MODULE                       | COURSE                                | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Atomic and molecular physics | Advanced Quantum Physics              | Z. Lenac           | 3 | 2 | 1 | 8    | C      |
|                              | Advanced Electrodynamics              | M. Karuza          | 3 | 1 | 1 | 8    | C      |
|                              | Statistical Mechanics                 | Ž. Bošnjak         | 3 | 1 | 1 | 8    | C      |
|                              | Quantum theory of Atoms and Molecules | Z. Kaliman         | 2 | 1 | 1 | 6    | C      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| Year of study: 1.            |                                   |                    |   |   |   |      |        |  |
|------------------------------|-----------------------------------|--------------------|---|---|---|------|--------|--|
| Semester: 2.                 |                                   |                    |   |   |   |      |        |  |
| MODULE                       | COURSE                            | COURSE COORDINATOR | L | E | S | ECTS | STATUS |  |
| Atomic and molecular physics | Experimental Methods in Physics I | M. Karuza          | 2 | 1 | 1 | 6    | C      |  |
|                              | Atomic and Molecular Physics      | N. Orlić           | 3 | 2 | 1 | 8    | C      |  |
|                              | Elective courses II               |                    |   |   |   | 14   | E      |  |
|                              | Seminar in Physics on English     | Ž. Bošnjak         | 0 | 0 | 1 | 2    | C      |  |

**LIST OF MODULES/COURSES – ELECTIVE COURSES II**

Students are required to take 2-3 courses with a total of 14 ECTS credits.

| Year of study: 1.            |                                |                    |   |   |   |      |        |  |
|------------------------------|--------------------------------|--------------------|---|---|---|------|--------|--|
| Semester: 2.                 |                                |                    |   |   |   |      |        |  |
| MODULE                       | COURSE                         | COURSE COORDINATOR | L | E | S | ECTS | STATUS |  |
| Atomic and molecular physics | Solid State Physics I          | Z. Lenac           | 3 | 2 | 1 | 8    | E      |  |
|                              | Nuclear Physics                | I. Orlić           | 3 | 1 | 0 | 6    | E      |  |
|                              | Practicals in Nuclear Physics  | I. Orlić           | 0 | 0 | 2 | 2    | E      |  |
|                              | Advanced Computational Physics | D. Dominis Prester | 2 | 1 | 1 | 6    | E      |  |
|                              | Electronics                    | D. Kotnik Karuza   | 2 | 1 | 1 | 6    | E      |  |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 2.</b>     |  |                    |   |   |   |      |        |
|------------------------------|--|--------------------|---|---|---|------|--------|
| <b>Semester: 3.</b>          |  |                    |   |   |   |      |        |
| MODULE                       | COURSE   | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Atomic and molecular physics | Experimental Methods in Physics II                   | I. Orlić           | 2 | 1 | 1 | 6    | C      |
|                              | Structure of Matter Lab                              | N. Orlić           | 0 | 0 | 4 | 6    | C      |
|                              | Selected topics of Atomic and Molecular Spectroscopy | N. Orlić           | 2 | 1 | 1 | 6    | C      |
|                              | Elective courses III                                 |                    |   |   |   | 12   | E      |

**LIST OF MODULES/COURSES – ELECTIVE COURSES III**

Students are required to take 2 courses with a total of 12 ECTS credits.

| <b>Year of study: 2.</b>     |   |                    |   |   |   |      |        |
|------------------------------|---|--------------------|---|---|---|------|--------|
| <b>Semester: 3.</b>          |   |                    |   |   |   |      |        |
| MODULE                       | COURSE                                      | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Atomic and molecular physics | Micro and Nano Sciences and Technologies    | S. Zelenika        | 2 | 1 | 1 | 6    | E      |
|                              | Solid State Physics II                      | Z. Lenac           | 2 | 1 | 1 | 6    | E      |
|                              | Semiconductors: Principles and Applications | M. Petravić        | 2 | 1 | 1 | 6    | E      |
|                              | Electronics Laboratory                      | D. Kotnik Karuza   | 0 | 0 | 4 | 6    | E      |
|                              | Physical Chemistry                          | D. Čakara          | 2 | 2 | 0 | 6    | E      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 2.</b>     |                       |                    |   |    |   |      |        |
|------------------------------|-----------------------|--------------------|---|----|---|------|--------|
| <b>Semester: 4.</b>          |                       |                    |   |    |   |      |        |
| MODULE                       | COURSE                | COURSE COORDINATOR | L | E  | S | ECTS | STATUS |
| Atomic and molecular physics | Master Thesis Seminar | D. Kotnik-Karuza   | 0 | 0  | 4 | 6    | C      |
|                              | Master Thesis         |                    | 0 | 12 | 0 | 18   | C      |
|                              | Elective courses IV   |                    |   |    |   | 6    | E      |
|                              |                       |                    |   |    |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES IV**

Students are required to take 1 course with a total of 6 ECTS credits.

| <b>Year of study: 2.</b>     |                                  |                    |   |   |   |      |        |
|------------------------------|----------------------------------|--------------------|---|---|---|------|--------|
| <b>Semester: 4.</b>          |                                  |                    |   |   |   |      |        |
| MODULE                       | COURSE                           | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Atomic and molecular physics | Electron Spin Resonance          | S. Valić           | 3 | 0 | 1 | 6    | E      |
|                              | Advanced Experimental Laboratory | M. Petravić        | 0 | 0 | 4 | 6    | E      |
|                              | Nuclear Physics                  | I. Orlić           | 3 | 1 | 0 | 6    | E      |
|                              | Quantum Field Theory             | P. Dominis Prester | 2 | 1 | 1 | 6    | E      |



**(D) GRADUATE STUDY PROGRAMME PHYSICS  
MODULE: Physics and Environmental science**

| LIST OF MODULES/COURSES – COMPULSORY COURSES |                       |                    |   |   |   |      |        |
|--|-----------------------|--------------------|---|---|---|------|--------|
| Year of study: 1.                            |                       |                    |   |   |   |      |        |
| Semester: 1.                                 |                       |                    |   |   |   |      |        |
| MODULE                                       | COURSE                | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Physics and Environmental science            | Electrodynamics       | P. Dominis Prester | 3 | 3 | 0 | 7    | C      |
|  | Statistical Mechanics | Ž. Bošnjak         | 3 | 1 | 1 | 8    | C      |
|  | Physical Chemistry    | D. Čakara          | 2 | 1 | 0 | 6    | C      |
|  | Atmospheric Physics   | I.Orlić            | 2 | 2 | 0 | 7    | C      |
|  |                       |                    |   |   |   |      |        |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 1.</b>          |   |                    |   |   |   |      |        |
|-----------------------------------|---|--------------------|---|---|---|------|--------|
| <b>Semester: 2.</b>               |   |                    |   |   |   |      |        |
| MODULE                            | COURSE  | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Physics and Environmental science | Experimental Methods in Physics I             | M. Karuza          | 2 | 1 | 1 | 6    | C      |
|                                   | Seminar in Physics on English                 | Ž. Bošnjak         | 0 | 0 | 1 | 2    | C      |
|                                   | Instrumental Methods in Environmental Physics | I. Krajcar Bronić  | 2 | 2 | 0 | 6    | C      |
|                                   | Elective courses II                           |                    |   |   |   | 18   | E      |
|                                   |   |                    |   |   |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES II**

Students are required to take 3-4 courses with a total of (at least) 18 ECTS credits.

| <b>Year of study: 1.</b>          |                                       |                    |   |   |   |      |        |
|-----------------------------------|---------------------------------------|--------------------|---|---|---|------|--------|
| <b>Semester: 2.</b>               |                                       |                    |   |   |   |      |        |
| MODULE                            | COURSE                                | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Physics and Environmental science | Environmental pollution               | A. Alebić-Juretić  | 2 | 0 | 2 | 6    | E      |
|                                   | Environmental impact assessment       | T. Legović         | 2 | 2 | 0 | 6    | E      |
|                                   | Modelling in environmental protection | T. Legović         | 2 | 2 | 0 | 6    | E      |
|                                   | Atomic and Molecular Physics          | N. Orlić           | 3 | 2 | 1 | 8    | E      |
|                                   | Nuclear Physics                       | I. Orlić           | 3 | 1 | 0 | 6    | E      |
|                                   | Practicals in Nuclear Physics         | I. Orlić           | 0 | 0 | 2 | 2    | E      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 2.</b>          |                                    |                    |   |   |   |      |        |
|-----------------------------------|------------------------------------|--------------------|---|---|---|------|--------|
| <b>Semester: 3.</b>               |                                    |                    |   |   |   |      |        |
| MODULE                            | COURSE                             | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Physics and Environmental science | Experimental Methods in Physics II | I. Orlić           | 2 | 1 | 1 | 6    | C      |
|                                   | Structure of Matter Lab            | N. Orlić           | 0 | 0 | 4 | 6    | C      |
|                                   | Physical oceanography              | N. Supić           | 2 | 2 | 0 | 6    | C      |
|                                   | Elective courses III               |                    |   |   |   | 12   | E      |
|                                   |                                    |                    |   |   |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES III**

Students are required to take 2 courses with a total of 12 ECTS credits.

| <b>Year of study: 2.</b>          |  |                    |   |   |   |      |        |
|-----------------------------------|--|--------------------|---|---|---|------|--------|
| <b>Semester: 3.</b>               |  |                    |   |   |   |      |        |
| MODULE                            | COURSE   | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Physics and Environmental science | Environmental Microbiology                           | T. Rukavina        | 2 | 2 | 0 | 6    | E      |
|                                   | Ecotoxicology  | A. Alebić-Juretić  | 2 | 0 | 2 | 6    | E      |
|                                   | Selected topics of Atomic and Molecular Spectroscopy | N. Orlić           | 2 | 1 | 1 | 6    | E      |



**LIST OF MODULES/COURSES – COMPULSORY COURSES**

| <b>Year of study: 2.</b>          |                       |                    |   |    |   |      |        |
|-----------------------------------|-----------------------|--------------------|---|----|---|------|--------|
| <b>Semester: 4.</b>               |                       |                    |   |    |   |      |        |
| MODULE                            | COURSE                | COURSE COORDINATOR | L | E  | S | ECTS | STATUS |
| Physics and Environmental science | Master Thesis Seminar | D. Kotnik-Karuza   | 0 | 0  | 4 | 6    | C      |
|                                   | Master Thesis         |                    | 0 | 12 | 0 | 18   | C      |
|                                   | Elective courses IV   |                    |   |    |   | 6    | E      |
|                                   |                       |                    |   |    |   |      |        |

**LIST OF MODULES/COURSES – ELECTIVE COURSES IV**

Students are required to take 1-2 courses with a total of 6 ECTS credits.

| <b>Year of study: 2.</b>          |   |                    |   |   |   |      |        |
|-----------------------------------|---|--------------------|---|---|---|------|--------|
| <b>Semester: 4.</b>               |   |                    |   |   |   |      |        |
| MODULE                            | COURSE  | COURSE COORDINATOR | L | E | S | ECTS | STATUS |
| Physics and Environmental science | Advanced Experimental Laboratory                  | M. Petravić        | 0 | 0 | 4 | 6    | E      |
|                                   | Terrestrial Ecology                               | B. Surina          | 2 | 2 | 0 | 6    | E      |
|                                   | Ecology of freshwaters                            | M. Kovačić         | 1 | 1 | 0 | 3    | E      |
|                                   | Biological oceanography                           | M. Kovačić         | 1 | 1 | 0 | 3    | E      |
|                                   | Protection of the marine and coastal environments | G. Kniewald        | 2 | 2 | 0 | 6    | E      |
|                                   | Global ecology                                    | D. Barišić         | 2 | 0 | 2 | 6    | E      |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Dijana Dominis Prester                      |              |
| <b>Course title</b>              | Advanced computational physics              |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | Optional                                    |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |  |   |
|--|--|---|
| <b>1.1. Course objectives</b>  |  |   |
| Learning of methods for solving complex physical problems using numerical methods. Learning and application of different optimization methods. Training programming skills. Preparing for future application of numerical methods in scientific research.  |  |   |
| <b>1.2. Course enrolment requirements</b>  |  |   |
| Operational knowledge of programming in FORTRAN or C++.  |  |   |
| <b>1.3. Expected course learning outcomes</b>  |  |   |
| Students will be expected to describe numerical methods in physics and mathematics, write simple computer codes using simulations, use existing packages for simulation, animation and visualization, define optimization, distinguish different optimization methods, describe genetic algorithms, write a computer code which optimizes a non-linear problem using a chosen optimization methods, and perform a computational analysis of simulated and measured data. |  |   |
| <b>1.4. Course content</b>   |  |   |
| Numerical methods in physics and mathematics. Monte Carlo simulation. Animation and visualisation of computer simulations. Numerical optimization methods of solving multidimensional physical problems. Simplex algorithm. Neural networks. Genetic algorithms. Simulations in high-energy physics and astrophysics. Computational analysis of simulated and measured physical data.  |  |   |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input checked="" type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   | The course will be subject to changes and continuous improvements, depending on the availability of new software and hardware.   |   |
| <b>1.7. Student's obligations</b>  |  |   |
| Course attendance, homework, individual project.   |  |   |
| <b>1.8. Evaluation of student's work</b>   |  |   |



|                   |     |                           |     |               |  |                   |   |
|-------------------|-----|---------------------------|-----|---------------|--|-------------------|---|
| Course attendance | 0.5 | Activity/Participation    | 0.5 | Seminar paper |  | Experimental work |   |
| Written exam      | 1   | Oral exam                 | 1   | Essay         |  | Research          |   |
| Project           | 1   | Sustained knowledge check | 1   | Report        |  | Practice          | 1 |
| Portfolio         |     |                           |     |               |  |                   |   |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Manner of knowledge checking: class participation, homework, project, written and oral exam. Student's work will be evaluated during the semester, and during the final exam.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. Course Web page
2. H. Gould and J. Tobochnik, *An Introduction to Computer Simulation Methods*, Addison-Wesley, Reading, Massachusetts
3. M. Metcalf, *Fortran 90 Tutorial*, CERN

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. W. H. Press, B. P. Flannery, S. A. Teukolsky, W. T. Vetterling, *Numerical Recipes*, Cambridge University Press
2. D. Frenkel, B. Smit, *Understanding Molecular Simulation (from algorithms to applications)*, Academic Press
3. M. P. Allen, D. J. Tildesley, *Computer Simulation of Liquids*, Clarendon Press, Oxford
4. D. C. Rapaport, *The Art of Molecular Dynamics Simulation*, Cambridge University Press
5. S. E. Koonin, *Computational Physics*, Benjamin Cummings
6. D. W. Heermann, *Computer Simulation Methods in Theoretical Physics*, Springer-Verlag, Berlin

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Interaction with students and student-faculty team work on quality of teaching process. Anonymous questionnaires on quality of teaching. Flexible adaptation of teaching to interests and needs of students.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Marin Karuza                                |              |
| <b>Course title</b>              | Advanced Electrodynamics                    |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | Compulsory                                  |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 8            |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 15 + 15 |

| 1. COURSE DESCRIPTION  |   |                        |   |   |   |                   |  |
|--|---|------------------------|---|---|---|-------------------|--|
| <b>1.1. Course objectives</b>  |   |                        |   |   |   |                   |  |
| Understanding, modelling and solution of complex problems related to electromagnetic interaction by using Maxwell's equations. Development of mathematical skills indepently of field of application.  |   |                        |   |   |   |                   |  |
| <b>1.2. Course enrolment requirements</b>  |   |                        |   |   |   |                   |  |
| The knowledge of the Electrodynamics course is required. If the student does not have such course in his curricula (or equivalent), a check of the knowledge can be required.  |   |                        |   |   |   |                   |  |
| <b>1.3. Expected course learning outcomes</b>  |   |                        |   |   |   |                   |  |
| Understanding of electrodynamics in a way that provides the student with a tool for studying physical phenomena related to electromagnetical interaction. Development of mathematical skills independently of field of application.  |   |                        |   |   |   |                   |  |
| <b>1.4. Course content</b>   |   |                        |   |   |   |                   |  |
| <ol style="list-style-type: none"> <li>1. Introduction</li> <li>2. Maxwell's equations</li> <li>3. Wavegudes, resonant cavites and optical fibers</li> <li>4. Diffraction and scattering</li> <li>5. Collisions and radiation of charged particles</li> <li>6. Cerenkov and Bremsstrahlung radiation</li> <li>7. Quantization of electromagnetic field</li> <li>8. Cavity QED</li> </ol> |   |                        |   |   |   |                   |  |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |                        |   | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |   |                   |  |
| <b>1.6. Comments</b>   |   |                        |   |   |   |                   |  |
| <b>1.7. Student's obligations</b>  |   |                        |   |   |   |                   |  |
| It is expected that the student will follow the course actively and write an seminar paper. Furthermore the student will take the final exam.  |   |                        |   |   |   |                   |  |
| <b>1.8. Evaluation of student's work</b>   |   |                        |   |   |   |                   |  |
| Course attendance  |   | Activity/Participation | 1 | Seminar paper   | 3 | Experimental work |  |
| Written exam   | 2   | Oral exam              | 2 | Essay   |   | Research          |  |



|   |  |                           |  |                         |  |                           |  |
|---|--|---------------------------|--|-------------------------|--|---------------------------|--|
| Project   |  | Sustained knowledge check |  | Report                  |  | Practice                  |  |
| Portfolio   |  |                           |  |                         |  |                           |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>                            |  |                           |  |                         |  |                           |  |
| The seminar paper will be evaluated during the term. At the end, final exam will be evaluated.                      |  |                           |  |                         |  |                           |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>                           |  |                           |  |                         |  |                           |  |
| J. D. Jackson, <i>Classical Electrodynamics</i> (3. edition, John Wiley & Sons, Inc.)                               |  |                           |  |                         |  |                           |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>                               |  |                           |  |                         |  |                           |  |
|   |  |                           |  |                         |  |                           |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b> |  |                           |  |                         |  |                           |  |
|   |  | <i>Title</i>              |  | <i>Number of copies</i> |  | <i>Number of students</i> |  |
|   |  |                           |  |                         |  |                           |  |
|   |  |                           |  |                         |  |                           |  |
|   |  |                           |  |                         |  |                           |  |
|   |  |                           |  |                         |  |                           |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>        |  |                           |  |                         |  |                           |  |
| Quality will be monitored by anonymous polls.   |  |                           |  |                         |  |                           |  |



| Basic description                |   |            |
|----------------------------------|---|------------|
| <b>Course coordinator</b>        | Mladen Petravić                             |            |
| <b>Course title</b>              | Advanced Experimental Laboratory            |            |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |            |
| <b>Course status</b>             | optional                                    |            |
| <b>Year</b>                      | 2.  |            |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6          |
|                                  | <b>Number of hours (L+E+S)</b>              | 0 + 0 + 60 |

| 1. COURSE DESCRIPTION   |   |   |
|---|---|---|
| <b>1.1. Course objectives</b>   |   |   |
| To gain the basic knowledge about modern analytical techniques used for the characterisation of advanced materials and to actively use the analytical instruments in real experiments.  |   |   |
| <b>1.2. Course enrolment requirements</b>   |   |   |
| Solid State Physics, Experimental Methods in Physics and Physics of Semiconductors  |   |   |
| <b>1.3. Expected course learning outcomes</b>   |   |   |
| To understand the theoretical background and operational principles of several analytical techniques, and to be able to use these techniques in solving different analytical problems in science.   |   |   |
| <b>1.4. Course content</b>  |   |   |
| Students will work in several laboratories of the Department of Physics and Center for Micro and Nano Sciences and Technologies. The following analytical techniques will be used:  |   |   |
| <ul style="list-style-type: none"> <li>-XPS (X-ray Photoelectron Spectroscopy)</li> <li>-SIMS (Secondary Ion Mass Spectrometry)</li> <li>-AFM (Atomic Force Microscopy)</li> <li>-SEM (Scanning Electron Microscopy)</li> <li>-XRF (X-ray Fluorescence)</li> </ul>  |   |   |
| These techniques will be used by students for elemental analysis and depth profiling of elements and impurities, study of surface chemical bonds, characterization of changes and defects on thin film surfaces of semiconductors heterostructures, compound semiconducting materials and nanosystems, including different nanotubes. |   |   |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>  |   |   |
| <b>1.7. Student's obligations</b>   |   |   |
| Active participation in experimental work, data acquisition, analysis and interpretation and oral presentation of experiments.  |   |   |
| <b>1.8. Evaluation of student's work</b>  |   |   |



|                   |  |                           |     |               |      |                   |      |
|-------------------|--|---------------------------|-----|---------------|------|-------------------|------|
| Course attendance |  | Activity/Participation    | 1.5 | Seminar paper | 1.5  | Experimental work | 1.5  |
| Written exam      |  | Oral exam                 |     | Essay         |      | Research          | 0.75 |
| Project           |  | Sustained knowledge check |     | Report        | 0.75 | Practice          |      |
| Portfolio         |  |                           |     |               |      |                   |      |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Performance of students will be evaluated for each experiment performed and data analysis as well as oral presentation of each experiment.. There will be no final exam.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. L.Feldman and J.Mayer: Fundamentals of Surface and Thin Film Analysis, PTR Prentice Hall, New Jersey, 1986.
2. H.Luth: Surfaces and Interfaces of Solid Materials, Springer Study Edition, Berlin, 2007.

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. D.P.Woodruff and T.A.Delchar, Modern Techniques of Surface Science-Second Edition, Cambridge University Press, Cambridge, 1994.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Implementation of the system of quality control of the Department of Physics. Continuous interaction with students and discussions on quality of teaching process.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Zdravko Lenac                               |              |
| <b>Course title</b>              | Advanced Quantum Physics                    |              |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 8            |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 30 + 15 |

| 1. COURSE DESCRIPTION   |   |   |
|---|---|---|
| <b>1.1. Course objectives</b>   |   |   |
| Understanding of the exact definition and principles of quantum mechanics. Understanding, from the physical point of view, the mathematical formulation of quantum mechanics, particularly the role of symmetry in the space and time transformations. Understanding the different pictures of quantum mechanics and the basic ideas of the field theory.   |   |   |
| <b>1.2. Course enrolment requirements</b>   |   |   |
| Completed the bachelor study with the passed course related to a basic knowledge of the quantum mechanics on a bachelor study or on a corresponding accredited life-long learning study.  |   |   |
| <b>1.3. Expected course learning outcomes</b>   |   |   |
| After completing the course, the student will be able to: understand the basic principles of quantum mechanics; use the acquired mathematical knowledge to understand the complex structure of quantum mechanics; understand the applications of instruments which function is based on the principles of quantum mechanics; follow and understand the new achievements related to the quantum principles.  |   |   |
| <b>1.4. Course content</b>  |   |   |
| Basic principles of quantum mechanics. Mathematical foundations of quantum mechanics. Symmetry in quantum mechanics. Harmonic oscillator: wave and matrix theory, creation and annihilation operators. Angular momentum: wave and matrix representation. Pictures of quantum mechanics. Time-dependent perturbation theory. Scattering theory. Quantization of the electromagnetic field. Interaction of electromagnetic field with charged particles. Spontaneous emission. Basic ideas of the field theory. |   |   |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>  | Students are evaluated regarding their activity on lectures and exercises. Two written midterm exams. Final exam: oral.   |   |
| <b>1.7. Student's obligations</b>   |   |   |
| Regular attending the lectures, seminars and exercises; in-time delivering required homework; passing two midterms (writing part of the exam) with numerical tasks within the semester; passing the oral exam.  |   |   |



### 1.8. Evaluation of student's work

|                   |     |                           |     |               |     |                   |  |
|-------------------|-----|---------------------------|-----|---------------|-----|-------------------|--|
| Course attendance | 0.5 | Activity/Participation    | 0.5 | Seminar paper | 1.0 | Experimental work |  |
| Written exam      | 2.4 | Oral exam                 | 2.4 | Essay         |     | Research          |  |
| Project           |     | Sustained knowledge check | 0.6 | Report        | 0.6 | Practice          |  |

### 1.9. Assessment and evaluation of student's work during classes and on final exam

Students are evaluated during the lectures and on the final exam. According to given Table 1.8, the student can get 70% of the total score during the lectures and 30% on the final (oral) exam.

### 1.10. Assigned reading (at the time of the submission of study programme proposal)

I. Supek, *Teorijska fizika i struktura materije*, 1. i 2. dio, Školska knjiga, Zagreb, 1977.  
 D. J. Griffiths, *Introduction to Quantum Mechanics*, 2nd ed., Prentice-Hall, New Jersey, 2005.  
 W. A. Harrison, *Applied quantum mechanics*, World Scientific, Singapore, 2001.

### 1.11. Optional / additional reading (at the time of proposing study programme)

L. I. Schiff, *Quantum Mechanics*, 3. izdanje, McGraw-Hill, New York, 1968.  
 J. J. Sakurai, *Modern Quantum Mechanics*, 2. izdanje, Addison-Wesley, Reading, 1994.  
 A. F. J. Levi, *Applied Quantum Mechanics*, 2. izdanje, Cambridge University Press, Cambridge, 2006.  
 A. Messiah, *Quantum Mechanics*, North-Holland, Amsterdam, 1970.

### 1.12. Number of assigned reading copies with regard to the number of students currently attending the course

| Title   | Number of copies | Number of students |
|---|------------------|--------------------|
| I. Supek, <i>Teorijska fizika i struktura materije</i> , 1. i 2. dio, Školska knjiga, Zagreb, 1977.   | 4                | 15                 |
| D. J. Griffiths, <i>Introduction to Quantum Mechanics</i> , 2nd ed., Prentice-Hall, New Jersey, 2005. | 3                | 15                 |
| W. A. Harrison, <i>Applied quantum mechanics</i> , World Scientific, Singapore, 2001.                 | 1                | 15                 |
|   |                  |                    |
|   |                  |                    |

### 1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences

The continuous interaction with students. The anonymous questionnaires about the quality of teaching. Flexible adaptation of teaching according to students requirements. Evaluation of a success-rate on exams.



| Basic description         |                                      |          |
|---------------------------|--------------------------------------|----------|
| Course coordinator        | Dubravka Kotnik-Karuza               |          |
| Course title              | Astronomy and astrophysics I         |          |
| Study programme           | Graduate Study Programme Physics     |          |
| Course status             | optional                             |          |
| Year                      | 1.                                   |          |
| ECTS credits and teaching | ECTS student 's workload coefficient | 8        |
|                           | Number of hours (L+E+S)              | 45+30+15 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

Introduce the students to fundamentals of stellar and galactic astronomy with an emphasis on selected topics in the recent astrophysical research. This course will serve as a basic course for more advanced astrophysical courses in this graduate study programme. The aim of the course is to enable the students to understand the new results and recent advances in this propulsive scientific field.

### 1.2. Course enrolment requirements

No formal prerequisites. Knowledge of general physics is assumed.

### 1.3. Expected course learning outcomes

The students are expected to obtain the basic knowledge of stellar and galactic astrophysics, to understand and to describe the dynamic and physical properties of different components of the universe as well as to improve their knowledge of the related areas of physics. The course should encourage their interest for scientific and technical achievements of modern astrophysical research. They should be able to:

1. define the stellar parallax\*,
2. define the apparent magnitude, the absolute magnitude and the distance module\*,
3. describe photometric systems and colour indices\*,
4. describe the structure, function and working principles of telescope, interferometers and detectors used in optical, radio-, IR, UV, X and  $\gamma$ - spectral regions. Give the representative examples\*,
5. define the seeing, angular resolution and magnification of a telescope\*,
6. describe the stellar characteristics which are derived from observations\*,
7. classify the stars according to their spectra\*,
8. derive and explain the Saha and Boltzmann equations,
9. describe and explain the Hertzsprung-Russel diagram,
10. define the radiation intensity and flux, the radiation pressure and energy density,
11. define opacity and optical depth, and explain Beer law,
12. define equivalent line-width, describe and understand different line-broadening mechanisms,
13. describe and understand interstellar extinction and the role of molecules and dust in interstellar medium,
14. derive the Jeans mass and radius, describe and explain gravitational collapse of a molecular cloud,
15. describe and understand the evolution of protostars up to the main sequence using the HR diagram,
16. describe energy sources and energy transport in the stellar interior,
17. describe the evolution of stars of different masses on the main sequence,
18. describe the final phases of stellar evolution, causes and mechanisms of helium flash and thermal pulsations,
19. describe the phenomena and explain the basic physical process of stellar pulsations,
20. describe the method of measurement of astronomical distances using Cepheid variables,



21. explain the processes of supernova explosion and classification of supernova types,
22. describe and understand the properties of white dwarves and the state of the degenerate electron gas
23. calculate the Chandrasekhar limit and derive the equation for the white dwarf radius,
24. describe and understand the degenerate neutron gas and derive the equation for the radius of a neutron star,
25. describe the basic physical model of a pulsar and understand its properties
26. describe the basic properties of a black hole and derive the equation for the Schwarzschild radius,
27. describe the general properties, structure and size of the Milky Way,
28. describe and understand the rotational curves of galaxies as a consequence of the presence of the dark matter,
29. describe the morphological classification of galaxies (Hubble fork),
30. describe active galaxies and quasars.

\* this topic is included in the astrophysics course of the undergraduate study programme. Those who have not attended this course will achieve these outcomes in seminars.

#### 1.4. Course content

Astronomical distances, units and methods of measurement – Stellar parallax – Magnitudes – Photometric Systems – Classification of stellar spectra – Saha equation – HR diagram – Stellar atmospheres – Stellar opacity – Spectral lines: formation and broadening mechanisms – Interstellar medium – Formation and evolution of protostars – Stellar evolution on main sequence – Energy sources and transport in stellar interior – Final phases in stellar evolution – Stellar pulsations – Cepheid variables – Supernova – Degenerate gas – White dwarves – Chandrasekhar limit – Neutron stars and pulsars – Milky Way – Basic properties, types and structure of galaxies – Quasars.

#### 1.5. Teaching methods

- |  |   |
|--|---|
| <input checked="" type="checkbox"/> lectures               | <input checked="" type="checkbox"/> individual assignment |
| <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> multimedia and network           |
| <input checked="" type="checkbox"/> exercises              | <input type="checkbox"/> laboratories                     |
| <input type="checkbox"/> long distance education           | <input type="checkbox"/> mentorship                       |
| <input type="checkbox"/> fieldwork                         | <input type="checkbox"/> other                            |

#### 1.6. Comments

#### 1.7. Student's obligations

Students should regularly attend and actively participate in the course (lecture, exercises and seminars), pass the mid-term and full-term exams, prepare and orally present one group project assignment. Each student should also prepare and orally present a 30 minute - seminar in a selected topic from the course contents.

#### 1.8. Evaluation of student's work

|                   |     |                           |     |               |     |                   |  |
|-------------------|-----|---------------------------|-----|---------------|-----|-------------------|--|
| Course attendance | 1   | Activity/Participation    | 0.5 | Seminar paper | 1.5 | Experimental work |  |
| Written exam      |     | Oral exam                 | 2   | Essay         |     | Research          |  |
| Project           | 1.5 | Sustained knowledge check | 1.5 | Report        |     | Practice          |  |
| Portfolio         |     |                           |     |               |     |                   |  |

#### 1.9. Assessment and evaluation of student's work during classes and on final exam

The students' work will be continuously assessed and evaluated during the course (mid-term and full-term exams, group project assignment and seminar) and at the final exam. The total number of credits a student can achieve during the course (reviewed activities specified in the table) are 70:

1. sustained knowledge check through mid-term and full-term exams – 30 points,
2. project assignment – 15 points,
3. seminar (oral presentation) – 20 points,
4. activity and participation – 5 points.

Student can earn additional 30 points at the final oral exam based on three tasks he/she is assigned (each has a value of 10 points).



**1.10. Assigned reading (at the time of the submission of study programme proposal)**

B.W.Carroll, D.A.Ostlie: An introduction to modern astrophysics, Addison-Wesley, 2007  
Rau A. R., Astronomy-inspired Atomic and Molecular Physics, Springer, Berlin, 2002.  
V. Vujnović: Astronomija I, Školska knjiga, Zagreb 1989.  
V. Vujnović: Astronomija II, Školska knjiga, Zagreb 1990.

**1.11. Optional / additional reading (at the time of proposing study programme)**

Hoyle F.: Astronomija, Marjan tisak, Split, 2005  
Couper H., Henbest N.: Enciklopedija svemira, Zagreb, Znanje, 2004  
A.Unsold, B.Baschek: The new cosmos, Springer 1991.  
M. Harwit: Astrophysical concepts, Springer 1988.  
E. Boehm-Vitense: Introduction to stellar astrophysics, Cambridge University press 1989.  
H. Scheffler, H. Elsasser: Physics of the Galaxy and Interstellar matter, Springer 1987.  
P. Lena: Observational astrophysics, Springer 1988.  
H. Karttunen, P. Kroger, M. Pontanen, K.J. Donner: Fundamental astronomy, Springer 1994.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title   | Number of copies | Number of students |
|---|------------------|--------------------|
| B.W.Carroll, D.A.Ostlie: An introduction to modern astrophysics, Addison-Wesley, 2007 | 4                | 8                  |
| A.R.Rau: Astronomy-inspired Atomic and Molecular Physics, Springer, Berlin, 2002.     | 2                | 8                  |
| V. Vujnović: Astronomija I, Školska knjiga, Zagreb 1989.                              | 5                | 8                  |
| V. Vujnović: Astronomija II, Školska knjiga, Zagreb 1990.                             | 3                | 8                  |
|   |                  |                    |
|   |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

The quality of the course will be permanently verified by the student's progress which is assessed through exams and other achievement records. The acquired knowledge, skills and competences are assessed through the student's success in solving problems during the course exercises and exams, as well as in preparation and seminar-presentation of a project on a selected topic.

At the final exam knowledge of the fundamental properties of different cosmic objects as well as of the most important astrophysical processes is assessed, and the student's final success will be a measure of quality and success of the course. Additional feedback on quality and efficiency of the course is gained by implementation of a students' questionnaire at the end of the course.



| Basic description                |   |          |
|----------------------------------|---|----------|
| <b>Course coordinator</b>        | Dubravka Kotnik-Karuza                      |          |
| <b>Course title</b>              | Astronomy and astrophysics II               |          |
| <b>Study programme</b>           | Graduate Study Programme Physics            |          |
| <b>Course status</b>             | optional                                    |          |
| <b>Year</b>                      | 2.  |          |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6        |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+15+15 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

Introduce the students to modern observations and advanced theoretical knowledge of stellar and galactic astrophysics. This will enable them to acquire knowledge and understanding of the new results and recent development in the field of astrophysics and acquaint them with actual topics of scientific research in astrophysics.

### 1.2. Course enrolment requirements

Accomplished course in Astronomy and astrophysics 1. Knowledge of general physics is assumed.

### 1.3. Expected course learning outcomes

The students are expected to obtain an advanced knowledge of stellar and galactic astrophysics, to understand and describe in more details the dynamic and physical properties of different cosmic objects and components of the universe and to encourage their interest for scientific research in the field of astrophysics. They should be able to:

1. describe and understand sources and mechanisms of atmospheric opacity and of Balmer jump,
2. describe the Rosseland mean opacity,
3. describe and understand the equation of radiative transfer and its particular contributions,
4. describe the source function and derive the equation of radiative transfer for a black body,
5. derive and understand the Eddington approximation and apply it on phenomena of limb darkening,
6. describe pp-chains and CNO cycle in the stellar core,
7. describe and understand energy transport in stellar interior,
8. describe and understand convection,
9. describe polytropic models,
10. define and calculate Eddington limit,
11. describe close binary stellar systems,
12. describe accretion disks and supernova type Ia,
13. describe the structure of the Milky way,
14. describe chemical composition, metallicity, age and kinematical properties of different components of the Milky way and distinguish between populations I, II and III,
15. describe the galactic centre of the Milky way and its properties, and connect them with the existence of supermassive black hole,
16. describe experimental observations of rotational curves of galaxies and of mass distribution and explain them by the dark matter phenomenon,
17. define stellar clusters and their classification, and describe their properties,
18. describe the properties of spiral and elliptical galaxies and their types and subtypes,
19. describe the Tully-Fisher relation and its use in measurement of the distances in the universe,



20. describe the Faber-Jackson relation,
21. describe and understand the formation of spiral arms in the spiral structure of galaxies\*,
22. describe the interaction and merging of galaxies,
23. describe and understand methods for measuring distances in the universe using globular clusters and supernovae,
24. describe Hubble law, determination of Hubble constant and measurements of cosmic distances,
25. describe and understand Big bang theory and support it with observations,
26. describe galaxy clusters and our local group,
27. describe the superclusters and structures on cosmologic scales and connect them with inhomogeneities of the cosmic microwave background radiation,
28. describe active galaxies, their spectra, types and subtypes,
29. describe and understand properties of quasars,
30. describe the nature and structure of the central source in AGN,
31. describe and understand the mechanism of the gravitational lens and the formation of Einstein ring, and connect them with the determination of the structure of the universe\*,
32. describe the cosmic microwave background radiation, its origin and observed anisotropy,
33. describe evolution of the early universe, cooling, neutrino decoupling, and transition from radiation dominated to the matter dominated universe,
34. describe and understand the primordial nucleosynthesis and recombination epoch,
35. describe basic cosmologic models and the role of the dark energy.

\* advanced learning outcomes which will be achieved through seminars and individual student's work.

#### 1.4. Course content

Stellar atmospheres and opacity – Radiative transfer – Source function – Energy sources and transport in stellar interior – Convection – Close binary stellar systems – Morphology of the Milky way galaxy – Milky way centre – Dark matter – Spiral galaxies – Tully-Fisher relation – Elliptical galaxies – Faber-Jackson relation – Evolution and interaction between galaxies – Structure of the universe – Distance scales and methods of their measurements – Big bang and expansion of the universe – Galaxy clusters – Active galaxies – Quasars – Evolution of the early universe – Cosmic microwave background radiation – Primordial nucleosynthesis.

#### 1.5. Teaching methods

- |  |   |
|--|---|
| <input checked="" type="checkbox"/> lectures               | <input checked="" type="checkbox"/> individual assignment |
| <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> multimedia and network           |
| <input checked="" type="checkbox"/> exercises              | <input type="checkbox"/> laboratories                     |
| <input type="checkbox"/> long distance education           | <input type="checkbox"/> mentorship                       |
| <input type="checkbox"/> fieldwork                         | <input type="checkbox"/> other                            |

#### 1.6. Comments

#### 1.7. Student's obligations

Students should regularly attend and actively participate in the course (lecture, exercises and seminars), pass the mid-term and full-term exams, prepare and orally present one group project assignment. Each student should also prepare and orally present in 30 minutes one seminar on a selected subject from the course.

#### 1.8. Evaluation of student's work

|                   |   |                           |     |               |   |                   |  |
|-------------------|---|---------------------------|-----|---------------|---|-------------------|--|
| Course attendance | 1 | Activity/Participation    | 0.5 | Seminar paper | 1 | Experimental work |  |
| Written exam      |   | Oral exam                 | 1.5 | Essay         |   | Research          |  |
| Project           | 1 | Sustained knowledge check | 1   | Report        |   | Practice          |  |
| Portfolio         |   |                           |     |               |   |                   |  |

#### 1.9. Assessment and evaluation of student's work during classes and on final exam

The students' work will be continuously assessed and evaluated during the course (mid-term and full-term exams, group project assignment and seminar) and in the final exam. The total number of credits a student can achieve during the course (reviewed activities specified in the table) are 70:

1. sustained knowledge check through mid-term and full-term exams – 30 points,



2. project assignment – 15 points,
3. seminar (oral presentation) – 20 points,
4. activity and participation – 5 points.

Student can earn additional 30 points at the final oral exam based on three tasks he/she is assigned (each has a value of 10 points).

### **1.10. Assigned reading (at the time of the submission of study programme proposal)**

B.W.Carroll, D.A.Ostlie: An introduction to modern astrophysics, Addison-Wesley, 2007  
S. G. Ryan, A. J. Norton: Stellar evolution and Nucleosynthesis, Cambridge University Press 2010  
A.R.Rau: Astronomy-inspired Atomic and Molecular Physics, Springer, Berlin, 2002.  
V. Vujnović: Astronomija I, Školska knjiga, Zagreb 1989.  
V. Vujnović: Astronomija II, Školska knjiga, Zagreb 1990.

### **1.11. Optional / additional reading (at the time of proposing study programme)**

F. Hoyle: Astronomija, Marjan tisak, Split, 2005  
J. Binney: Galactic Astronomy, Princeton University Press 1998  
S. G. Ryan, A. J. Norton: Stellar evolution and Nucleosynthesis, Cambridge University Press 2010  
D. Prialnik: An Introduction to the Theory of Stellar Structure and Evolution, Cambridge University Press 2009  
A.Unsold, B.Baschek: The new cosmos, Springer 1991.  
M. Harwit: Astrophysical concepts, Springer 1988.  
E. Boehm-Vitense: Introduction to stellar astrophysics, Cambridge University press 1989.  
H. Scheffler, H. Elsasser: Physics of the Galaxy and Interstellar matter, Springer 1987.  
P. Lena: Observational astrophysics, Springer 1988.  
H. Karttunen, P. Kroger, M. Pontanen, K.J. Donner: Fundamental astronomy, Springer 1994.

### **1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>   | <i>Number of copies</i> | <i>Number of students</i> |
|--|-------------------------|---------------------------|
| B.W.Carroll, D.A.Ostlie: An introduction to modern astrophysics, Addison-Wesley, 2007            | 4                       | 8                         |
| S. G. Ryan, A. J. Norton: Stellar evolution and Nucleosynthesis, Cambridge University Press 2010 | 2                       | 8                         |
| A.R.Rau: Astronomy-inspired Atomic and Molecular Physics, Springer, Berlin, 2002.                | 3                       | 8                         |
| V. Vujnović: Astronomija I, Školska knjiga, Zagreb 1989.   | 5                       | 8                         |
| V. Vujnović: Astronomija II, Školska knjiga, Zagreb 1990.  | 3                       | 8                         |

### **1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

The quality of the course will be permanently verified by the student's progress which is assessed through exams and other achievement records, while the acquired knowledge, skills and competences are assessed through the student's success in solving problems during the course exercises and exams, as well as in preparation and presentation of a group project and an individual seminar on a chosen topic in astronomy and astrophysics.

At the final exam advanced knowledge of the astrophysical processes and cosmic objects is assessed, and the student's final success will be a measure of the quality and success of the course. Additional feedback on quality and efficiency of the course is gained by implementation of a students' questionnaire at the end of the course.



| Basic description                |   |          |
|----------------------------------|---|----------|
| <b>Course coordinator</b>        | Željka Bošnjak                              |          |
| <b>Course title</b>              | Astroparticle Physics                       |          |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |          |
| <b>Course status</b>             | Optional                                    |          |
| <b>Year</b>                      | 2.  |          |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6        |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+15+15 |

| 1. COURSE DESCRIPTION   |  |  |   |  |                                    |   |  |                                       |                                     |                                |
|---|--|--|---|--|------------------------------------|---|--|---------------------------------------|-------------------------------------|--------------------------------|
| <b>1.1. Course objectives</b>   |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| To give a broad overview of astrophysics – expose students to current developments in physics.  |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| <b>1.2. Course enrolment requirements</b>   |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| Elementary Particle Physics 1 ; Astronomy and Astrophysics 1  |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| <b>1.3. Expected course learning outcomes</b>   |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| Training students to apply physics in understanding of the Universe. Preparation for the research work in modern physics.   |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| <b>1.4. Course content</b>  |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| Broad survey: overview of astroparticle physics. EM signal from stars and galaxies, interstellar medium, CMB, cosmic rays, neutrinos – different sources. Major source of neutrinos: stars that produce neutrinos in nuclear reactions (low energy neutrinos ~ MeV). Supernova neutrinos of energies 10-30 MeV. The lowest energy neutrinos from Big Bang. High energy neutrinos from outside of our galaxy, produced in shocks (relativistic or sub-relativistic). Cosmic rays. Physics of the shocks (particle acceleration, neutrino production). Synchrotron radiation, inverse Compton radiation. Examples in astrophysics where synchrotron radiation is observed (gamma ray bursts, quasars, SN remnants, microquasars). Gravitational waves. Dark matter (evidence; laboratory searches). |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input checked="" type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment | <input checked="" type="checkbox"/> multimedia and network | <input type="checkbox"/> laboratories | <input type="checkbox"/> mentorship | <input type="checkbox"/> other |
| <b>1.6. Comments</b>  |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| <b>1.7. Student's obligations</b>   |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| Active participation, home and class assignments and tests, preparing one seminar with presentation, passing final exam.  |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| <b>1.8. Evaluation of student's work</b>  |  |  |   |  |                                    |   |  |                                       |                                     |                                |
| Course attendance   |  | Activity/Participation                                     | 0.5   | Seminar paper                                    | 1                                  | Experimental work   |  |                                       |                                     |                                |
| Written exam  | 1  | Oral exam  | 1.5   | Essay  |                                    | Research  |  |                                       |                                     |                                |
| Project   |  | Sustained knowledge check                                  | 2   | Report   |                                    | Practice  |  |                                       |                                     |                                |
| Portfolio   |  |  |   |  |                                    |   |  |                                       |                                     |                                |



**1.9. Assessment and evaluation of student's work during classes and on final exam**

Students will be evaluated and valued continuously during the course through home assignments and periodic tests. They have to write one seminar, which should be publicly presented. The course finishes with a final exam. Activities during the course bring at least 70% of the total mark.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

M. Longair: High Energy Astrophysics

**1.11. Optional / additional reading (at the time of proposing study programme)**

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i> | <i>Number of copies</i> | <i>Number of students</i> |
|--------------|-------------------------|---------------------------|
|              |                         |                           |
|              |                         |                           |
|              |                         |                           |
|              |                         |                           |
|              |                         |                           |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Consultations, standard anonymous student questionnaires, discussions after the final exam.



| Basic description                |   |        |
|----------------------------------|---|--------|
| <b>Course coordinator</b>        | Dijana Dominis Prester                      |        |
| <b>Course title</b>              | Astrophysics lab                            |        |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |        |
| <b>Course status</b>             | Optional                                    |        |
| <b>Year</b>                      | 2.  |        |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6      |
|                                  | <b>Number of hours (L+E+S)</b>              | 0+0+60 |

| 1. COURSE DESCRIPTION   |  |   |
|---|--|---|
| <b>1.1. Course objectives</b>   |  |   |
| Gaining practical knowledge and skills in experimental (observational) astrophysics and data reduction. Preparing for scientific research in astrophysics.  |  |   |
| <b>1.2. Course enrolment requirements</b>   |  |   |
| Mandatory: Courses „Astronomy and Astrophysics I“ and „Observational astrophysics“.   |  |   |
| <b>1.3. Expected course learning outcomes</b>   |  |   |
| Students will be expected to develop skills in using of observational instruments in astrophysics, data analysis and visualisation of the results. Practical work in astrophysical experimental methods will prepare students for scientific research. Solving problems in the data reduction and analysis will develop creativity and independence in solving particular scientific problems.  |  |   |
| <b>1.4. Course content</b>  |  |   |
| 1) Optical telescopes reflector and refractor.<br>CCD camera.<br>Spectrometer.<br>2) Data reduction of photometric CCD images.<br>Determining stellar photometric colors.<br>Determining width of the spectral lines.<br>Spectral classification.<br>Simulating atmospheric showers (CORSIKA).<br>Visualisation of analysis results in astrophysics. (ROOT, SuperMongo)<br>3) Observing atmospheric showers using Cherenkov telescope (*) |  |   |
| <b>1.5. Teaching methods</b>  | <input type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>  | Part 1) of this lab will be performed at the Astronomical center (observatory for public and outreach) at Sv. Kriz, Rijeka.<br>Part 2) will be performed in the computing lab at the Department of physics of the University of Rijeka.    |   |



|  |   |                           |   |                  |   |                    |  |
|--|---|---------------------------|---|------------------|---|--------------------|--|
| <p>Part 3) will be performed at the ORM observatory on La Palma, Canary Islands, Spain, on the MAGIC telescopes, in case sending of the students there is financially possible from a research grant. The course coordinator is a member of the MAGIC collaboration and has access to the telescopes and the corresponding hardware. In case this is not possible, part 3 will not be performed.</p> |   |                           |   |                  |   |                    |  |
| <p><b>1.7. Student's obligations</b></p>   |   |                           |   |                  |   |                    |  |
| <p>Course attendance, labs, preparing labs, lab reports, final exam.</p>   |   |                           |   |                  |   |                    |  |
| <p><b>1.8. Evaluation of student's work</b></p>  |   |                           |   |                  |   |                    |  |
| Course attendance  |   | Activity/Participation    | 1 | Seminar paper    | 1 | Experimental work  |  |
| Written exam   | 1 | Oral exam                 | 2 | Essay            |   | Research           |  |
| Project  |   | Sustained knowledge check | 1 | Report           |   | Practice           |  |
| Portfolio  |   |                           |   |                  |   |                    |  |
| <p><b>1.9. Assessment and evaluation of student's work during classes and on final exam</b></p>  |   |                           |   |                  |   |                    |  |
| <p>Manner of knowledge checking: class participation, homework, project, written and oral exam. Student's work will be evaluated during the semester, and during the final exam.</p>   |   |                           |   |                  |   |                    |  |
| <p><b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b></p>   |   |                           |   |                  |   |                    |  |
| <p>1. Course Web page<br/>2. Vladis Vujnović: Astronomija 1 i 2, Školska knjiga, 2010</p>  |   |                           |   |                  |   |                    |  |
| <p><b>1.11. Optional / additional reading (at the time of proposing study programme)</b></p>   |   |                           |   |                  |   |                    |  |
| <p>1. M. Zeilik and E.P. Smith: "Introductory Astronomy and Astrophysics", 1987, CBS College publishing<br/>2. Léna, P., Rouan, D., Lebrun, F., Mignard, F., Pelat, D.: "Observational astrophysics", 2012, Springer<br/>3. CORSIKA manual<br/>4. ROOT manual</p>  |   |                           |   |                  |   |                    |  |
| <p><b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b></p>   |   |                           |   |                  |   |                    |  |
| Title  |   |                           |   | Number of copies |   | Number of students |  |
|  |   |                           |   |                  |   |                    |  |
|  |   |                           |   |                  |   |                    |  |
|  |   |                           |   |                  |   |                    |  |
|  |   |                           |   |                  |   |                    |  |
| <p><b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b></p>  |   |                           |   |                  |   |                    |  |
| <p>Interaction with students and student-faculty team work on quality of teaching process. Anonymous questionnaires on quality of teaching. Flexible adaptation of teaching to interests and needs of students. Complex laboratory exercise will include consultatory work, and develop creativity through active learning.</p>  |   |                           |   |                  |   |                    |  |



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Ivica Orlić                                 |         |
| <b>Course title</b>              | Atmospheric Physics                         |         |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |         |
| <b>Course status</b>             | compulsory                                  |         |
| <b>Year</b>                      | 1.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 7       |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+30+0 |

| 1. COURSE DESCRIPTION  |   |  |
|--|---|--|
| <b>1.1. Course objectives</b>  |   |  |
| To gain knowledge and develop understanding of principles of atmospheric physics, basic thermodynamic model, weather formation, global warming and aerosol pollution and its effect on human health.   |   |  |
| <b>1.2. Course enrolment requirements</b>  |   |  |
| Diploma  |   |  |
| <b>1.3. Expected course learning outcomes</b>  |   |  |
| Familiarize students with the concepts of atmospheric physics such as thermodynamics and chemistry of the atmosphere (radiative transfer, albedo, wind, currents, weather patterns, aerosol pollution and modeling). Practical consequences of increased global pollution and effects on global warming and climate change. Fine aerosol component will be sampled and analyzed in the Physics department.   |   |  |
| <b>1.4. Course content</b>   |   |  |
| <ol style="list-style-type: none"> <li>1. Introduction to the physics of atmosphere: A brief survey of the atmosphere</li> <li>2. The Earth System: Oceans, atmosphere, the earth's crust and mantle, a brief history of climate,</li> <li>3. Atmospheric Thermodynamics: gas laws, hydrostatic equation, thermodynamic laws, water vapour in the air.</li> <li>4. Radiative transfer: blackbody radiation, scattering and absorption, radiative transfer and balance</li> <li>5. Atmospheric chemistry: composition of troposphere. Sources, transport and sinks. Aerosols, concentration and size distribution, anthropogenic pollution, measurements and identification of major pollutants, statistical methods.</li> <li>6. Atmospheric dynamics: general circulation, weather systems, weather prediction.</li> <li>7. Climate dynamics: climate monitoring and predictions, recent climate changes, greenhouse warming, projections of future climate.</li> </ol> |   |  |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   |   |  |
| <b>1.7. Student's obligations</b>  |   |  |



Active participation of students in classes and project work, with presentations of seminars. Acquirement, analysis and synthesis of competences in topics being taught via readings of bibliographical references. Discussion of these topics on lectures and exercises as well as via written and oral presentations, partial and final exams.

**1.8. Evaluation of student's work**

|                   |   |                           |   |               |   |                   |  |
|-------------------|---|---------------------------|---|---------------|---|-------------------|--|
| Course attendance | 1 | Activity/Participation    | 1 | Seminar paper | 1 | Experimental work |  |
| Written exam      | 2 | Oral exam                 | 1 | Essay         |   | Research          |  |
| Project           |   | Sustained knowledge check | 1 | Report        |   | Practice          |  |
| Portfolio         |   |                           |   |               |   |                   |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Tuitions will be in form of lectures, project work and students' seminar work. Knowledge checking during classes will be performed via two partial exams and seminars.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

John M.Wallace, Peter V. Hobbs, Atmospheric Science, Academic Press, Elsevier Inc., 2006  
 David G. Andrews: An Introduction to Atmospheric Physics, Cambridge University Press (2000)  
 Boeker, E., van Grondelle: Environmental Science: Physical Principles and Applications, John Wiley & Sons, 2001  
 Dana Desonie, Atmosphere, Air Pollution and Its Effects, Chelsea House, 2007

**1.11. Optional / additional reading (at the time of proposing study programme)**

S.A.E. Johansson, J.L. Campbell and K.G. Malmqvist, Eds., Particle-Induced X-Ray Emission Spectroscopy (PIXE), John Wiley and Sons Ltd., 199 ISBN 0-471-58944-6  
 KR Spurny, Analytical Chemistry of Aerosols, 1999, CRC Publisher, USA.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Implementation of the system of quality control of the Department of Physics. Continuous interaction with students and discussions on quality of teaching process.



| Basic description                |   |          |
|----------------------------------|---|----------|
| <b>Course coordinator</b>        | Nada Orlić                                  |          |
| <b>Course title</b>              | Atomic and molecular physics                |          |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |          |
| <b>Course status</b>             | compulsory                                  |          |
| <b>Year</b>                      | 1.  |          |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 8        |
|                                  | <b>Number of hours (L+E+S)</b>              | 45+30+15 |

| 1. COURSE DESCRIPTION  |  |   |
|--|--|---|
| <b>1.1. Course objectives</b>  |  |   |
| The acquisition of advanced knowledge of atomic and molecular physics. Introduction to modern theoretical and experimental methods in physics research.  |  |   |
| <b>1.2. Course enrolment requirements</b>  |  |   |
| There are no formal prerequisites for entering this course, but it assumes knowledge of general and theoretical physics and mathematical methods of physics.   |  |   |
| <b>1.3. Expected course learning outcomes</b>  |  |   |
| <p>Students after passing the exam will be able to:</p> <ul style="list-style-type: none"> <li>• describe atoms, their size, electronic structure, mass, cross section and the distribution of electrons in the atom;</li> <li>• provide a complete quantum-mechanical description of the hydrogen atom;</li> <li>• describe and analyze the spectrum of helium and alkali atoms;</li> <li>• describe the theoretical models for multielectron atoms;</li> <li>• define and distinguish between ground and excited states of atoms;</li> <li>• describe and analyze the transition probabilities, selection rules, lifetimes of excited states of atoms and profiles of spectral lines;</li> <li>• describe diatomic molecules, molecular orbitals and electronic states of these molecules;</li> <li>• apply the fundamentals of group theory to determine the symmetry of molecules;</li> <li>• explain and analyze the spectra of polyatomic molecules;</li> <li>• describe and analyze the molecules in the excited state and the associated dynamic processes;</li> <li>• give examples of applications of atomic and molecular physics and the role of atomic and molecular physics in modern research.</li> </ul> |  |   |
| <b>1.4. Course content</b>   |  |   |
| The concept of the atom. Atoms with one and atoms with more than one electron. The interaction of atoms with electromagnetic radiation: transition probabilities, selection rules, excited state lifetimes, the spectral line profiles. Different approximations for calculating the electronic wave functions and their energy. Diatomic and polyatomic molecules. Fundamentals of group theory and its importance in molecular physics. Symmetry of molecules. Molecular spectra. Excited states of molecules. Dynamic processes. Basic concepts and types of spectroscopy. Applications of atomic and molecular physics.  |  |   |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |



|  |     |                           |     |                  |     |                    |  |
|--|-----|---------------------------|-----|------------------|-----|--------------------|--|
| <b>1.6. Comments</b>   |     |                           |     |                  |     |                    |  |
| <b>1.7. Student's obligations</b>  |     |                           |     |                  |     |                    |  |
| Students must attend lectures and seminar in accordance with the Rules of the study.   |     |                           |     |                  |     |                    |  |
| <b>1.8. Evaluation of student's work</b>   |     |                           |     |                  |     |                    |  |
| Course attendance  | 0.5 | Activity/Participation    | 0.5 | Seminar paper    | 2.0 | Experimental work  |  |
| Written exam   |     | Oral exam                 | 3.0 | Essay            |     | Research           |  |
| Project  |     | Sustained knowledge check | 2.0 | Report           |     | Practice           |  |
| Portfolio  |     |                           |     |                  |     |                    |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |     |                           |     |                  |     |                    |  |
| Students will be evaluated during lectures and on final exam. Maximum percentage during lectures is 70%, and on final exam 30%. On final exam student should have at least 50% point to pass. Detailed elaboration will be given in executive program. |     |                           |     |                  |     |                    |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |     |                           |     |                  |     |                    |  |
| 1. W. Demtröder, <i>Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics</i> , Springer, 2011.   |     |                           |     |                  |     |                    |  |
| 2. W. Demtröder, <i>Molecular Physics: Theoretical Principles and Experimental Methods</i> , John Wiley&Sons, 2008.  |     |                           |     |                  |     |                    |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |     |                           |     |                  |     |                    |  |
| 1. B. H. Bransden, C. J. Joachain, <i>Physics of Atoms and Molecules</i> , Pearson Education, 2003.  |     |                           |     |                  |     |                    |  |
| 2. L. Klasinc, Z. Maksić, N. Trinajstić, <i>Simetrija molekula</i> , Školska knjiga, Zagreb, 1979.   |     |                           |     |                  |     |                    |  |
| 3. G. Herzberg, <i>Atomic Spectra and Atomic Structure</i> , Dover Publications, 2010.   |     |                           |     |                  |     |                    |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |     |                           |     |                  |     |                    |  |
| Title  |     |                           |     | Number of copies |     | Number of students |  |
| W. Demtröder, <i>Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics</i> , Springer, 2011.  |     |                           |     | 1                |     |                    |  |
| W. Demtröder, <i>Molecular Physics: Theoretical Principles and Experimental Methods</i> , John Wiley&Sons, 2008.   |     |                           |     | 1                |     |                    |  |
|  |     |                           |     |                  |     |                    |  |
|  |     |                           |     |                  |     |                    |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |     |                           |     |                  |     |                    |  |
| The quality will be monitored through consultations, surveys and interviews after the exam.  |     |                           |     |                  |     |                    |  |



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Marcelo Kovačić                             |         |
| <b>Course title</b>              | Biological oceanography                     |         |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |         |
| <b>Course status</b>             | optional                                    |         |
| <b>Year</b>                      | 2.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 3       |
|                                  | <b>Number of hours (L+E+S)</b>              | 15+15+0 |

| 1. COURSE DESCRIPTION   |  |  |
|---|--|--|
| <b>1.1. Course objectives</b>   |  |  |
| The goal of the course is to introduce students to basics of ecology of marine ecosystems and marine biogeography. Learned knowledge is necessary for understanding of subjects involved in work on marine ecosystems and in the protection of marine environment.  |  |  |
| <b>1.2. Course enrolment requirements</b>   |  |  |
| General Ecology   |  |  |
| <b>1.3. Expected course learning outcomes</b>   |  |  |
| After the passed exam the students will be qualified for:   |  |  |
| 1. understanding the problems of the freshwater ecosystems and managing the project tasks on description and estimation of conditions in the marine ecosystems.   |  |  |
| 2. understanding the problems and managing the project tasks on the environmental impacts and on the protection of the environment in the seas.   |  |  |
| 3. understanding the problems and managing the project tasks on the nature protection in the seas.  |  |  |
| <b>1.4. Course content</b>  |  |  |
| Characteristics of marine ecosystems. Classifications of marine habitats. The history of biological oceanography. Abiotic factors in sea. Phytoplankton and primary production. Zooplankton. Mineral cycling and energy flow in sea. Nekton and fisheries oceanography. Benthos. Division of pelagial. Division of benthos and benthic communities. Zoogeography of littoral. Ecology and zoogeography of pelagial. Ecology and zoogeography of deep sea. Research methods in biological oceanography. Human impact on marine ecosystems and the protection of sea. Adriatic Sea. |  |  |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratory work<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> consultations |
| <b>1.6. Comments</b>  |  |  |
| <b>1.7. Student's obligations</b>   |  |  |
| Course attendance, Activity/Participation, Practice, Written exam   |  |  |
| <b>1.8. Evaluation of student's work</b>  |  |  |



|                   |     |                           |  |               |     |                   |     |
|-------------------|-----|---------------------------|--|---------------|-----|-------------------|-----|
| Course attendance | 0.3 | Activity/Participation    |  | Seminar paper | 0.3 | Experimental work |     |
| Written exam      | 2.1 | Oral exam                 |  | Essay         |     | Research          |     |
| Project           |     | Sustained knowledge check |  | Report        |     | Practice          | 0.3 |
| Portfolio         |     |                           |  |               |     |                   |     |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Student's work will be assessed and evaluated during classes and on the final exam. Total number of points that could be collected during classes is 30 (evaluated activities are presented in the table). Total number of points on the final exam is 70.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Lalli, C.M. and T.R. Parsons, 1995. Biological Oceanography: An Introduction. Oxford, UK: Butterworth-Heinemann.

Pérès, J.M. & H. Gamulin-Brida, 1973. Biološka oceanografija. Bentos. Bentoska bionomija Jadranskog mora. Školska knjiga, Zagreb.

**1.11. Optional / additional reading (at the time of proposing study programme)**

Briggs, J.C., 1974. Marine Zoogeography. McGraw-Hill Book Company, New York.

Požar-Domac, A. 1988. O biologiji mora. Hrvatsko ekološko društvo, Zagreb.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title   | Number of copies | Number of students |
|---|------------------|--------------------|
| Lalli, C.M. and T.R. Parsons, 1995. Biological Oceanography: An Introduction. Oxford, UK: Butterworth-Heinemann.                  | 0                | 1-5                |
| Pérès, J.M. & H. Gamulin-Brida, 1973. Biološka oceanografija. Bentos. Bentoska bionomija Jadranskog mora. Školska knjiga, Zagreb. | 0                | 1-5                |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

*Student's portfolio:* Continuous monitoring of student's activities during practical work and lectures, with information on the efficacy and accomplished progress.

*Questionnaire:* Introductory questionnaire on the course's expectations. Final anonymous questionnaire on the quality of the performed class.



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Marcelo Kovačić                             |         |
| <b>Course title</b>              | Ecology of freshwaters                      |         |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |         |
| <b>Course status</b>             | optional                                    |         |
| <b>Year</b>                      | 2.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 3       |
|                                  | <b>Number of hours (L+E+S)</b>              | 15+15+0 |

| 1. COURSE DESCRIPTION   |  |  |
|---|--|--|
| <b>1.1. Course objectives</b>   |  |  |
| The goal of the course is to introduce students to basics of ecology of freshwaters. Learned knowledge is necessary for understanding of subjects involved in work on freshwater ecosystems and in the protection of freshwater environment.  |  |  |
| <b>1.2. Course enrolment requirements</b>   |  |  |
| General Ecology   |  |  |
| <b>1.3. Expected course learning outcomes</b>   |  |  |
| After the passed exam the students will be qualified for:   |  |  |
| 1. understanding the problems of the freshwater ecosystems and managing the project tasks on description and estimation of conditions in the freshwater ecosystems.   |  |  |
| 2. understanding the problems and managing the project tasks on the environmental impacts and on the protection of the environment in the freshwaters.  |  |  |
| 3. understanding the problems and managing the project tasks on the nature protection in the freshwaters.   |  |  |
| <b>1.4. Course content</b>  |  |  |
| Chemical and physical proprieties of freshwater. Light and heating of water. Hydrological cycles, groundwater and wetlands. Flowing water. Lakes and reservoirs. Bacteria, fungi and plantes in freshwaters. Invertebrates and vertebrates in freshwaters. Biodiversity of freshwaters, invasive species, extinctions. Cycles of matter in freshwaters. Toxic chemicals and other pollutants in freshwaters. Unusal or exstreme freshwater habitats. Nutrients, trophic state and eutrophication. Food chains in freshwaters. Nonpredatory interactions of organisms in in freshwater communities. Fish ecology and fishery. Methods in ecological researches of freshwaters. Zonation of Croatian rivers and their biocenoses. |  |  |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratory work<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> consultations |
| <b>1.6. Comments</b>  |  |  |
| <b>1.7. Student's obligations</b>   |  |  |
| Course attendance, Activity/Participation, Practice, Written exam   |  |  |
| <b>1.8. Evaluation of student's work</b>  |  |  |



|                   |     |                           |  |               |     |                   |     |
|-------------------|-----|---------------------------|--|---------------|-----|-------------------|-----|
| Course attendance | 0.3 | Activity/Participation    |  | Seminar paper | 0.3 | Experimental work |     |
| Written exam      | 2.1 | Oral exam                 |  | Essay         |     | Research          |     |
| Project           |     | Sustained knowledge check |  | Report        |     | Practice          | 0.3 |
| Portfolio         |     |                           |  |               |     |                   |     |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Student's work will be assessed and evaluated during classes and on the final exam. Total number of points that could be collected during classes is 30 (evaluated activities are presented in the table). Total number of points on the final exam is 70.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Dodds, W.K. 2002. Freshwater Ecology. Academic Press, San Diego.

Kerovec, M. 1988. Ekologija kopnenih voda. Hrvatsko ekološko društvo, Zagreb.

**1.11. Optional / additional reading (at the time of proposing study programme)**

Wetzel, R.G. 2001. Limnology. Lake and River Ecosystems. Third Ed. Academic Press, San Diego.

Matonićkin I. i Z. Pavletić. 1972. Život naših rijeka. Školska knjiga, Zagreb.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>  | <i>Number of copies</i> | <i>Number of students</i> |
|---|-------------------------|---------------------------|
| Dodds, W.K. 2002. Freshwater Ecology. Academic Press, San Diego.              | 0                       | 1-5                       |
| Kerovec, M. 1988. Ekologija kopnenih voda. Hrvatsko ekološko društvo, Zagreb. | 0                       | 1-5                       |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

*Student's portfolio*: Continuous monitoring of student's activities during practical work and lectures, with information on the efficacy and accomplished progress.

*Questionnaire*: Introductory questionnaire on the course's expectations. Final anonymous questionnaire on the quality of the performed class.



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Ana Alebić-Juretić                          |         |
| <b>Course title</b>              | Ecotoxicology                               |         |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |         |
| <b>Course status</b>             | optional                                    |         |
| <b>Year</b>                      | 2.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6       |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+0+30 |

| 1. COURSE DESCRIPTION  |  |  |                                    |  |                                    |   |   |
|--|--|--|------------------------------------|--|------------------------------------|---|---|
| <b>1.1. Course objectives</b>  |  |  |                                    |  |                                    |   |   |
| Get knowledge on harmful effects of environmental pollutants on living organisms (atmosphere, hydrosphere, lithosphere).   |  |  |                                    |  |                                    |   |   |
| <b>1.2. Course enrolment requirements</b>  |  |  |                                    |  |                                    |   |   |
| Past attendance and exam of chemical courses   |  |  |                                    |  |                                    |   |   |
| <b>1.3. Expected course learning outcomes</b>  |  |  |                                    |  |                                    |   |   |
| Getting knowledge of harmful effects of environmental pollutants   |  |  |                                    |  |                                    |   |   |
| <b>1.4. Course content</b>   |  |  |                                    |  |                                    |   |   |
| Definition. Cycling of environmental pollutants. Bioaccumulation and biomonitoring. Lichens as bioindicators of air pollution. Biomonitoring of water and sea. Agrochemicals in the environment: nitric fertilizers, additives in .. reising. Persistant organic pollutants: chlorinated hydrocarbons (dioxines, polychlorirated byphenils, chlorinated pesticides) and polycyclci aromatic hydrocarbons. Toxic metals (mercury, lead, cadmium). Environmental pollution impact on human health. Basic toxicolog. Determination of harmful effects on human health. Epidemiological studies. |  |  |                                    |  |                                    |   |   |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment | <input type="checkbox"/> multimedia and network |
|  |  |  |                                    |  |                                    | <input type="checkbox"/> laboratory work                  | <input checked="" type="checkbox"/> mentorship  |
|  |  |  |                                    |  |                                    | <input type="checkbox"/> consultations                    |   |
| <b>1.6. Comments</b>   |  |  |                                    |  |                                    |   |   |
| <b>1.7. Student's obligations</b>  |  |  |                                    |  |                                    |   |   |
| Attending lecturs and seminars   |  |  |                                    |  |                                    |   |   |
| <b>1.8. Evaluation of student's work</b>   |  |  |                                    |  |                                    |   |   |
| Course attendance  | 0,3  | Activity/Participation                                     | 0,3                                | Seminar paper                                    | 1,8                                | Experimental work   |   |
| Written exam   | 1,8  | Oral exam  |                                    | Essay  |                                    | Research  |   |
| Project  |  | Sustained knowledge check                                  | 1,8                                | Report   |                                    | Practice  |   |
| Portfolio  |  |  |                                    |  |                                    |   |   |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |  |                                    |  |                                    |   |   |
| Students' work will be evaluated through test and seminar paper during the course and written final exam.  |  |  |                                    |  |                                    |   |   |



**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. C. Baird: Environmental Chemistry, 2nd Ed, W.H. Freeman and Co, New York, 2003
2. R.E.Hester & R.M. Harrison (Eds): Agricultural Chemicals and the Environment, The Royal Society of Chemistry, Cambridge, 1996
3. R.E.Hester & R.M. Harrison (Eds): Chlorinated Organic Micropollutants, The Royal Society of Chemistry, Cambridge, 1996

**1.11. Optional / additional reading (at the time of proposing study programme)**

Original scientific and professional papers on recommendation

Notes from the lectures

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>   | <i>Number of copies</i> | <i>Number of students</i> |
|--|-------------------------|---------------------------|
| 1. C. Baird: Environmental Chemistry, 2nd Ed, W.H. Freeman and Co, New York, 2003  | 1                       | 10                        |
| 2. R.E.Hester & R.M. Harrison (Eds): Agricultural Chemicals and the Environment, The Royal Society of Chemistry, Cambridge, 1996 | 1                       | 10                        |
| 3. R.E.Hester & R.M. Harrison (Eds): Chlorinated Organic Micropollutants, The Royal Society of Chemistry, Cambridge, 1996        | 1                       | 10                        |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Anonymus students' poll and their grades at final exam will prove the acquired skills.



| Basic description                |   |             |
|----------------------------------|---|-------------|
| <b>Course coordinator</b>        | Predrag Dominis Prester                     |             |
| <b>Course title</b>              | Electrodynamics                             |             |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |             |
| <b>Course status</b>             | compulsory                                  |             |
| <b>Year</b>                      | 1.  |             |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 7           |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 45 + 0 |

| 1. COURSE DESCRIPTION  |  |  |
|--|--|--|
| <b>1.1. Course objectives</b>  |  |  |
| <ul style="list-style-type: none"> <li>- Giving the basic knowledge of classical electrodynamics and special theory of relativity</li> <li>- Connecting the exact theoretical results with the relevant objects from electricity and magnetism that students have learned in earlier courses (Physics I-III)</li> </ul>  |  |  |
| <b>1.2. Course enrolment requirements</b>  |  |  |
| None.  |  |  |
| <b>1.3. Expected course learning outcomes</b>  |  |  |
| <ul style="list-style-type: none"> <li>- Understanding the idea how simple and basic equations for the electromagnetic field, with the help of mathematical methods, can explain complex physical phenomena.</li> <li>- Understanding the significance of the exact definition of physical quantities for their correct interpretation.</li> </ul>   |  |  |
| <b>1.4. Course content</b>   |  |  |
| <p>1. Electrostatics<br/>Coulomb law. Electric field. Scalar potential. Equations of electrostatics. Energy. Multipole expansion. Electrostatics in media. Dielectrics. Boundary conditions.</p> <p>2. Magnetostatics<br/>Electric current. Continuity equation. Magnetic field and force. Vector potential. Equations of magnetostatics. Magnetostatics in media. Diamagnetism. Paramagnetism. Ferromagnetism.</p> <p>3. Maxwell equations<br/>Faraday law of induction. Energy of magnetic field. Maxwell equations. 4-potential. Gauge transformations. Poynting theorem. Conservation laws. Electrodynamics in the media.</p> <p>4. Radiation<br/>Retarded and advanced potentials. Dipole approximation. Radiation reaction force.</p> <p>5. Special relativity<br/>Kinematics and dynamics. 4-vectors and tensors. Lorentz transformations of fields, charge density and currents. Covariant formulation of electrodynamics.</p> |  |  |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> Lectures<br><input type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   |  |  |



**1.7. Student's obligations**

Active participation, doing home assignments and tests, passing the final exam.

**1.8. Evaluation of student's work**

|                   |  |                           |     |               |  |                   |  |
|-------------------|--|---------------------------|-----|---------------|--|-------------------|--|
| Course attendance |  | Activity/Participation    | 0.5 | Seminar paper |  | Experimental work |  |
| Written exam      |  | Oral exam                 | 2.5 | Essay         |  | Research          |  |
| Project           |  | Sustained knowledge check | 4   | Report        |  | Practice          |  |
| Portfolio         |  |                           |     |               |  |                   |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Students will be evaluated and valued continuously during the course through home assignments and periodic tests. There will be a final exam. Activities during the course bring at least 70% of the total mark.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. Griffiths D. J., *Introduction to Electrodynamics*, 3. izdanje, Prentice-Hall, New Jersey, 1999.

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. Jackson J. D., *Classical Electrodynamics*, 3. izdanje, John Wiley, New York, 1999.
2. Nayfeh M. H., Brussel M. K., *Electricity and Magnetism*, John Wiley and Sons, 1985.
3. Wegner F., <http://www.tphys.uni-heidelberg.de/~wegner/e.dyn/>

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title   | Number of copies | Number of students |
|---|------------------|--------------------|
| Griffiths D. J., <i>Introduction to Electrodynamics</i> | 3                | 10                 |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Consultations, standard anonymous student questionnaires, discussions after the final exam.



| Basic description         |                                      |         |
|---------------------------|--------------------------------------|---------|
| Course coordinator        | Srećko Valić                         |         |
| Course title              | Electron Spin Resonance              |         |
| Study programme           | Graduate study programme PHYSICS     |         |
| Course status             | optional                             |         |
| Year                      | 2.                                   |         |
| ECTS credits and teaching | ECTS student 's workload coefficient | 6       |
|                           | Number of hours (L+E+S)              | 45+0+15 |

| 1. COURSE DESCRIPTION  |  |  |  |                                    |  |                                    |   |
|--|--|--|--|------------------------------------|--|------------------------------------|---|
| <b>1.1. Course objectives</b>  |  |  |  |                                    |  |                                    |   |
| The acquisition of basic knowledge in ESR spectroscopy. Introduction to modern techniques of ESR spectroscopy.   |  |  |  |                                    |  |                                    |   |
| <b>1.2. Course enrolment requirements</b>  |  |  |  |                                    |  |                                    |   |
| The knowledge of general and theoretical physics is assumed.   |  |  |  |                                    |  |                                    |   |
| <b>1.3. Expected course learning outcomes</b>  |  |  |  |                                    |  |                                    |   |
| Students after passing the exam will be able to: <ul style="list-style-type: none"> <li>• describe the fundamental meaning of ESR spectroscopy;</li> <li>• describe and analyze selected ESR spectra;</li> <li>• describe the theoretical basis of ESR spectroscopy;</li> <li>• describe and explain the application of ESR spectroscopy in studying inorganic and biological materials.</li> </ul>  |  |  |  |                                    |  |                                    |   |
| <b>1.4. Course content</b>   |  |  |  |                                    |  |                                    |   |
| Physical principles of electron spin resonance (ESR), selection rules, the appearance of ESR signal. The conventional ESR technique, double modulation (DMESR), pulsed techniques. The characteristics of certain ESR spectrometers. Monitoring molecular dynamics, fast and slow rotational motions. Application of ESR spectroscopy in the study of materials and biological systems. The use of stable nitroxide radicals. Zeeman interaction, hyperfine interaction. |  |  |  |                                    |  |                                    |   |
| <b>1.5. Teaching methods</b>   |  | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment |
|  |  |  |  |                                    |  |                                    | <input type="checkbox"/> multimedia and network           |
|  |  |  |  |                                    |  |                                    | <input type="checkbox"/> laboratories                     |
|  |  |  |  |                                    |  |                                    | <input type="checkbox"/> mentorship                       |
|  |  |  |  |                                    |  |                                    | <input type="checkbox"/> other                            |
| <b>1.6. Comments</b>   |  |  |  |                                    |  |                                    |   |
| <b>1.7. Student's obligations</b>  |  |  |  |                                    |  |                                    |   |
| Students must attend lectures and prepare the seminar in accordance with the rules of the study.   |  |  |  |                                    |  |                                    |   |
| <b>1.8. Evaluation of student's work</b>   |  |  |  |                                    |  |                                    |   |
| Course attendance  |  | Activity/Participation                       | 1  | Seminar paper                      | 2  | Experimental work                  |   |
| Written exam   |  | Oral exam                                    | 3  | Essay                              |  | Research                           |   |
| Project  |  | Sustained knowledge check                    |  | Report                             |  | Practice                           |   |
| Portfolio  |  |  |  |                                    |  |                                    |   |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |  |  |                                    |  |                                    |   |



Work on the student will be evaluated during the lectures and on the final exam. The total number of points (in percentage) that a student can achieve following the lectures is 50 %, while on the final oral exam can achieve 50 %. Detailed elaboration of ways of monitoring and evaluation of students' work will be given in the execution plan.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. C.P. Slichter, Principles of Magnetic resonance, Springer Series in Solid State Sciences, 3rd Enlarged and Updated Edition, Corrected 3rd Printing, Springer, 1996.
2. M. Drescher, G. Jeschke, EPR Spectroscopy: Application in Chemistry and Biology, Springer-Verlag, Berlin, 2012.

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. L.J. Berliner, Spin Labeling; Theory and Application, Academic Press, New York, 1976.
2. L.J. Berliner, J. Reuben, Biological Magnetic Resonance, Vol.6, Plenum Press, New York, 1984.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>  | <i>Number of copies</i> | <i>Number of students</i> |
|---|-------------------------|---------------------------|
| C.P. Slichter, Principles of Magnetic resonance, Springer Series in Solid State Sciences, 3rd Enlarged and Updated Edition, Corrected 3rd Printing, Springer, 1996. | 2                       |                           |
| M. Drescher, G. Jeschke, EPR Spectroscopy: Application in Chemistry and Biology, Springer-Verlag, Berlin, 2012.   | 2                       |                           |
|   |                         |                           |
|   |                         |                           |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Student's questionnaire.



| Basic description                |   |        |
|----------------------------------|---|--------|
| <b>Course coordinator</b>        | Dubravka Kotnik-Karuza                      |        |
| <b>Course title</b>              | Electronics laboratory                      |        |
| <b>Study programme</b>           | Graduate Study Programme Physics            |        |
| <b>Course status</b>             | optional                                    |        |
| <b>Year</b>                      | 2.  |        |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6      |
|                                  | <b>Number of hours (L+E+S)</b>              | 0+0+60 |

| 1. COURSE DESCRIPTION   |   |  |
|---|---|--|
| <b>1.1. Course objectives</b>   |   |  |
| To provide a better understanding of electronics, semiconductor and solid state physics. By use of experimental approach to consolidate basic knowledge of electronics and improve student's understanding of the structure and function of electronic elements, circuits and devices with special emphasis on their practical use and thus to train the students to build step-by-step the basic analog and digital electronic circuits and systems.   |   |  |
| <b>1.2. Course enrolment requirements</b>   |   |  |
| Students must have passed the exam in Electronics.  |   |  |
| <b>1.3. Expected course learning outcomes</b>   |   |  |
| By completing the practical laboratory exercises the students should achieve the following skills and knowledge:<br>- develop the ability to solve independently new problems based on previously adopted knowledge of electronics and semiconductor physics, and to connect theory with experiment, thus getting insight in the scientific methodology of natural science,<br>- develop specific skills in planning and carrying out experiment in order to solve specific physical problem,<br>- perform measurements of specific physical entities using appropriate measuring techniques and instruments in order to investigate the physical phenomena or/and hypothesis,<br>- gaining competence in statistical analysis, display and interpretation of experimental results,<br>- acquire practical knowledge in application of basic electronic elements, circuits, devices and systems.<br>- independently construct simpler electronic devices and circuits, such as transistor amplifier, operational amplifier in analog circuits, active filters, electronic oscillator, multivibrators, digital circuits. |   |  |
| <b>1.4. Course content</b>  |   |  |
| Students perform individually and independently the following laboratory exercises:<br>1. Characteristics of bipolar transistor<br>2. Low-signal transistor amplifier<br>3. Operational amplifier<br>4. Active electronic filters<br>5. Oscillator<br>6. Multivibrators (bistable, monostable, astable)<br>7. Digital circuits (OR, AND, NOT, NOR, NAND)  |   |  |
| <b>1.5. Teaching methods</b>  | <input type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> other |



|  |   |   |   |                         |   |                           |   |
|--|---|---|---|-------------------------|---|---------------------------|---|
| <b>1.6. Comments</b>   |   |   |   |                         |   |                           |   |
| <b>1.7. Student's obligations</b>  |   |   |   |                         |   |                           |   |
| Regular attendance and active participation in all laboratory exercises. Students should go through all experimental exercises one by one: by preparing the basic theory, carrying out the required observations and measurements, writing a report on measurements and discussion of results. Student should be prepared for each specific exercise, including knowledge of the needed theoretical background. Each of these steps is verified by the teacher, while the student's ability to successfully finish the laboratory exercise is verified orally before and during the exercise.  |   |   |   |                         |   |                           |   |
| <b>1.8. Evaluation of student's work</b>   |   |   |   |                         |   |                           |   |
| Course attendance  | 1 | Activity/Participation  |   | Seminar paper           |   | Experimental work         | 1 |
| Written exam   |   | Oral exam   |   | Essay                   |   | Research                  |   |
| Project  |   | Sustained knowledge check   | 2 | Report                  | 2 | Practice                  |   |
| Portfolio  |   |   |   |                         |   |                           |   |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |   |   |   |                         |   |                           |   |
| The students' work is being permanently followed by assessment of their written preparations and reports as well as by checking their knowledge colloquially during the laboratory exercises. The total number of credits a student can achieve during the course amounts to 100 points:<br>- sustained knowledge check required to successfully finish the laboratory exercise – 50 points,<br>- report on performed measurements, with their statistical analysis and interpretation – 50 points.<br>Before and during the laboratory exercises oral checkup will be carried out of the following: theoretical knowledge and student's ability to build the experiment, use of the measuring devices and methods, measurement procedure, statistical analysis and interpretation of the results. The statistical analysis of measurements, the display and physical interpretation of obtained results are assessed in written report on each of the laboratory exercises. |   |   |   |                         |   |                           |   |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |   |   |   |                         |   |                           |   |
| D.L. EGGLESTON: Basic electronics for scientists and engineers, Cambridge University Press, 2011<br>D. KOTNIK-KARUZA: Osnove elektronike s laboratorijskim vježbama, Filozofski fakultet u Rijeci, 2000<br>P. BILJANOVIĆ: Elektronički sklopovi, Školska knjiga, Zagreb, 2001<br>P. BILJANOVIĆ: Mikroelektronika (Integrirani elektronički sklopovi), Školska knjiga, Zagreb, 2001   |   |   |   |                         |   |                           |   |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |   |   |   |                         |   |                           |   |
| D.V. HALL: Digital circuits and systems, Mc Graw-Hill, 1989<br>D.L. SCHILLING, C. BELOVE: Electronic circuits, Mc Graw-Hill, 1989<br>K. SEGER: Semiconductor physics, Springer 1991<br>B. JUZBAŠIĆ: Elektronički elementi, Školska knjiga, Zagreb, 1980  |   |   |   |                         |   |                           |   |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |   |   |   |                         |   |                           |   |
|  |   | <i>Title</i>  |   | <i>Number of copies</i> |   | <i>Number of students</i> |   |
|  |   | D.L. EGGLESTON: Basic electronics for scientists and engineers, Cambridge University Press, 2011    |   | 4                       |   | 10                        |   |
|  |   | D. KOTNIK-KARUZA: Osnove elektronike s laboratorijskim vježbama, Filozofski fakultet u Rijeci, 2000 |   | 10                      |   | 10                        |   |
|  |   | P. BILJANOVIĆ: Elektronički sklopovi, Školska knjiga, Zagreb, 2001                                  |   | 4                       |   | 10                        |   |
|  |   | P. BILJANOVIĆ: Mikroelektronika (Integrirani elektronički sklopovi), Školska knjiga, Zagreb, 2001   |   | 4                       |   | 10                        |   |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |   |   |   |                         |   |                           |   |
| Permanent monitoring of students' laboratory work is carried out in continuous interaction with the teacher, thus developing their creativity through active learning, as well as their experimental skills. Their work and progress is being permanently followed by assessment of their written preparations and reports on results and their interpretation, and by colloquial checkup of their knowledge during the laboratory exercises. Student's final achievement in the above process can be used as a measure of success of the course. Additional feedback on quality and efficiency of the course is gained by implementation of students' questionnaire at the end of the course.   |   |   |   |                         |   |                           |   |



| Basic description                |   |          |
|----------------------------------|---|----------|
| <b>Course coordinator</b>        | Dubravka Kotnik-Karuza                      |          |
| <b>Course title</b>              | Electronics                                 |          |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |          |
| <b>Course status</b>             | optional                                    |          |
| <b>Year</b>                      | 1.  |          |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6        |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+15+15 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

Starting from the basic knowledge of semiconductor physics, the aim is to provide the necessary theoretical knowledge and to acquaint the students with electronic devices, circuits and systems through a step-by-step approach in order to prepare them to apply this knowledge in practical use.

### 1.2. Course enrolment requirements

Foreknowledge in general physics – electromagnetism, structure of matter and statistical physics

### 1.3. Expected course learning outcomes

The student is expected to understand the structure and function of electronic elements, devices and circuits based on physical characteristics of the material they are built from. Further, the student should understand the function of the basic electronic circuits as well as to be able to design more complex electronic circuits, devices and systems.

In particular, the student should be able to:

1. describe and analyze the open-circuited, forward and reverse biased *pn* junction,
2. describe the Zener diode as a voltage stabilizer, tunnel diode and Schottky diode as a HF rectifier, and their use in most common circuits,
3. explain the basic elements, function and application of rectifiers (half-wave, full-wave, Graetz bridge circuit, voltage multiplier)
4. understand the structure, function and application of bipolar and unipolar transistors,
5. describe, analyze the working principles, compare the structure and function of transistors in common-emitter, common-base and common-collector configuration and their practical applications, with special emphasize on energy diagrams,
6. make distinction between different types of transistors and describe in details transistor in common-emitter configuration,
7. describe the emitter follower (voltage follower) as a transistor in common-collector configuration and its application,
8. understand the structure, application and function of a DC power supply (rectifier),
9. understand the principles, structure and function of a low-signal transistor amplifier and discuss the conditions of linearity,
10. explain the transistor feedback amplifying circuits, focusing on the current amplifier and amplifier stabilization,
11. describe the cascade amplifiers,
12. analyze and understand the structure and working principles of the differential DC amplifier and its application,
13. analyze the structure, function and application of operational amplifier and describe the inverting and non-inverting circuit with operational amplifier,
14. distinguish between passive and active low-frequency and high-frequency filters and explain their function, structure and application in electronic circuits,



15. explain application and use of operational amplifiers in analog electronic circuits, especially as voltage follower, phase inverter and voltage multiplier,  
 16. explain the basic operational amplifier operations (analog inverter, scale changer, adder, DC voltage follower),  
 17. analyze the analog computational circuits performing differentiation, integration, exponentiation, finding logarithms,  
 18. explain and describe the structure and function of basic digital circuits (OR, AND, NOT, NOR, NAND) and their application in modern computers.

#### 1.4. Course content

Semiconductor (*pn*) diode. Special diodes (Zener, tunnel, Schottky). Rectifiers (half-wave, full-wave, Graetz, voltage multipliers). Bipolar and unipolar transistor. Bipolar transistor in different configurations. Transistor amplifiers, emitter (voltage) follower, feedback amplifiers, differential amplifier, cascade amplifiers. Operational amplifier. Electronic filters – passive and active. Multivibrators. Digital circuits.

#### 1.5. Teaching methods

- |  |   |
|--|---|
| <input checked="" type="checkbox"/> lectures               | <input checked="" type="checkbox"/> individual assignment |
| <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> multimedia and network           |
| <input checked="" type="checkbox"/> exercises              | <input checked="" type="checkbox"/> laboratories          |
| <input type="checkbox"/> long distance education           | <input type="checkbox"/> mentorship                       |
| <input type="checkbox"/> fieldwork                         | <input type="checkbox"/> other                            |

#### 1.6. Comments

#### 1.7. Student's obligations

Course (lectures and exercises) attendance, passing the written mid-term and full-term exams, passing the final oral course exam. Each student should prepare and orally present one seminar of selected topic in electronics.

#### 1.8. Evaluation of student's work

|                   |     |                           |     |               |   |                   |  |
|-------------------|-----|---------------------------|-----|---------------|---|-------------------|--|
| Course attendance | 1   | Activity/Participation    | 0.5 | Seminar paper | 1 | Experimental work |  |
| Written exam      | 1.5 | Oral exam                 | 1.5 | Essay         |   | Research          |  |
| Project           |     | Sustained knowledge check | 0.5 | Report        |   | Practice          |  |
| Portfolio         |     |                           |     |               |   |                   |  |

#### 1.9. Assessment and evaluation of student's work during classes and on final exam

The students' work is being permanently assessed and evaluated during the course and at the final exam. During the course (reviewed activities specified in the table) the student can achieve a total number of 70 credits:

1. Activity and participation – 5
2. Seminar (oral presentation) – 25
3. Mid-term and full-term written exams – 40

Student can earn additional 30 points at the final oral exam based on three tasks he/she is assigned (each has a value of 10 points).

#### 1.10. Assigned reading (at the time of the submission of study programme proposal)

D.L. EGGLESTON: Basic electronics for scientists and engineers, Cambridge University Press, 2011  
 N.W. ASCHROFT, N.D. MERMIN: Solid state physics, Saunders College Publishing, Harcourt Brace College Publishers, 1996  
 D. KOTNIK-KARUZA: Osnove elektronike s laboratorijskim vježbama, Filozofski fakultet u Rijeci, 2000  
 P. BILJANOVIĆ: Elektronički sklopovi, Školska knjiga, Zagreb, 2001  
 P. BILJANOVIĆ: Mikroelektronika (Integrirani elektronički sklopovi), Školska knjiga, Zagreb, 2001  
 P. BILJANOVIĆ, I. ZULIM: Elektronički sklopovi (zbirka zadataka), Školska knjiga, Zagreb, 1994  
 DeMASSA, THOMAS A.: Digital Integrated Circuits, New York, John Wiley & Sons, 1996

#### 1.11. Optional / additional reading (at the time of proposing study programme)

D.V. HALL: Digital circuits and systems, Mc Graw-Hill, 1989  
 MILLMAN-HALKIAS: Integrated electronics, Analog and digital circuits and systems, Mc Graw-Hill Kogakusha, 1972  
 D.L. SCHILLING, C. BELOVE: Electronic circuits, Mc Graw-Hill, 1989  
 K. SEGER: Semiconductor physics, Springer 1991  
<http://wnt.cc.utexas.edu/~wlh/index.cfm>



<http://vipser.hep.princeton.edu/~mcdonald/examples/>

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>  | <i>Number of copies</i> | <i>Number of students</i> |
|---|-------------------------|---------------------------|
| D.L. Eggleston: Basic electronics for scientists and engineers, Cambridge University Press, 2011                    | 4                       | 10                        |
| N.W.Aschroft, N.D.Mermin: Solid state physics, Saunders College Publishing, Harcourt Brace College Publishers, 1996 | 2                       | 10                        |
| D. Kotnik-Karuza: Osnove elektronike s laboratorijskim vježbama, Filozofski fakultet u Rijeci, 2000                 | 10                      | 10                        |
| P. Biljanović: Elektronički sklopovi, Školska knjiga, Zagreb, 2001  | 4                       | 10                        |
| P. Biljanović: Mikroelektronika (Integrirani elektronički sklopovi), Šk. knjiga, Zagreb, 2001                       | 4                       | 10                        |
| P. Biljanović, I. Zulim: Elektronički sklopovi (zbirka zadataka), Šk. knjiga, Zagreb, 1994                          | 4                       | 10                        |
| DeMassa, Thomas A.: Digital Integrated Circuits, New York, John Wiley & Sons, 1996                                  | 1                       | 10                        |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

The quality of the course will be permanently verified by the student's progress which is assessed through exams and other achievement records (solving problems during the course exercises and written tests, preparation and presentation of a seminar on a chosen topic in electronics). Basic knowledge of semiconductor electronics, elements and circuits is assessed in the course exams (written and oral). Additional feedback on quality and efficiency of the course is gained by implementation of a students' questionnaire at the end of the course.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Predrag Dominis Prester                     |              |
| <b>Course title</b>              | Elementary Particle Physics 1               |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | optional                                    |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 8            |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 30 + 15 |

| 1. COURSE DESCRIPTION  |   |   |
|--|---|---|
| <b>1.1. Course objectives</b>  |   |   |
| A unified view of our current understanding of fundamental forces in nature. Introduction to main ideas and theoretical frameworks used in our description of elementary particles and interactions. A description and applications of the Standard model of elementary particle physics. During work on seminars students will make contact with current scientific literature, scientific approaches and research methods.   |   |   |
| <b>1.2. Course enrolment requirements</b>  |   |   |
| None.  |   |   |
| <b>1.3. Expected course learning outcomes</b>  |   |   |
| General understanding of connection between phenomena in the Nature and the underlying fundamental forces and elementary particles, and mathematical formalism used in this description. Knowledge of basic facts about microscopic world. Ability to understand and solve elementary problems in the framework of the Standard Model of elementary particle physics, with a special emphasis on processes of scattering and decay calculated in the tree-level approximation in the realm of Quantum Electrodynamics.   |   |   |
| <b>1.4. Course content</b>   |   |   |
| <ol style="list-style-type: none"> <li>"Fundamental" forces – ranges (scales) and strength, coupling constants</li> <li>Quantum field theories – particles as excitations of fields, importance of symmetries, antiparticles</li> <li>Particle processes – decays, scattering, cross sections, bound states, Feynman diagrams</li> <li>Quantum electrodynamics – gauge invariance, Compton scattering, positronium</li> <li>Strong force – quark model, confinement, basics of Quantum Chromodynamics</li> <li>Weak force – beta-decay, basics of electroweak unification (spontaneous symmetry breaking, Higgs bosons)</li> <li>Brief introduction to the Standard model of elementary particle physics</li> <li>Experiments and connections with astrophysics and cosmology</li> </ol> |   |   |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   |   |   |
| <b>1.7. Student's obligations</b>  |   |   |
| Active participation, home and class assignments and tests, preparing one seminar with presentation, passing final exam.   |   |   |



**1.8. Evaluation of student's work**

|                   |  |                           |     |               |   |                   |  |
|-------------------|--|---------------------------|-----|---------------|---|-------------------|--|
| Course attendance |  | Activity/Participation    | 0.5 | Seminar paper | 1 | Experimental work |  |
| Written exam      |  | Oral exam                 | 2   | Essay         |   | Research          |  |
| Project           |  | Sustained knowledge check | 4.5 | Report        |   | Practice          |  |
| Portfolio         |  |                           |     |               |   |                   |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Students will be evaluated and valued continuously during the course through home assignments and periodic tests. They have to write one seminar, which should be publicly presented. The course finishes with a final exam. Activities during the course bring at least 70% of the total mark.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Griffiths D., *Introduction to elementary particles*, 2. izdanje, Wiley–VHC, 2008.

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. Cottingham W. N., Greenwood D. A., *An Introduction to The Standard Model of Particle Physics*, 2. izdanje, Cambridge University Press, 2007.
2. I. Picek, *Elementary Particle Physics* (Hinuz, Zagreb, 1997.)

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title  | Number of copies | Number of students |
|--|------------------|--------------------|
| I. Picek, <i>Fizika elementarnih čestica</i> | 3                |                    |
|  |                  |                    |
|  |                  |                    |
|  |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Consultations, standard anonymous student questionnaires, discussions after the final exam.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Blaženka Melić                              |              |
| <b>Course title</b>              | Elementary Particle Physics 2               |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | optional                                    |              |
| <b>Year</b>                      | 2. year                                     |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION   |   |   |
|---|---|---|
| <b>1.1. Course objectives</b>   |   |   |
| This course builds on the course <i>Elementary Particle Physics 1</i> by taking a more advanced level. Advanced methods of QFT are developed and used to describe theory and phenomenology of strong and electroweak interactions. A goal is to achieve advanced and thorough understanding of the Standard Model of elementary particle physics through a direct contact with research work.   |   |   |
| <b>1.2. Course enrolment requirements</b>   |   |   |
| Completed courses: <i>Advanced Electrodynamics, Advanced Quantum Mechanics, Elementary Particle Physics 1, Quantum Field Theory</i>   |   |   |
| <b>1.3. Expected course learning outcomes</b>   |   |   |
| Achieving high level of understanding of methods, techniques and mathematical formalism of the Standard Model of elementary particles, which allows student to actively participate in scientific research immediately after finishing the course.  |   |   |
| <b>1.4. Course content</b>  |   |   |
| <p><b>Quantization of nonabelian gauge field theories</b> – unitary gauges, nonunitary gauges and Faddeev-Popov method, ghosts.</p> <p><b>Quark interactions and Quantum Chromodynamics</b> – partons, running coupling constant, asymptotic freedom, parton distribution functions.</p> <p><b>Higher-order processes</b> – elementary one-loop calculations.</p> <p><b>Effective theories</b> – pions as Goldstone bosons, effective theories and renormalisation, Fermi theory.</p> <p><b>Weak interactions</b> – generalisation of the Fermi theory, heavy bosons, GIM mechanism, CP violation in neutral meson systems.</p> <p><b>Standard Model</b> – Glashow-Weinberg-Salam theory.</p> <p><b>Anomalies</b> – chiral anomaly, global and local anomalies.</p> <p><b>Beyond Standard Model physics</b> – why SM is not satisfactory theory, behaviour of amplitudes on high energies, Higgs boson physics, violation of the lepton and baryon number, neutrino masses, CP violations, axions, unification of forces.</p> |   |   |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>  |   |   |
| <b>1.7. Student's obligations</b>   |   |   |



Active participation, home and class assignments and tests, preparing one seminar with presentation, passing final exam.

**1.8. Evaluation of student's work**

|                   |  |                           |     |               |   |                   |  |
|-------------------|--|---------------------------|-----|---------------|---|-------------------|--|
| Course attendance |  | Activity/Participation    | 0.5 | Seminar paper | 1 | Experimental work |  |
| Written exam      |  | Oral exam                 | 1.5 | Essay         |   | Research          |  |
| Project           |  | Sustained knowledge check | 3   | Report        |   | Practice          |  |
| Portfolio         |  |                           |     |               |   |                   |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Students will be evaluated and valued continuously during the course through home assignments and periodic tests. They have to write one seminar, which should be publicly presented. The course finishes with a final exam. Activities during the course bring at least 70% of the total mark.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory* (Westview Press; 1995)
2. A. Seiden: *Particle Physics, A Comprehensive Introduction* (Addison-Wesley; 2004)

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. F. Halzen, A. D. Martin: *Quarks and Leptons* (Wiley; 1984)
2. S. Weinberg: *The Quantum Theory of Fields 1 and 2* (Cambridge University Press; 2005)

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Consultations, standard anonymous student questionnaires, discussions after the final exam.



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Tarzan Legović                              |         |
| <b>Course title</b>              | Environmental impact assessment             |         |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |         |
| <b>Course status</b>             | optional                                    |         |
| <b>Year</b>                      | 1.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6       |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+30+0 |

| 1. COURSE DESCRIPTION   |     |   |     |               |   |                   |  |
|---|-----|---|-----|---------------|---|-------------------|--|
| <b>1.1. Course objectives</b>   |     |   |     |               |   |                   |  |
| Gaining competence in working on environmental impact assessment studies  |     |   |     |               |   |                   |  |
| <b>1.2. Course enrolment requirements</b>   |     |   |     |               |   |                   |  |
| One course in ecology or environmental protection.  |     |   |     |               |   |                   |  |
| <b>1.3. Expected course learning outcomes</b>   |     |   |     |               |   |                   |  |
| Students will be able to work productively on environmental impact assessment studies..   |     |   |     |               |   |                   |  |
| <b>1.4. Course content</b>  |     |   |     |               |   |                   |  |
| History of environmental impact assessment process (EIS) as a legal tool with a view into the future. Steps and rules during EIS process. Legal framework. EIS study. Strategic EIS study. Legal binding of the body performin EIS study. The role of committee member evaluating EIS study. Methods of defence. Examples of current practice. Expected changes in EIS study methods. Seminar on EIS. |     |   |     |               |   |                   |  |
| <b>1.5. Teaching methods</b>  |     | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |     |               | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratory work<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> consultations |                   |  |
| <b>1.6. Comments</b>  |     |   |     |               |   |                   |  |
| <b>1.7. Student's obligations</b>   |     |   |     |               |   |                   |  |
| Attendance to lectures and participation in a seminar with a project. Independent problem solving.  |     |   |     |               |   |                   |  |
| <b>1.8. Evaluation of student's work</b>  |     |   |     |               |   |                   |  |
| Course attendance   | 0.5 | Activity/Participation  | 0.5 | Seminar paper | 1   | Experimental work |  |
| Written exam  | 2   | Oral exam   | 1.5 | Essay         |   | Research          |  |
| Project   |     | Sustained knowledge check   | 0.5 | Report        |   | Practice          |  |
| Portfolio   |     |   |     |               |   |                   |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |     |   |     |               |   |                   |  |



Control of progress in learning. Exam: written (50%) and oral (50 %)

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Zakon o zaštiti okoliša, NN, 128(1999). Pravilnik o procjeni utjecaja na okoliš, NN, 59 (2000). Državni plan za zaštitu voda, NN, 8 (1999).

Legović, T., van der Well K., van Breusegem W. And Barić A. Guidelines for strategic environmental impact assessment. Ministry for environmental protection physical planning and construction. Zagreb, 2007. 88 pp.

Environmental Impact Assessment Tools, <http://www.uneptie.org/pc/pc/tools/eia.htm>

**1.11. Optional / additional reading (at the time of proposing study programme)**

Canter, L.W.: Environmental Impact assessment of Development Projects, A Handbook for practitioners, Elsevier, London, 1992

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>  | <i>Number of copies</i> | <i>Number of students</i> |
|---|-------------------------|---------------------------|
| Laws and bylaws on environment                            | Not limited             |                           |
| Guidelines for strategic environmental impact assessment. | Not limited             |                           |
| Environmental Impact Assessment Tools                     | Not limited             |                           |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Monitoring of acquired knowledge is performed after each lecture and prior to the next lecture.

Anonymous questionnaire at the end of the course. Results are analyzed and improvements are implemented.



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Tomislav Rukavina                           |         |
| <b>Course title</b>              | Environmental Microbiology                  |         |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |         |
| <b>Course status</b>             | optional                                    |         |
| <b>Year</b>                      | 2.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6       |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+30+0 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

Introducing students with microorganisms and their significance in natural environments, with special emphasis on the role of microorganisms in the cycling of matter in nature and their public health significance; Introduction to the positive effects of microorganisms on the environment; Introduction to the basic techniques of work in the microbiological laboratory; Introduction to microbiological environmental monitoring, Introduction to modern molecular methods for the detection of microorganisms; Introduction to microbiological standards in the current legislation of the Republic of Croatia; Introduce students to relevant scientific and professional literature on environmental microbiology

### 1.2. Course enrolment requirements

Attended classes and passed exams in following subjects: Biology, General Chemistry and General Ecology

### 1.3. Expected course learning outcomes

Acquiring basic knowledge about the historical development of microbiology; Acquiring knowledge regarding the basic structure and physiology of microorganisms and their role in the environment; Acquiring basic skills to work in a microbiological laboratory; Adoption of the basic techniques for sampling, transport, processing and microbiological analysis of environmental samples; Acquiring basic knowledge about biological associations; Acquiring the basis of modern molecular methods for the detection of microorganisms in environmental samples; Adoption of knowledge about the microbiological standards in the current legislation of the Republic of Croatia; Enable students to track scientific and professional literature in the field of environmental microbiology

### 1.4. Course content

Overview of the historical development of microbiology as a science; Importance of microorganisms in nature; Public health significance of microorganisms in the environment; Anatomy and physiology of microorganisms, Microbial growth conditions in laboratory; Biochemism and identification of microorganisms, Microbial genetics, Microbial associations with other organisms, Microbiology of the most important segments of the environment; Indicator organisms and their importance in the microbiological monitoring of the environment; Molecular laboratory methods in environmental microbiology; Evaluation of the results of microbiological analyses of environmental samples, Applied Microbiology, Sampling, transport and processing of environmental microbiological samples: microscopy, cultivation, identification and quantitative determination of microorganisms

### 1.5. Teaching methods

- |  |  |
|--|--|
| <input checked="" type="checkbox"/> lectures     | <input type="checkbox"/> individual assignment   |
| <input type="checkbox"/> seminars and workshops  | <input type="checkbox"/> multimedia and network  |
| <input checked="" type="checkbox"/> exercises    | <input checked="" type="checkbox"/> laboratories |
| <input type="checkbox"/> long distance education | <input type="checkbox"/> mentorship              |
| <input checked="" type="checkbox"/> fieldwork    | <input type="checkbox"/> other                   |

### 1.6. Comments

The course is organized in the form of lectures and practical laboratory exercises and field sampling of various environmental samples. Students will be given lectures on the theoretical basis which will be supplemented by practical work in the field and in the



|   |     |  |     |                         |  |                           |  |
|---|-----|--|-----|-------------------------|--|---------------------------|--|
| laboratory. Through the processing of real specimens, students will be familiarized with the methodology of work in the microbiological laboratory, the current legislation and recent scientific and professional literature.                                    |     |  |     |                         |  |                           |  |
| <b>1.7. Student's obligations</b>   |     |  |     |                         |  |                           |  |
| Attendance on lectures and exercises and passing the exam.  |     |  |     |                         |  |                           |  |
| <b>1.8. Evaluation of student's work</b>  |     |  |     |                         |  |                           |  |
| Course attendance   | 0,6 | Activity/Participation   | 1,2 | Seminar paper           |  | Experimental work         |  |
| Written exam  | 1,8 | Oral exam  |     | Essay                   |  | Research                  |  |
| Project   |     | Sustained knowledge check  | 2,4 | Report                  |  | Practice                  |  |
| Portfolio   |     |  |     |                         |  |                           |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |     |  |     |                         |  |                           |  |
| In accordance with the Regulations on the Assessment of the University of Rijeka.   |     |  |     |                         |  |                           |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>   |     |  |     |                         |  |                           |  |
| Duraković S, Redžepović S. Uvod u opću mikrobiologiju – knjiga prva. Kugler, Zagreb, 2002.  |     |  |     |                         |  |                           |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>   |     |  |     |                         |  |                           |  |
| Hurst CJ, Crawford RL, Garland JL, Lipson DA, Mills AL, Stetzenbach LD. Manual of Environmental Microbiology – Third edition. ASM Press, Washington D.C., 2007.   |     |  |     |                         |  |                           |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>   |     |  |     |                         |  |                           |  |
|   |     | <i>Title</i>   |     | <i>Number of copies</i> |  | <i>Number of students</i> |  |
|   |     | Duraković S, Redžepović S. Uvod u opću mikrobiologiju – knjiga prva. Kugler, Zagreb, 2002. |     | ?                       |  | ?                         |  |
|   |     |  |     |                         |  |                           |  |
|   |     |  |     |                         |  |                           |  |
|   |     |  |     |                         |  |                           |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>  |     |  |     |                         |  |                           |  |
| Upon completion of the course, students will fulfil the survey that is identical for the entire University, and based on students' evaluation, analyses of the performance and workload ECTS and quality of teaching process during the course will be valorised. |     |  |     |                         |  |                           |  |



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Ana Alebić Juretić                          |         |
| <b>Course title</b>              | Environmental pollution                     |         |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |         |
| <b>Course status</b>             | optional                                    |         |
| <b>Year</b>                      | 1.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6       |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+0+30 |

| 1. COURSE DESCRIPTION   |  |  |                                    |  |                                    |   |   |
|---|--|--|------------------------------------|--|------------------------------------|---|---|
| <b>1.1. Course objectives</b>   |  |  |                                    |  |                                    |   |   |
| Getting knowledge of environmental pollution.   |  |  |                                    |  |                                    |   |   |
| <b>1.2. Course enrolment requirements</b>   |  |  |                                    |  |                                    |   |   |
| Past attendance and exam of chemical courses.   |  |  |                                    |  |                                    |   |   |
| <b>1.3. Expected course learning outcomes</b>   |  |  |                                    |  |                                    |   |   |
| Getting insight into principal environmental pollutants and problems with the possible solutions. Gaining knowledge on analyses of environmental samples  |  |  |                                    |  |                                    |   |   |
| <b>1.4. Course content</b>  |  |  |                                    |  |                                    |   |   |
| Air pollution: sources, physical and chemical properties of common pollutants. Meteorological and other conditions affecting air pollution. Harmful effects of air pollution on environment and human health. Prevention of air pollution: technologies and strategies.<br>Water pollution: definition and principal parameters of pollution. Sources of water pollution. Waste water treatment and control. Purification of potable water. Legislativa protection of waters.<br>Soil pollution: chemical and physical properties of soil. Ecological importance of soil and agricultural soil. Sediments.<br>Waste and harmful materials in the ecosphere: pesticides, carcinogenic compounds, toxic metals. Waste management. |  |  |                                    |  |                                    |   |   |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment | <input type="checkbox"/> multimedia and network |
|   |  |  |                                    |  |                                    | <input type="checkbox"/> laboratory work                  | <input checked="" type="checkbox"/> mentorship  |
|   |  |  |                                    |  |                                    | <input type="checkbox"/> consultations                    |   |
| <b>1.6. Comments</b>  |  |  |                                    |  |                                    |   |   |
| <b>1.7. Student's obligations</b>   |  |  |                                    |  |                                    |   |   |
| Attending lecturs and seminars  |  |  |                                    |  |                                    |   |   |
| <b>1.8. Evaluation of student's work</b>  |  |  |                                    |  |                                    |   |   |
| Course attendance   | 0,3  | Activity/Participation                                     | 0,3                                | Seminar paper                                    | 1,8                                | Experimental work   |   |
| Written exam  | 1,8  | Oral exam  |                                    | Essay  |                                    | Research  |   |
| Project   |  | Sustained knowledge check                                  | 1,8                                | Report   |                                    | Practice  |   |



|  |  |  |   |  |                         |  |                           |
|--|--|--|---|--|-------------------------|--|---------------------------|
| Portfolio  |  |  |   |  |                         |  |                           |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |  |   |  |                         |  |                           |
| Students' work will be evaluated through test and seminar paper during the course and written final exam.  |  |  |   |  |                         |  |                           |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |  |  |   |  |                         |  |                           |
| 1. C. Baird: Environmental Chemistry, 2nd Ed, W.H. Freeman and Co, New York, 2003<br>2. V. Glavač: Uvod u globalnu ekologiju, Državna uprava za zaštitu prirode i okoliša i Hrvatske šume, Zagreb, 1999<br>3. B. Penzar i sur.: Meteorologija za korisnike, Školska knjiga i Hrvatsko meteorološko društvo, 1996.<br>4. S. Tedeschi: Zaštita voda, Sveučilište u Zagrebu i Hrvatsko društvo građevinskih inženjera, 1997 |  |  |   |  |                         |  |                           |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |  |  |   |  |                         |  |                           |
| 1. C.E. Kupchella & M.C.Hyland: Environmental Sciences, 2nd Ed, Allyn and Bacon, Boston-London-Sydney-Toronto, 1986<br>Original scientific and professional papers by teacher's suggestion<br>Notes from lectures  |  |  |   |  |                         |  |                           |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |  |  |   |  |                         |  |                           |
|  |  |  | <i>Title</i>  |  | <i>Number of copies</i> |  | <i>Number of students</i> |
|  |  |  | 1. C. Baird: Environmental Chemistry, 2nd Ed, W.H. Freeman and Co, New York, 2003                                 |  | 1                       |  | 10                        |
|  |  |  | 2.V. Glavač: Uvod u globalnu ekologiju, Državna uprava za zaštitu prirode i okoliša i Hrvatske šume, Zagreb, 1999 |  | 1                       |  | 10                        |
|  |  |  | 3.B. Penzar i sur.: Meteorologija za korisnike, Školska knjiga i Hrvatsko meteorološko društvo, 1996              |  | 1                       |  | 10                        |
|  |  |  | 5.S. Tedeschi: Zaštita voda, Sveučilište u Zagrebu i Hrvatsko društvo građevinskih inženjera, 1997.               |  | 1                       |  | 10                        |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |  |  |   |  |                         |  |                           |
| Anonymus students' poll and their grades at final exam will prove the acquired skills.   |  |  |   |  |                         |  |                           |



| Basic description                |   |             |
|----------------------------------|---|-------------|
| <b>Course coordinator</b>        | Marin Karuza                                |             |
| <b>Course title</b>              | Experimental methods in Physics I           |             |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |             |
| <b>Course status</b>             | Compulsory                                  |             |
| <b>Year</b>                      | 1.  |             |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6           |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 +15 |

| 1. COURSE DESCRIPTION  |     |  |     |               |  |                   |     |
|--|-----|--|-----|---------------|--|-------------------|-----|
| <b>1.1. Course objectives</b>  |     |  |     |               |  |                   |     |
| Teach the students about basic optical methods and devices used in moder day experiments.  |     |  |     |               |  |                   |     |
| <b>1.2. Course enrolment requirements</b>  |     |  |     |               |  |                   |     |
| none   |     |  |     |               |  |                   |     |
| <b>1.3. Expected course learning outcomes</b>  |     |  |     |               |  |                   |     |
| The student should be capable of autonomously performing experiments and solving problems. Understanding of experiments is expected,   |     |  |     |               |  |                   |     |
| <b>1.4. Course content</b>   |     |  |     |               |  |                   |     |
| 1. Light source – LASER<br>2. Optics (basics of Geometrical Optics, Gaussian beam propagation, notions of Fourier optics)<br>3. Wave nature of light – interference<br>4. Interferometers – Optical, Atom<br>5. Resonators – Fabry – Perot resonator<br>6. Particle nature of light – photoelectric effect<br>7. Detectors, PD, SiPM, APD, PMT, SQUID + TES (Superconductivity basics) |     |  |     |               |  |                   |     |
| <b>1.5. Teaching methods</b>   |     | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |     |               | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |                   |     |
| <b>1.6. Comments</b>   |     |  |     |               |  |                   |     |
| <b>1.7. Student's obligations</b>  |     |  |     |               |  |                   |     |
| Students should write a seminar paper and take the final exam.   |     |  |     |               |  |                   |     |
| <b>1.8. Evaluation of student's work</b>   |     |  |     |               |  |                   |     |
| Course attendance  | 0.5 | Activity/Participation   |     | Seminar paper | 1  | Experimental work | 1.5 |
| Written exam   | 1.5 | Oral exam  | 1.5 | Essay         |  | Research          |     |
| Project  |     | Sustained knowledge  |     | Report        |  | Practice          |     |



|  |  |                        |                         |                           |  |  |  |
|--|--|------------------------|-------------------------|---------------------------|--|--|--|
|  |  | check                  |                         |                           |  |  |  |
| Portfolio  |  |                        |                         |                           |  |  |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |                        |                         |                           |  |  |  |
| Student's activity will be evaluated on the basis of the seminar paper and final exam. During term the student can obtain maximum 50% of his final grade, while the remaining 50% can be obtained at the final exam. |  |                        |                         |                           |  |  |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |  |                        |                         |                           |  |  |  |
| G.S. Landsberg, Optika   |  |                        |                         |                           |  |  |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |  |                        |                         |                           |  |  |  |
| M. Born, E. Wolf, Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light<br>E. Hecht, Optics<br>M.Thinkham, Superconductivity<br>A.E. Siegman, Lasers                    |  |                        |                         |                           |  |  |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |  |                        |                         |                           |  |  |  |
|  |  | <i>Title</i>           | <i>Number of copies</i> | <i>Number of students</i> |  |  |  |
|  |  | G.S. Landsberg, Optika | 1                       |                           |  |  |  |
|  |  |                        |                         |                           |  |  |  |
|  |  |                        |                         |                           |  |  |  |
|  |  |                        |                         |                           |  |  |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |  |                        |                         |                           |  |  |  |
| Quality will be monitored by anonymous polls.  |  |                        |                         |                           |  |  |  |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Ivica Orlić                                 |              |
| <b>Course title</b>              | Experimental Methods in Physics 2           |              |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 2.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |     |   |   |               |   |                   |  |
|--|-----|---|---|---------------|---|-------------------|--|
| <b>1.1. Course objectives</b>  |     |   |   |               |   |                   |  |
| Familiarise students with experimental techniques used in various fields of physics, medicine and technology. The accent is put on the experimental techniques that are used at the University of Rijeka (XRF, XPS, AFM, SIMS, IRMS) as well as at the Rudjer Boskovic Institute (Laboratory for Ion beam interactions, techniques such as PIXE, PIGE, RBS, AMS).  |     |   |   |               |   |                   |  |
| <b>1.2. Course enrolment requirements</b>  |     |   |   |               |   |                   |  |
| Experimental Physics I   |     |   |   |               |   |                   |  |
| <b>1.3. Expected course learning outcomes</b>  |     |   |   |               |   |                   |  |
| It is expected that the students will grasp the idea of importance of experimental techniques in the history of the development of our knowledge of natural laws.  |     |   |   |               |   |                   |  |
| <b>1.4. Course content</b>   |     |   |   |               |   |                   |  |
| 1. Introduction: Accelerators, Interaction of charged particles with matter, Scattering and coincidence measurements, Measurements of cross sections,<br>2. Introduction to nuclear analytical techniques: theoretical and experimental aspects of: XRF, PIXE, PIGE, RBS, NRA, AMS, XPS, SIMS. Quantitative analysis and Tomographic imaging,<br>3. Applications of experimental methods in medicine, environmental and material science, geochronology.<br>4. Practical examples in fine aerosol analysis using Nuclear analytical techniques and identification of major pollution sources in Rijeka by means of Positive Matrix Factorisation analysis. |     |   |   |               |   |                   |  |
| <b>1.5. Teaching methods</b>   |     | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |               |   |                   |  |
| <b>1.6. Comments</b>   |     |   |   |               |   |                   |  |
| <b>1.7. Student's obligations</b>  |     |   |   |               |   |                   |  |
| Attending lectures, success in continuous assessment, active participation in project work   |     |   |   |               |   |                   |  |
| <b>1.8. Evaluation of student's work</b>   |     |   |   |               |   |                   |  |
| Course attendance  | 0.5 | Activity/Participation  | 0.5   | Seminar paper | 1 | Experimental work |  |
| Written exam   | 2   | Oral exam   | 1   | Essay         |   | Research          |  |
| Project  |     | Sustained knowledge check   | 1   | Report        |   | Practice          |  |
| Portfolio  |     |   |   |               |   |                   |  |



**1.9. Assessment and evaluation of student's work during classes and on final exam**

Tuitions will be in form of lectures, project work and students' seminar work. Student's work will be evaluated with two mid-term exams and seminars.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Stephan Tavernier, *Experimental Techniques in Nuclear and Particle Physics*, Springer-Verlag 2010  
S.A.E. Johansson, J.L. Campbell, C.G. Malmqvist, *Particle Induced X-Ray Emission Spectroscopy*, J. Wiley & Sons, 1995.  
Furić, M. *Moderne eksperimentalne metode, tehnike i mjerenja u fizici*, Školska knjiga, Zagreb, 1992.

**1.11. Optional / additional reading (at the time of proposing study programme)**

K.R. Spurney, *Analytical Chemistry of Aerosols*, Chapter: Analysis of Individual Aerosol Particles Using Nuclear Microprobe, Lewis Publisher, 1999.  
C. Leroy and PG Rancoita, *Principles of Radiation Interaction in Matter and Detection*, World Scientific, 2009.  
Leo, W. R. *Techniques for Nuclear and Particle Physics Experiments: A How-to Approach*, Springer-Verlag, Berlin, 1994.  
Colin Cooke, *An Introduction to Experimental Physics*, UCL Press, 1996  
<http://www.physics.it/>

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Student's feedback through discussions and by means of anonymous questionnaires on quality of teaching organized by the lecturer as well as the official survey organized by the University.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Predrag Dominis Prester                     |              |
| <b>Course title</b>              | General Relativity                          |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |  |  |   |               |  |                   |  |
|--|--|--|---|---------------|--|-------------------|--|
| <b>1.1. Course objectives</b>  |  |  |   |               |  |                   |  |
| This is a course of General Relativity on a beginning/medium level, in which nature of gravitational interaction is described in terms of properties of a curved space-time. The course gives necessary base knowledge essential for the following of some other courses in astrophysics, astroparticle physics and cosmology belonging to later semesters.  |  |  |   |               |  |                   |  |
| <b>1.2. Course enrolment requirements</b>  |  |  |   |               |  |                   |  |
| None.  |  |  |   |               |  |                   |  |
| <b>1.3. Expected course learning outcomes</b>  |  |  |   |               |  |                   |  |
| Understanding of the gravitational force as a consequence of a space-time curvature. Ability to use mathematical formalism of differential geometry which enables applications of General Relativity to some real problems important either in technological developments or in a scientific research. Understanding of the phenomena, structures, history and the future of the objects on a various astronomical scales – Earth, Solar system, Milky Way (galaxy), up to the Universe as a whole. Developing and improving of broad competences in applying advanced mathematical apparatus for modeling and solving complex problems. |  |  |   |               |  |                   |  |
| <b>1.4. Course content</b>   |  |  |   |               |  |                   |  |
| Equivalence principle. Gravitation as a curvature of the space-time. Basics of the differential geometry. Geodesics and particle trajectories. Einstein-Hilbert equation. Schwarzschild metric. Post-newtonian approximation. Tests of General Relativity in the Solar system. Applications: GPS navigation. Energy and momentum. Gravitational lensing. Stars: stability and collapses. Black holes. Introduction to cosmology.   |  |  |   |               |  |                   |  |
| <b>1.5. Teaching methods</b>   |  | <input checked="" type="checkbox"/> lectures     | <input checked="" type="checkbox"/> individual assignment |               |  |                   |  |
|  |  | <input type="checkbox"/> seminars and workshops  | <input type="checkbox"/> multimedia and network           |               |  |                   |  |
|  |  | <input checked="" type="checkbox"/> exercises    | <input type="checkbox"/> laboratories                     |               |  |                   |  |
|  |  | <input type="checkbox"/> long distance education | <input type="checkbox"/> mentorship                       |               |  |                   |  |
|  |  | <input type="checkbox"/> fieldwork               | <input type="checkbox"/> other                            |               |  |                   |  |
| <b>1.6. Comments</b>   |  |  |   |               |  |                   |  |
| <b>1.7. Student's obligations</b>  |  |  |   |               |  |                   |  |
| Active participation, home and class assignments and tests, passing final exam.  |  |  |   |               |  |                   |  |
| <b>1.8. Evaluation of student's work</b>   |  |  |   |               |  |                   |  |
| Course attendance  |  | Activity/Participation                           | 0.5   | Seminar paper |  | Experimental work |  |
| Written exam   |  | Oral exam  |   | Essay         |  | Research          |  |



|   |  |                           |                  |                    |  |          |
|---|--|---------------------------|------------------|--------------------|--|----------|
|   |  |                           | 2                |                    |  |          |
| Project   |  | Sustained knowledge check | 3.5              | Report             |  | Practice |
| Portfolio   |  |                           |                  |                    |  |          |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |  |                           |                  |                    |  |          |
| Students will be evaluated and valued continuously during the course through home assignments and periodic tests. The course finishes with a final exam. Activities during the course bring at least 70% of the total mark.   |  |                           |                  |                    |  |          |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>   |  |                           |                  |                    |  |          |
| H. C. Ohanian, R. Ruffini: <i>Gravitation and Spacetime</i> (2. edition, W. W. Norton & Co., 1994.)   |  |                           |                  |                    |  |          |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>   |  |                           |                  |                    |  |          |
| 1. P. A. M. Dirac: <i>General Theory of Relativity</i> (Princeton University Press; 1996.)<br>2. S. Weinberg: <i>Gravitation and Cosmology</i> (John Wiley & Sons, Inc; 1972.)<br>3. C. W. Misner, K. S. Thorne, J. A. Wheeler: <i>Gravitation</i> (W. H. Freeman, 1973.) |  |                           |                  |                    |  |          |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>   |  |                           |                  |                    |  |          |
| Title   |  |                           | Number of copies | Number of students |  |          |
|   |  |                           |                  |                    |  |          |
|   |  |                           |                  |                    |  |          |
|   |  |                           |                  |                    |  |          |
|   |  |                           |                  |                    |  |          |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>  |  |                           |                  |                    |  |          |
| Consultations, standard anonymous student questionnaires, discussions after the final exam.   |  |                           |                  |                    |  |          |



| Basic description                |   |             |
|----------------------------------|---|-------------|
| <b>Course coordinator</b>        | Delko Barišić                               |             |
| <b>Course title</b>              | Global ecology                              |             |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |             |
| <b>Course status</b>             | Optional                                    |             |
| <b>Year</b>                      | 2.  |             |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6           |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 0 + 30 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

Achievement of fundamentals knowledge of ecology as science discipline, as well as knowledge of formation, development, dynamics and structure of planet Earth's spheres. Understanding of concept of biogeochemical element cycling in nature, and introducing into recent global ecological problems

### 1.2. Course enrolment requirements

### 1.3. Expected course learning outcomes

Student's would be able to:

- distinguish ecology from environmental protection
- understand the basic planetary processes
- evaluate, critically from ecological point of view, ecological potentials of different human action and activities
- critically estimate possible ecological consequences of different solution offered for intervention in environment
- know capabilities of nuclear analytical methods usage in environment monitoring as well as following environmental processes
- select appropriate environmental samples as well as analysing methods in goal of environment preservation, protection or monitoring

### 1.4. Course content

fundamental terms in ecology; - historic development of ecology and difference among ecology and environmental protection; - natural systems; - limits of global growth and sustainable development concept; - Agenda 21; - chaos and ecology; - entropy and ecology; - human ecological potential; - natural systems and ecosystems dynamic; - ecological disasters in past; - Earth's interior; - planet Earth as ecosystem; - Earth's formation, development, dynamics and structure; - life development on Earth; - Earth's crust, atmosphere, hydrosphere and cryosphere with main natural planetary processes in them; - climatic changes as result of natural processes; - atmosphere and global climate; - greenhouse effect; - stratospheric and tropospheric ozone; - pollution of atmosphere, cryosphere and hydrosphere; - acid rains; - global water circulation; - fresh waters; - seas and oceans; - erosion; - impact of big dam and/or hydro-meioration systems on environment; - selected elements biogeochemical cycles; - sorption/desorption processes in soils and waters; - transport of pollutants by underground water; - bio-indicator organisms; - time chemical bomb concept; - isotopic and nuclear analytical methods and techniques

### 1.5. Teaching methods

- |  |   |
|--|---|
| <input checked="" type="checkbox"/> lectures               | <input type="checkbox"/> individual assignment  |
| <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> multimedia and network |
| <input type="checkbox"/> exercises                         | <input type="checkbox"/> laboratory work        |
| <input type="checkbox"/> long distance education           | <input type="checkbox"/> mentorship             |
| <input type="checkbox"/> fieldwork                         | <input type="checkbox"/> consultations          |



|  |  |                             |     |                         |     |                           |  |
|--|--|-----------------------------|-----|-------------------------|-----|---------------------------|--|
| <b>1.6. Comments</b>   |  |                             |     |                         |     |                           |  |
| <b>1.7. Student's obligations</b>  |  |                             |     |                         |     |                           |  |
| Classes attendance (lessons and seminar), 70 % minimum<br>Seminar paper refer in written form after oral presentation<br>To give preliminary exams as conditio for signature   |  |                             |     |                         |     |                           |  |
| <b>1.8. Evaluation of student's work</b>   |  |                             |     |                         |     |                           |  |
| Course attendance  |  | Activity/Participation      |     | Seminar paper           | 1.2 | Experimental work         |  |
| Written exam   |  | Oral exam                   | 3.6 | Essay                   |     | Research                  |  |
| Project  |  | Sustained knowledge check   |     | Report                  |     | Practice                  |  |
| Portfolio  |  | Preliminary exam (2 x 10 %) | 1.2 |                         |     |                           |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |                             |     |                         |     |                           |  |
| <ul style="list-style-type: none"> <li>- preliminary exam after 7. weeks of teaching</li> <li>- preliminary exam after 14. weeks of teaching</li> <li>- rating of seminar paper</li> <li>- oral exam</li> </ul>  |  |                             |     |                         |     |                           |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |  |                             |     |                         |     |                           |  |
| <ul style="list-style-type: none"> <li>- Prohić E. (1998): GEOKEMIJA, Targa, Zagreb</li> <li>- Glavač V. (2001): UVOD U GLOBALNU EKOLOGIJU, Hrvatska sveučilišna naklada, Ministarstvo zaštite okoliša i prostornog uređenja, Pučko otvoreno učilište, Zagreb</li> <li>- Barišić D. (2009): Priručna skripta (lecture drafts)</li> </ul>   |  |                             |     |                         |     |                           |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |  |                             |     |                         |     |                           |  |
| <ul style="list-style-type: none"> <li>- Andrews J. E., Brimbleconibe P., Jickens T. D. Luiss P. S. (1996): An introduction to environmental chemistry, Blackwell Science, Oxford.</li> <li>- Libes S. M. (1992): An introduction to marine biogeochemistry, John Wiley &amp; Sons, New York.</li> <li>- Salomons W. &amp; Stigliani W.M. (1995): Biogeochemistry of pollutants in soils and sediments (risk assessment of delayed and non-linear responses), Springer. Berlin, Heideberg</li> <li>- Schlesinger W. H. (1997): Biogeochemistry, an analysis of global change, Academic Press</li> <li>- Devillers, J. &amp; Pham-Delegue, Minh-Ha (2002): Honey Bees: Estimating the Environmental Impact of Chemicals, Taylor &amp; Francis. London and New York</li> </ul> |  |                             |     |                         |     |                           |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |  |                             |     |                         |     |                           |  |
| <i>Title</i>   |  |                             |     | <i>Number of copies</i> |     | <i>Number of students</i> |  |
|  |  |                             |     |                         |     |                           |  |
|  |  |                             |     |                         |     |                           |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |  |                             |     |                         |     |                           |  |
| Undergraduates nameless questionnaire after finish of course   |  |                             |     |                         |     |                           |  |



| Basic description                |   |             |
|----------------------------------|---|-------------|
| <b>Course coordinator</b>        | Ines Krajcar Bronić                           |             |
| <b>Course title</b>              | Instrumental methods in environmental physics |             |
| <b>Study programme</b>           | Graduate study programme PHYSICS              |             |
| <b>Course status</b>             | Compulsory                                    |             |
| <b>Year</b>                      | 1.  |             |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b>   | 6           |
|                                  | <b>Number of hours (L+E+S)</b>                | 30 + 30 + 0 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

Introduce instrumental methods and related physics to students. Discuss possibilities, advantages and disadvantages of specific techniques. Prepare students for multidisciplinary approach to environmental monitoring.

### 1.2. Course enrolment requirements

Exams in physics related subjects iz predmeta, perhaps some chemical exams. Ionizing and non-ionizing radiation. Basic knowledge on statistical analysis.

### 1.3. Expected course learning outcomes

Knowledge about instrumental methods and their possibilities.  
Capability of planing and executing complex environmental monitoring

### 1.4. Course content

Atomic absorption and emission spectroscopy/metry, XRF, Mass spectrometry, Alpha- betha- and gamma-spectroskopy, Neutron activation analysis, Methods of nuclear physics based on accelerator application, Quality control, Statistical analysis of measured data.

### 1.5. Teaching methods

- |  |  |
|--|--|
| <input checked="" type="checkbox"/> lectures     | <input checked="" type="checkbox"/> individual assignment: |
| <input type="checkbox"/> seminars and workshops  | <input type="checkbox"/> multimedia and network            |
| <input checked="" type="checkbox"/> exercises    | <input type="checkbox"/> laboratory work                   |
| <input type="checkbox"/> long distance education | <input type="checkbox"/> mentorship                        |
| <input type="checkbox"/> fieldwork               | <input type="checkbox"/> consultations                     |

### 1.6. Comments

Generally, most of the presented instruments are sofisticated (and expensive) instruments, therefore student would not be allowed to performed exercises by themselves. The exams are ment to be demonstrational, i.e., student will be introduced to the instruments while visiting specialized laboratories where the specialists will demonstrate instrument performances.

### 1.7. Student's obligations

Regular attendace of lectures and exercises. Active participation. Preparation of one essey and its presentation in front of other students. Oral exam.

### 1.8. Evaluation of student's work

|                   |     |                           |     |               |     |                   |  |
|-------------------|-----|---------------------------|-----|---------------|-----|-------------------|--|
| Course attendance | 1.2 | Activity/Participation    | 0.6 | Seminar paper |     | Experimental work |  |
| Written exam      |     | Oral exam                 | 2.4 | Essay         | 1.8 | Research          |  |
| Project           |     | Sustained knowledge check |     | Report        |     | Practice          |  |



|  |  |              |  |                         |  |                           |
|--|--|--------------|--|-------------------------|--|---------------------------|
| Portfolio  |  |              |  |                         |  |                           |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |              |  |                         |  |                           |
| <p>Pratit će se redovito pohađanje predavanja i posebno vježbi (ukupno do 20% ECTS bodova kolegija), aktivno sudjelovanje u nastavi (do 10% ECTS bodova). Svaki student će dobiti jednu temu vezanu uz sadržaj kolegija da ju razradi u obliku kratkog eseja kojeg predaje u pismenom obliku, te će tu istu temu izložiti pred ostalim studentima u kratkom (do 15 minuta) usmenom izlaganju (pismeni i esej, te usmeno izlaganje ukupno donose do 30% ECTS bodova). Završni ispit je usmeni, na kojem se studentu postavljaju tri pitanja (dva iz metoda, ali nijedno iz teme koju je obradio u eseju, te jedno pitanje iz statističke obrade ili kontrole kakvoće), a na ispitu može dobiti do 40% ukupnog broja ECTS bodova. Za konačnu pozitivnu ocjenu potrebno je skupiti najmanje pola mogućih bodova iz svakog navedenog segmenta.</p> |  |              |  |                         |  |                           |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |  |              |  |                         |  |                           |
|  |  |              |  |                         |  |                           |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |  |              |  |                         |  |                           |
|  |  |              |  |                         |  |                           |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |  |              |  |                         |  |                           |
|  |  | <i>Title</i> |  | <i>Number of copies</i> |  | <i>Number of students</i> |
|  |  |              |  |                         |  |                           |
|  |  |              |  |                         |  |                           |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |  |              |  |                         |  |                           |
| <p><i>Portfolio of the student:</i> Continuous monitoring of student's activities during the course, information on success and advance.</p> <p><i>Questionnaires:</i> introductory questionnaire about student's expectations. Final (anonymous) questionnaire on quality of the lectures. After successfully finished exam, the teacher asks student oral information on realized aim of the lectures, difficulties experienced during learning, suggestions for improvements.</p>   |  |              |  |                         |  |                           |



| Basic description                |   |            |
|----------------------------------|---|------------|
| <b>Course coordinator</b>        | Dubravka Kotnik-Karuza                      |            |
| <b>Course title</b>              | Master Thesis Seminar                       |            |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |            |
| <b>Course status</b>             | compulsory                                  |            |
| <b>Year</b>                      | 2. year                                     |            |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6          |
|                                  | <b>Number of hours (L+E+S)</b>              | 0 + 0 + 60 |

| 1. COURSE DESCRIPTION  |  |                                   |   |                                    |  |                                    |  |
|--|--|-----------------------------------|---|------------------------------------|--|------------------------------------|--|
| <b>1.1. Course objectives</b>  |  |                                   |   |                                    |  |                                    |  |
| The goal of the course is to give students a support in writing their master theses. During a semester students can discuss their work, problems and plans regarding the thesis. In this way students obtain additional space and time for critical reflections and asking questions about research project. Student must prepare one seminar, which should be publicly presented, based on a research leading to their theses.  |  |                                   |   |                                    |  |                                    |  |
| <b>1.2. Course enrolment requirements</b>  |  |                                   |   |                                    |  |                                    |  |
| None.  |  |                                   |   |                                    |  |                                    |  |
| <b>1.3. Expected course learning outcomes</b>  |  |                                   |   |                                    |  |                                    |  |
| <ul style="list-style-type: none"> <li>- Ability to read, present and discuss relevant literature.</li> <li>- Ability to critically think and to reflect on different approaches during a research.</li> <li>- Ability to work both in an analytical and synthetic mode.</li> <li>- Developing communication skills and abilities for presenting work and results to scientific community.</li> <li>- Gain insight into the field and scientific culture of respective fields and research questions.</li> <li>- Understanding and awareness of problems in processes of writing a master thesis.</li> </ul> |  |                                   |   |                                    |  |                                    |  |
| <b>1.4. Course content</b>   |  |                                   |   |                                    |  |                                    |  |
| A part of the time is reserved for meetings, which may include mentors, on which students discuss their research and problems appearing in the process of writing a master thesis. Course coordinators should stimulate interaction between students. The rest of the time is reserved for student's public presentations.   |  |                                   |   |                                    |  |                                    |  |
| <b>1.5. Teaching methods</b>   |  | <input type="checkbox"/> lectures | <input type="checkbox"/> seminars and workshops | <input type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   |  |                                   |   |                                    |  |                                    |  |
| <b>1.7. Student's obligations</b>  |  |                                   |   |                                    |  |                                    |  |
| Active participation in discussions. Preparation of a seminar, based on the master thesis research, which must be publicly presented.  |  |                                   |   |                                    |  |                                    |  |
| <b>1.8. Evaluation of student's work</b>   |  |                                   |   |                                    |  |                                    |  |
| Course attendance  |  | Activity/Participation            |   | Seminar paper                      | 2  | Experimental work                  |  |
| Written exam   |  | Oral exam                         |   | Essay                              |  | Research                           | 2  |



|   |  |                           |   |                         |  |                           |  |
|---|--|---------------------------|---|-------------------------|--|---------------------------|--|
| Project   |  | Sustained knowledge check |   | Report                  |  | Practice                  |  |
| Portfolio   |  | Public presentation       | 2 |                         |  |                           |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>                                    |  |                           |   |                         |  |                           |  |
| Evaluation is based on an assesment of quality of the research work and presented results, seminar and public presentation. |  |                           |   |                         |  |                           |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>                                   |  |                           |   |                         |  |                           |  |
| None.   |  |                           |   |                         |  |                           |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>                                       |  |                           |   |                         |  |                           |  |
| None.   |  |                           |   |                         |  |                           |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>         |  |                           |   |                         |  |                           |  |
| <i>Title</i>  |  |                           |   | <i>Number of copies</i> |  | <i>Number of students</i> |  |
|   |  |                           |   |                         |  |                           |  |
|   |  |                           |   |                         |  |                           |  |
|   |  |                           |   |                         |  |                           |  |
|   |  |                           |   |                         |  |                           |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>                |  |                           |   |                         |  |                           |  |
| Consultations, standard anonymous student questionnaires, discussions after completion of the course.                       |  |                           |   |                         |  |                           |  |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Saša Zelenika                               |              |
| <b>Course title</b>              | Micro and nano sciences and technologies    |              |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 2.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
|--|---|--|--|--|---|---|---------------------------------------|--|-------------------------------------|---|--------------------------------|
| <b>1.1. Course objectives</b>  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| Gain knowledge of basic principles, modeling, design, manufacturing and use of micro and nano systems. Team work and ability to communicate with experts in the field.   |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.2. Course enrolment requirements</b>  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| None.  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.3. Expected course learning outcomes</b>  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <p>Explain concepts and fundamental terminology of MEMS and NEMS systems. Explain and implement concepts of resolution, precision and accuracy. Distinguish and characterize scaling laws. Distinguish and characterize manufacturing technologies for micro- and nano-systems. Recall the fundamental properties of materials used in this field. Distinguish and characterize innovative materials and technological processes. Explain procedure of handling and assembly of microsystems. Explain phenomena and concepts of micro and nano tribology and micro fluidodynamics systems. Explain basic measurement procedures of mechanical characteristics of MEMS and NEMS components and systems. Explain ethical and social aspects of application of nanotechnology.</p> <p>Team work and oral and written communication with experts from this and other fields.</p> |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.4. Course content</b>   |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| Orders of magnitude. Basic principles of micro- and nanotechnologies. Definition of micro- and nano-electromechanical systems (MEMS and NEMS). Basic terminology. Scaling laws in miniaturization. Micro- and nanosystems technologies. Materials. Handling and assembly of microsystems' components. Use of biological and other innovative materials and technological processes. Design and integration of systems. Modelling of systems. Fundamentals of micro and nano tribology. Fundamentals of micro fluidodynamics. Application of MEMS and NEMS systems. Analysis, modelling and measurements of micro electro-mechanical components and systems. Examples of micro and nano systems.  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.5. Teaching methods</b>   | <table border="0"> <tr> <td><input checked="" type="checkbox"/> lectures</td> <td><input type="checkbox"/> individual assignment</td> </tr> <tr> <td><input checked="" type="checkbox"/> seminars and workshops</td> <td><input type="checkbox"/> multimedia and network</td> </tr> <tr> <td><input checked="" type="checkbox"/> exercises</td> <td><input type="checkbox"/> laboratories</td> </tr> <tr> <td><input type="checkbox"/> long distance education</td> <td><input type="checkbox"/> mentorship</td> </tr> <tr> <td><input checked="" type="checkbox"/> fieldwork</td> <td><input type="checkbox"/> other</td> </tr> </table> | <input checked="" type="checkbox"/> lectures | <input type="checkbox"/> individual assignment | <input checked="" type="checkbox"/> seminars and workshops | <input type="checkbox"/> multimedia and network | <input checked="" type="checkbox"/> exercises | <input type="checkbox"/> laboratories | <input type="checkbox"/> long distance education | <input type="checkbox"/> mentorship | <input checked="" type="checkbox"/> fieldwork | <input type="checkbox"/> other |
| <input checked="" type="checkbox"/> lectures   | <input type="checkbox"/> individual assignment  |  |  |  |   |   |                                       |  |                                     |   |                                |
| <input checked="" type="checkbox"/> seminars and workshops   | <input type="checkbox"/> multimedia and network   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <input checked="" type="checkbox"/> exercises  | <input type="checkbox"/> laboratories   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <input type="checkbox"/> long distance education   | <input type="checkbox"/> mentorship   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <input checked="" type="checkbox"/> fieldwork  | <input type="checkbox"/> other  |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.6. Comments</b>   |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.7. Student's obligations</b>  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| Attendance of classes, activity of students in classes, project work with presentations of seminars, individual learning.  |   |  |  |  |   |   |                                       |  |                                     |   |                                |
| <b>1.8. Evaluation of student's work</b>   |   |  |  |  |   |   |                                       |  |                                     |   |                                |



|   |   |                           |   |                         |   |                           |  |
|---|---|---------------------------|---|-------------------------|---|---------------------------|--|
| Course attendance   | 2 | Activity/Participation    |   | Seminar paper           | 2 | Experimental work         |  |
| Written exam  |   | Oral exam                 | 1 | Essay                   |   | Research                  |  |
| Project   |   | Sustained knowledge check | 1 | Report                  |   | Practice                  |  |
| Portfolio   |   |                           |   |                         |   |                           |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |   |                           |   |                         |   |                           |  |
| Attendance of classes, activity in classes, project work, colloquiums, written and/or oral final exam.  |   |                           |   |                         |   |                           |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>   |   |                           |   |                         |   |                           |  |
| <p>***: Springer Handbook of Nanotechnology, Springer Verlag, Berlin (D), 2004.<br/> T.-R. Hsu: MEMS &amp; MICROSYSTEMS – Design and Manufacture, McGraw Hill, Boston (MA, USA), 2002.<br/> M. J. Madou: Fundamentals of Microfabrication, CRC Press, Boca Raton (FL, USA), 2002.</p>   |   |                           |   |                         |   |                           |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>   |   |                           |   |                         |   |                           |  |
| <p>J. J. Allen: Micro Electro Mechanical System Design, CRC Press, Boca Raton (FL, USA), 2005.<br/> S. D. Senturia: Microsystems Design, Kluwer Academic Publishers, Dordrecht (NL), 2000.<br/> N. Maluf and K. Willimas: An Introduction to Microelectromechanical Systems Engineering - 2nd ed., Artech House, Boston (MA, USA), 2004.<br/> ***: Microsystems Mechanical Design – CISM Courses and Lectures No. 478, Springer Verlag, Wien (A), 2006.</p> |   |                           |   |                         |   |                           |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>   |   |                           |   |                         |   |                           |  |
| <i>Title</i>  |   |                           |   | <i>Number of copies</i> |   | <i>Number of students</i> |  |
| ***: Springer Handbook of Nanotechnology – 2nd ed., Springer Verlag, Berlin (D), 2007.  |   |                           |   | 1                       |   | 15                        |  |
| T.-R. Hsu: MEMS & MICROSYSTEMS – Design and Manufacture, McGraw Hill, Boston (MA, USA), 2002.   |   |                           |   | 1                       |   | 15                        |  |
| M. J. Madou: Fundamentals of Microfabrication – The Science of Miniaturisation, CRC Press, Boca Raton (FL, USA), 2002.  |   |                           |   | 1                       |   | 15                        |  |
| J. J. Allen: Micro Electro Mechanical System Design, CRC Press, Boca Raton (FL, USA), 2005.   |   |                           |   | 1                       |   | 15                        |  |
| S. D. Senturia: Microsystems Design, Kluwer Academic Publishers, Dordrecht (NL), 2000.  |   |                           |   | 1                       |   | 15                        |  |
| N. Maluf and K. Willimas: An Introduction to Microelectromechanical Systems Engineering - 2nd ed., Artech House, Boston (MA, USA), 2004.  |   |                           |   | 1                       |   | 15                        |  |
| ***: Microsystems Mechanical Design – CISM Courses and Lectures No. 478, Springer Verlag, Wien (A), 2006.   |   |                           |   | 1                       |   | 15                        |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>  |   |                           |   |                         |   |                           |  |
| Implementation of the system of quality control of the Department of Physics. Continuous interaction with students and discussions on quality of teaching process.  |   |                           |   |                         |   |                           |  |



| Basic description                |   |             |
|----------------------------------|---|-------------|
| <b>Course coordinator</b>        | Tarzan Legović                              |             |
| <b>Course title</b>              | Modelling in environmental protection       |             |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |             |
| <b>Course status</b>             | optional                                    |             |
| <b>Year</b>                      | 1.  |             |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6           |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 30 + 0 |

| 1. COURSE DESCRIPTION  |  |  |     |               |  |                   |  |
|--|--|--|-----|---------------|--|-------------------|--|
| <b>1.1. Course objectives</b>  |  |  |     |               |  |                   |  |
| Enable understanding of reasons for model construction and application, prediction and control.  |  |  |     |               |  |                   |  |
| <b>1.2. Course enrolment requirements</b>  |  |  |     |               |  |                   |  |
| One course in ecology or environmental protection. Mathematics (differential and integral calculus, differential equations)  |  |  |     |               |  |                   |  |
| <b>1.3. Expected course learning outcomes</b>  |  |  |     |               |  |                   |  |
| Using obtained knowledge, students will be able to assess when a model is needed, how to build it, analyze and use it.   |  |  |     |               |  |                   |  |
| <b>1.4. Course content</b>   |  |  |     |               |  |                   |  |
| Dynamics of one population in an unbounded, bounded, constant, periodic and stochastic environment. Maximum sustainable yield. Dynamics of non-overlapping populations. Discrete model and chaotic dynamics. Stabilization. Dynamics of two populations: prey-predator, competition and cooperation. Metapopulations. Food chains and food webs. Epidemics and invasion of a population in space. Control. |  |  |     |               |  |                   |  |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratory work<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> consultations |     |               |  |                   |  |
| <b>1.6. Comments</b>   |  |  |     |               |  |                   |  |
| <b>1.7. Student's obligations</b>  |  |  |     |               |  |                   |  |
| Attendance to lectures and exercises. Independent problem solving.   |  |  |     |               |  |                   |  |
| <b>1.8. Evaluation of student's work</b>   |  |  |     |               |  |                   |  |
| Course attendance  | 0.5  | Activity/Participation   | 0.5 | Seminar paper |  | Experimental work |  |
| Written exam   | 2  | Oral exam  | 2   | Essay         |  | Research          |  |
| Project  |  | Sustained knowledge check  | 1   | Report        |  | Practice          |  |
| Portfolio  |  |  |     |               |  |                   |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |  |     |               |  |                   |  |
| Control of solved problems during exercises. Exam: written (50%) and oral (50 %)   |  |  |     |               |  |                   |  |



**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Sharov A. Quantitative Population Ecology, Virginia Tech., 1996  
<http://www.gypsymoth.ento.vt.edu/~sharov/PopEcol/popecol.html>  
Legović T., Lectures in Ecological Modelling, CD, R.Bošković Institute, 2004.

**1.11. Optional / additional reading (at the time of proposing study programme)**

Edelstein-Keshet, L., Mathematical Models in Biology, SIAM, 2005.  
Kott, M. Elements of Mathematical Ecology, Cambridge Univ. Press, 2001  
Murray J. D., Mathematical Biology, Springer, 2004.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i>                                 | <i>Number of copies</i> | <i>Number of students</i> |
|--|-------------------------|---------------------------|
| Sharov A. Quantitative Population Ecology    | Not limited             |                           |
| Legović T., Lectures in Ecological Modelling | Not limited             |                           |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Monitoring of acquired knowledge is performed after each lecture and prior to the next lecture.  
Anonymous questionnaire at the end of the course. Results are analyzed and improvements are implemented.



| Basic description                |   |             |
|----------------------------------|---|-------------|
| <b>Course coordinator</b>        | Ivica Orlić                                 |             |
| <b>Course title</b>              | Nuclear Physics                             |             |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |             |
| <b>Course status</b>             | optional                                    |             |
| <b>Year</b>                      | 1.  |             |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6           |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 15 + 0 |

| 1. COURSE DESCRIPTION   |  |  |   |  |   |   |  |
|---|--|--|---|--|---|---|--|
| <b>1.1. Course objectives</b>   |  |  |   |  |   |   |  |
| To gain broad knowledge of nuclear physics with it's various applications in other sciences and technologies.   |  |  |   |  |   |   |  |
| <b>1.2. Course enrolment requirements</b>   |  |  |   |  |   |   |  |
| Bachelor degree in Physics  |  |  |   |  |   |   |  |
| <b>1.3. Expected course learning outcomes</b>   |  |  |   |  |   |   |  |
| <b>1.4. Course content</b>  |  |  |   |  |   |   |  |
| 1. Introduction – Nuclear cross section, Rutherford scattering, measuring cross sections,<br>2. Nuclear Phenomenology – Properties of nuclei, Nuclear force,<br>3. Nuclear models – Liquid drop model, Fermi-gas model, Shell model, Square well and harmonic oscillator, Collective model,<br>4. Nuclear Radiation – Tunnelling, Alpha, Beta and Gamma Decay,<br>5. Applications of Nuclear Physics – Fission and Fusion, Natural radioactivity and dating, interactions of particles with matter, Energy loss, Particle accelerators and Particle detectors,<br>6. Applications in medicine and elemental analysis – Nuclear imaging and diagnosing, Radioisotopes and radiotherapy, Nuclear analytical techniques such as PIXE, RBS, ERDA, AMS |  |  |   |  |   |   |  |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input checked="" type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input checked="" type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment | <input checked="" type="checkbox"/> multimedia and network |
|   |  |  |   |  |   | <input checked="" type="checkbox"/> laboratories          | <input type="checkbox"/> mentorship                        |
|   |  |  |   |  |   | <input type="checkbox"/> other                            |  |
| <b>1.6. Comments</b>  |  |  |   |  |   |   |  |
| <b>1.7. Student's obligations</b>   |  |  |   |  |   |   |  |
| Active participation of students in classes and project work, with presentations of seminars. Acquirement, analysis and synthesis of competences in topics being taught via readings of bibliographical references. Discussion of these topics on lectures and exercises as well as via written and oral presentations, partial and final exams.  |  |  |   |  |   |   |  |
| <b>1.8. Evaluation of student's work</b>  |  |  |   |  |   |   |  |
| Course attendance   | 0.5  | Activity/Participation                                     | 0.5   | Seminar paper                                    | 1   | Experimental  |  |



|              |   |                           |   |        |          |  |
|--------------|---|---------------------------|---|--------|----------|--|
|              |   |                           |   |        | work     |  |
| Written exam | 2 | Oral exam                 | 1 | Essay  | Research |  |
| Project      |   | Sustained knowledge check | 1 | Report | Practice |  |
| Portfolio    |   |                           |   |        |          |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Tuitions will be in form of lectures, project work and students' seminar work. Knowledge checking during classes will be performed via two partial exams and seminars.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

Krane, K. S. *Introductory Nuclear Physics*, John Wiley & Sons, New York, 1987.

Ashok Das and Thomas Ferbel, *Introduction to Nuclear and Particle Physics*, John Wiley & Sons, New York, 1994.

**1.11. Optional / additional reading (at the time of proposing study programme)**

S.A.E. Johansson, J.L. Campbell and K.G. Malmqvist, Eds., *Particle-Induced X-Ray Emission Spectroscopy (PIXE)*, John Wiley and Sons Ltd., 199 ISBN 0-471-58944-6

KR Spurny, *Analytical Chemistry of Aerosols*, 1999, CRC Publisher, USA.

Shirokov, Z. M., Yudin, N. P. *Nuclear Physics*, MIR, Moskow, 1982.

Wong, S. S. M. *Introductory Nuclear Physics*, John Wiley & Sons, New York, 1999.

Heyde, K. *Basic Ideas and Concepts in Nuclear Physics: An Introductory* (Series in Fundamental and Applied Nuclear Physics), Institute of Physics Publishing, 2004.

Lilley, J. S. *Nuclear Physics: Principles and Applications*, John Wiley, New York, 2001.

<http://pdg.lbl.gov>

<http://particleadventure.org/>

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Student's feedback by means of survey organized by the lecturer as well as the official survey organized by the University.



| Basic description                |   |          |
|----------------------------------|---|----------|
| <b>Course coordinator</b>        | Dijana Dominis Prester                      |          |
| <b>Course title</b>              | Observational astrophysics                  |          |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |          |
| <b>Course status</b>             | Optional                                    |          |
| <b>Year</b>                      | 2.  |          |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6        |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+15+15 |

| 1. COURSE DESCRIPTION  |  |   |
|--|--|---|
| <b>1.1. Course objectives</b>  |  |   |
| Gaining knowledge in experimental (observational) astrophysics on an advanced level. Getting familiar with the modern methods of astrophysical research and important scientific results, with an emphasis on the recent results and new open questions. Preparing for scientific research in astrophysics.  |  |   |
| <b>1.2. Course enrolment requirements</b>  |  |   |
| <p><i>Mandatory:</i> Course „Astronomy and Astrophysics I“.</p> <p><i>Recommended:</i> enrolling courses „Astroparticle physics“ and „Astrophysics Lab“.</p> <p>This course is a prerequisite for „Astrophysics Lab“.</p>  |  |   |
| <b>1.3. Expected course learning outcomes</b>  |  |   |
| Students will be expected to show understanding of the course contents. Learning experimental methods in astrophysics will prepare students for the practical work within the Astrophysics Lab, and their future scientific work in astrophysics.  |  |   |
| <b>1.4. Course content</b>   |  |   |
| <p><i>Observational (experimental) methods and instruments:</i><br/>           Optical telescope networks. CCD cameras in astrophysics. Differential photometry. Radio telescopes. Cherenkov telescopes (IACT) and the corresponding technology. Cameras with photodetectors. Astroparticle experiments. Astrometry. Interferometry. Adaptive optics. Space missions and satellites. Sky surveys. Application of the experimental methods developed in astrophysics in the public sector.</p> <p><i>Selected chapters:</i><br/>           Gravitational microlensing. Searching for extrasolar planets. Active galactic nuclei (AGN). Observing the whole electromagnetic spectrum and determining of the spectral energy distribution (SED). Correlations between light curves in different energy bands.</p> |  |   |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork   | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   | In this course, assuming previously attended course “Astronomy and astrophysics I”, special weight will be given to the most recent methods in astrophysics, following the leading results in the field. Each year the materials will be updated. Therefore, in future years, some differences from the above described course content will be possible. |   |



**1.7. Student's obligations**

Course attendance, seminar, final exam.

**1.8. Evaluation of student's work**

|                   |   |                           |   |               |   |                   |  |
|-------------------|---|---------------------------|---|---------------|---|-------------------|--|
| Course attendance |   | Activity/Participation    | 1 | Seminar paper | 1 | Experimental work |  |
| Written exam      | 1 | Oral exam                 | 2 | Essay         |   | Research          |  |
| Project           |   | Sustained knowledge check | 1 | Report        |   | Practice          |  |
| Portfolio         |   |                           |   |               |   |                   |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Manner of knowledge checking: class participation, homework, project, written and oral exam. Student's work will be evaluated during the semester, and during the final exam.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. Course Web page
2. Vladis Vujnović: *Astronomija 1 i 2*, Školska knjiga, 2010

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. M. Zeilik and E.P. Smith: "Introductory Astronomy and Astrophysics", 1987, CBS College publishing
2. Léna, P., Rouan, D., Lebrun, F., Mignard, F., Pelat, D.: "Observational astrophysics", 2012, Springer
3. Selected review papers in the field of observational astrophysics

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Interaction with students and student-faculty team work on quality of teaching process. Anonymous questionnaires on quality of teaching. Flexible adaptation of teaching to interests and needs of students. Individual public seminars given by students.



| Basic description         |                                      |         |
|---------------------------|--------------------------------------|---------|
| Course coordinator        | Duško Čakara                         |         |
| Course title              | Physical chemistry                   |         |
| Study programme           | Graduate study programme PHYSICS     |         |
| Course status             | compulsory                           |         |
| Year                      | 1.                                   |         |
| ECTS credits and teaching | ECTS student 's workload coefficient | 6       |
|                           | Number of hours (L+E+S)              | 30+30+0 |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

- Acquisition of the basic knowledge in the field of physical chemistry
- Acquisition of the advanced and selected knowledges in the field of physical chemistry
- Application of the acquired knowledge in the independent resolution of problems and tasks
- Exploration of the scientific problem and the available literature within the selected seminar topic
- Familiarization with the experiments and analytical methods used for the investigation of the physico-chemical properties in the environmental systems and processes.

### 1.2. Course enrolment requirements

Mathematics, General chemistry, Physics

### 1.3. Expected course learning outcomes

General competences:

- The capacity of observing the structure of matter at the molecular level, and the chemical reactions, starting from the physical principles
- The capacity of independent solving of problems and computational tasks from the fields of chemical thermodynamics, electrochemistry, chemical kinetics, molecular quantum mechanics and spectroscopy
- The capacity of independent observation of the scientific problems and the literature within the selected seminar topic, writing of the seminar paper

Specific competences:

- The capacity of observing the chemical systems occurring in nature, in the light of the physico-chemical laws.
- The basic usage of the computational methods for solving the numerical problems within the above topics – numerical programming using a computer language most familiar to the student

### 1.4. Course content

Quantum mechanics. The failures of classical physics. The quantization of energy levels. The Planck's formula. The photoelectric effect. The hydrogen molecule spectrum. Rutherford's model of the atom. Bohr's model of the atom. The wave-particle duality, the De Broglie's formula. Schrödinger's equation. The hamiltonian. Eigenvalues and eigenfunctions. The wave function. The normalization and interpretation of the wave function. The hamiltonian expected value. The superposition of the wave functions. The Heissenberg's uncertainty principle. The application of the quantum theory in the particle motion mechanics: translations (particle in the box), vibrations, rotations. The degeneracy of the energy states. The hydrogenic atoms: Electronic structure, Schrödinger's equation. The separation of the internal motion. Atomic orbitals and energies. The electronic transitions. The many-electron atoms: helium atom. The Pauli's exclusion principle. The shielding effect. The spin. The Hund's rule.  
The molecular structure: the Born-Oppenheimer approximation. The valence bond theory. The molecular orbital theory.



The hybridization. The basics of the atomic and molecular spectroscopy: the Interaction btw. the EM radiation and atoms and molecules. Spectroscopic measurements. The rotational spectra. The vibrational spectra. The electronic spectra. The selection rules. Nuclear magnetic resonance.

Chemical thermodynamics. The quantities of phenomenological thermodynamics – functions, variables. Temperature definition - 0th law. Pressure. The pPartial gas laws. The equation of state of an ideal gas. The kinetic theory of gases. Real gases. Molecular interactions. The critical point ( $p, V_m, T$ ). The Van der Waals eq. od state. The 1st law: the internal energy, heat, work. State functions vs. the functions dependent upon the path. The reversible and irreversible expansion. The heat capacity. The enthalpy. The examples of enthalpy change in chemical processes (thermochemistry). The Hess law. Kirchoff's law. The total differential. The relations among the partial derivatives of the thermodynamic functions ( $c_v, \mu, \beta, c_p, \mu, \dots$ ). The isenthalpic process. The work of adiabatic expansion. The 2nd law. The entropy. The spontaneous processes. Carnot's cycle. The entropy of irreversible processes. The entropy of phase transition. The entropy of id. gas expansion. The temperature dependence of entropy. The 3<sup>rd</sup> law. The absolute temperature scale. The efficiency of heat-to-work converion. The Gibbs energy. The Helmholtz energy. The meaning of  $\Delta G$  i  $\Delta A$  (maximum work). The properties of internal energy. The properties of Gibbs energy. The dependence of  $G$  upon  $T$  and  $p$ . The chemical potential. The fundamental equation of chemical thermodynamics. The fugacity. The standard state of a gas. Phase transitions. The phase diagram. The triple point. Phase stability. Temperature and pressure dependence of the equilibrium. Clapeyron's equation. Eherenfest classification of teh phase transitions. The mixtures. The partial molar quantities. The Gibbs-Duhem equation.  $\mu_{\text{mix}}G, \mu_{\text{mix}}H, \mu_{\text{mix}}S$ . The chemical potential of a liquid, the ideal liquids, the Raoult's law, the Henry's law, the ideally dilute liquids. Solutions. The colligative properties. Osmosis. Phases, components, degrees of freedom. The phase rule. The two-component systems. The vapor pressure diagram. The temperature-composition diagram. Distillation. The zeotropes and the azeotropes. The three-component mixtures. Chemical equilibrium. The extent of the reaction. The reaction Gibbs energy. The endergonic and the exergonic processes (reactions). The equilibrium composition of the reaction mixture. The activity. The equilibrium constant. The relationship btw the theoretical and practical equilibrium constants. The response of the chemical equilibrium to the change of the conditions ( $T, p$ ). Le Chatelier's principle. The Van't Hoff equation. The acid-base equilibrium. The autoprotolysis (dissociation) of water. The pH. The acid-base titrations. The Hendersson-Hasselbalch equation. The calculation of pH in mixtures of acids and bases. Buffers.

Electrochemitry. Equilibrium electrochemitry. The thermodynamic properties of ionic solutions. The thermodynamic functions of formation. The hydratization of ions. The solvation. The ion activity. The ionic strength. Bjerrum's theory. The Debye-Hueckel law. Potentiometry. The el electrochemical cell. The half-reactions and the electrode processes. The types of electrodes. Cell reactions. The electromotive force (EMF). The liquid junciton pot. The EMF vs.  $G$  relationship. The Nernst equation. Concentration cells. The cell in equilibrium. The standard electrode potential. The dependence of the EMF on the cell composition. The measurement of the standard reduction pot. The measurement of the ion activity coefficients. The el electrochemical order. The dissolution constant. Ion-selective electrodes. pH measurement. Potentiometric titrations – determination of the pK value. The thermodynamic functions derived in terms of the EMF. The solution conductivity. Strong electrolytes. The law of independent motion of ions. Kohlrausch's law. Weak electrolytes. The Ostwald's dilution rule. Ion mobility. The transport number. Ionic interactions (Debye-Hueckel-Onsager theory). Diffusion. Fick's law. Einstein's relation. The diffusion coefficient. The Nernst-Einstein equation. The Stokes-Einstein equation.

Chemical kinetics. The reaction rate and the rate constant. The reaction order. The empirical rate laws. The integrated rate laws. First order reactions. The reactant half-life. Second order reaction. The steady state - relation between the rate constants and the equilibrium constants. The temperature dependence of the rate constants. The Arrhenius equation. The activation energy. Elementary reactions. The consecutive elementary reactions – the variation of concentration, the rate determining step, the steady-state approximation. The activated complex theory. The reaction coordinate. The transition state. Eyring's equation. The activation Gibbs energy, enthalpy and entropy. Ionic reactions. The kinetic salt effect. The molecular collision theory.

**1.5. Teaching methods**

- lectures
- seminars and workshops
- exercises
- long distance education
- fieldwork

- individual assignment
- multimedia and network
- laboratory work
- mentorship
- consultations

**1.6. Comments**

**1.7. Student's obligations**



Seminars – mandatory presence with the absence policy according to the University statute

The presence at lectures is being evidenced, however it is not mandatory

**1.8. Evaluation of student's work**

|                   |   |                           |     |               |     |                   |   |
|-------------------|---|---------------------------|-----|---------------|-----|-------------------|---|
| Course attendance |   | Activity/Participation    |     | Seminar paper | 0,5 | Experimental work |   |
| Written exam      | 1 | Oral exam                 | 1   | Essay         |     | Research          |   |
| Project           |   | Sustained knowledge check | 2,5 | Report        |     | Practice          | 1 |
| Portfolio         |   |                           |     |               |     |                   |   |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

In the case of group smaller than 40 students, the grading is on the absolute scale according to the achieved final score. In the case of a group larger than 40 students, the grading is on a relative scale, by distributing all the students who successfully finished the course. For a successful accomplishment of the course, a minimum score is required for all of the below evaluation categories:

Sustained knowledge check (max. 40, min. 20) – three separate colloquia

Practice (laboratory course, max. 20, min. 10)

Seminar paper (max. 10, min. 5)

Final exam – written exam (max. 15, min. 7.5) + oral exam (max. 15, min. 7.5)

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

P.W. Atkins, Physical Chemistry, 5th Ed., Oxford University Press, 1994

**1.11. Optional / additional reading (at the time of proposing study programme)**

P. W. Atkins, The Elements of Physical Chemistry, 3rd Ed., Oxford University Press, 2000.

V. Simeon, Termodinamika, Školska knjiga, Zagreb 1980.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Quality monitoring at the institution level, according to the article 83. of the Book of studies regulations of the University of Rijeka.

Quality monitoring by the lecturer by means of a non-mandatory student poll.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Hrvoje Štefančić                            |              |
| <b>Course title</b>              | Physical Cosmology                          |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | optional                                    |              |
| <b>Year</b>                      | 2. year                                     |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |
|--|
| <p><b>1.1. Course objectives</b></p> <p>Course objectives comprise:</p> <ol style="list-style-type: none"> <li>1. Familiarizing students with the modern observational data on structure and dynamics of the universe</li> <li>2. Developing understanding of the principles of modern cosmology and their connection with the fundamental theoretical and experimental results in other areas of physics.</li> <li>3. Achieving understanding and quantitative elaboration of General theory of relativity in the cosmological context.</li> <li>4. Gaining insight into the theory of Big Bang and the thermal evolution of the universe</li> <li>5. Getting familiar with the theory of cosmic inflation, onset and evolution of inhomogeneities in the universe and the formation of observed cosmic structures.</li> <li>6. Adoption of analytical and numerical approaches to solving main equations of the global evolution of the universe.</li> <li>7. Development of the unified picture and chronology of the evolution of the universe and dominant physical effects in particular epochs of its development.</li> </ol> |
| <p><b>1.2. Course enrolment requirements</b></p> <p>Passed courses: Statistical mechanics, General relativity, Elementary particle physics 1.</p>  |
| <p><b>1.3. Expected course learning outcomes</b></p> <p>Expected course learning outcomes comprise:</p> <ol style="list-style-type: none"> <li>1. An insight into modern observational results on dynamics and structure of the universe</li> <li>2. An operational application of the Theory of general relativity in the quantitative description of the homogeneous and isotropic universe</li> <li>3. Experience of the application of knowledge from high-energy physics and statistical physics to understanding of the thermal history of the universe</li> <li>4. Qualitative understanding of the process of cosmic inflation, phase transitions in the early universe and formation of observed cosmic structures</li> <li>5. Completed project of the numerical solution of the model of the evolution of the universe</li> </ol>   |
| <p><b>1.4. Course content</b></p> <p>Introduction</p> <ul style="list-style-type: none"> <li>• historical development of concepts about universe</li> <li>• results and techniques of modern observations in cosmology (supernovae of the Ia type, cosmic microwave background, distribution of galaxies, gravitational lens effects, galaxy cluster dynamics, ...)</li> <li>• observational basis of the Standard cosmological model (averaging of matter and energy density, homogeneity and isotropy at large scales)</li> <li>• cosmological principle and alternative approaches</li> </ul>   |



- composition of the universe

**Isotropic and homogeneous universe**

- overview of the Theory of general relativity
- Robertson Walker metrics (motivation from the cosmological principle, derivation, discussion of the character of the space for different spatial curvatures (graphical presentation), generic character of expansion/contraction)
- elaboration of Einstein equation for RW metrics (derivation of Friedmann equations)
- types of matter (nonrelativistic matter, radiation, dark energy and its types)
- continuity equations for matter
- solutions of Friedmann equations for different types of matter in the universe (and their combinations)
- asymptotic solutions and singularities

**Hot Big Bang**

- particle fluids in thermal equilibrium in the expanding universe (mechanisms of maintaining equilibrium and the relation with expansion)
- process of exiting of individual particle species from thermal equilibrium and relic densities of components from the early universe
- phase transitions in the early universe
- primordial nucleosynthesis
- formation of photonic and neutrino background radiation

**Inflation**

- a need for the phase of inflationary expansion and problems solved by inflation
- models of inflation (scalar field, modified gravity)
- production of initial inhomogeneities in the final phases of inflation

**Inhomogeneities in the universe**

- growth of inhomogeneities in various phases of the evolution of the universe
- the role of dark matter
- cosmic microwave background anisotropies
- nonlinear growth of inhomogeneities and the formation of cosmic structures

**1.5. Teaching methods**

- lectures
- seminars and workshops
- exercises
- long distance education
- fieldwork

- individual assignment
- multimedia and network
- laboratories
- mentorship
- other

**1.6. Comments**

**1.7. Student's obligations**

The obligations of students comprise regular attendance to all forms of classes and active participation in classes, completion of individual computer-based project (numerical solution of a problem in cosmology), two written exams (mid-term and final) and oral exam. The report on the completed computer-based project should be delivered before the oral exam.

**1.8. Evaluation of student's work**

|                   |     |                           |     |               |  |                   |  |
|-------------------|-----|---------------------------|-----|---------------|--|-------------------|--|
| Course attendance | 0.3 | Activity/Participation    | 0.3 | Seminar paper |  | Experimental work |  |
| Written exam      | 3.0 | Oral exam                 | 1.8 | Essay         |  | Research          |  |
| Project           | 0.6 | Sustained knowledge check |     | Report        |  | Practice          |  |
| Portfolio         |     |                           |     |               |  |                   |  |



**1.9. Assessment and evaluation of student's work during classes and on final exam**

Each of specified elements of assesment and evaluation of student's work (attendance, activity in classes, written exams (mid-term and final), project, oral exam) is graded with the following maximal number of points: attendance 5 points, activity in classes 5 points, first written exam 25 points, second written exam 25 points, project 10 points, oral exam 30 points.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

A. Liddle, An Introduction to Modern Cosmology, John Wiley and Sons, Chichester (2003)

**1.11. Optional / additional reading (at the time of proposing study programme)**

S. Dodelson, Modern Cosmology, Academic Press, San Diego (2003)

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Quality will be monitored by consultations, anonymous polls and conversations after passing the exam.



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Nastjenjka Supić                            |         |
| <b>Course title</b>              | Physical oceanography                       |         |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |         |
| <b>Course status</b>             | compulsory                                  |         |
| <b>Year</b>                      | 2.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6       |
|                                  | <b>Number of hours (L+E+S)</b>              | 30+30+0 |

| 1. COURSE DESCRIPTION  |  |  |
|--|--|--|
| <b>1.1. Course objectives</b>  |  |  |
| Course objectives are that students get the basic knowledge on the methodology in physical oceanography and on the importance of this science in sea research.   |  |  |
| <b>1.2. Course enrolment requirements</b>  |  |  |
| /  |  |  |
| <b>1.3. Expected course learning outcomes</b>  |  |  |
| <p>Students should</p> <ul style="list-style-type: none"> <li>- recognize the subject of physical oceanography,</li> <li>- recognize the basic parameters of physical oceanography and methods of their derivation,</li> <li>- get the basic knowledge on data analysis in physical oceanography (i. e. analysis of time series and spatial distribution charts),</li> <li>- recognize the role of physical oceanography in understanding global and regional climatic changes,</li> </ul> <p>and</p> <ul style="list-style-type: none"> <li>- relate different processes in sea environment to changes in sea dynamic.</li> </ul>   |  |  |
| <b>1.4. Course content</b>   |  |  |
| <ul style="list-style-type: none"> <li>- Subject of physical oceanography,</li> <li>- Sea conditions (temperature, salinity, density, sea pressure, water masses),</li> <li>- air-sea fluxes and their impact on sea conditions,</li> <li>- forces drawing sea dynamics, equations of state and methods of their solving,</li> <li>- geostrophic currents, wind induced currents, inertial currents,</li> <li>- waves,</li> <li>- air-sea interaction and climatic changes,</li> <li>- equipment in physical oceanography,</li> <li>- data analysis in physical oceanography,</li> </ul> <p>and</p> <ul style="list-style-type: none"> <li>- impact of physical processes on sea ecosystem.</li> </ul> |  |  |
| <b>1.5. Teaching methods</b>   | <input type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratory work<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> consultations |
| <b>1.6. Comments</b>   | If possible, students would attend a course on research vessel Vila Velebita in organisation of Center for Marine Research in Rovinj, of Rudjer Bošković Institute.  |  |



### 1.7. Student's obligations

Student's obligations are to attend the courses.

### 1.8. Evaluation of student's work

|                   |     |                           |     |               |     |                   |  |
|-------------------|-----|---------------------------|-----|---------------|-----|-------------------|--|
| Course attendance | 0.3 | Activity/Participation    | 0.3 | Seminar paper | 0.5 | Experimental work |  |
| Written exam      | 1.6 | Oral exam                 | 1.1 | Essay         |     | Research          |  |
| Project           |     | Sustained knowledge check | 2.2 | Report        |     | Practice          |  |
| Portfolio         |     |                           |     |               |     |                   |  |

### 1.9. Assessment and evaluation of student's work during classes and on final exam

Student's obligations are to attend the courses and to finalize all the tasks given during them. Students will be evaluated during two preliminary written exams, and final written and oral exams. To pass the exams it is necessary to get a detailed knowledge of matter presented in the course, especially to understand the most important (golden) points.

### 1.10. Assigned reading (at the time of the submission of study programme proposal)

- Gill, A.E., 1982. Atmosphere Ocean Dynamics. Academic Press, Orlando, 662 pp.
- Oceanography Course Team, 1989. Seawater: Its Composition, Properties and Behaviour. Pergamon Press, Oxford, 165 pp.
- Oceanography Course Team, 1989. Ocean Circulation. Pergamon Press, Oxford, 165 pp.
- Oceanography Course Team, 1989. Waves, Tides and Shallow Water Processes. Pergamon Press, Oxford, 165 pp.
- Stewart, R., 2008. Introduction to physical oceanography, Texas A&M University, 353 pp. (udžbenik dostupan na web-u)
- Penzar, B., Penzar, I., Orlić, M., 2001. Vrijeme i klima hrvatskog Jadrana. Nakladnička kuća "Dr. Feletar", Zagreb, 258 pp.
- Cushman-Roisin, B., 1994. Introduction to Geophysical Fluid Dynamics. Prentice Hall, New Jersey, 318 pp.
- Buljan, M., Zore-Armanda, M., 1976. Oceanographic properties of the Adriatic Sea. Oceanography and Marine Biology - Annual Review, 14, 11-98.

### 1.11. Optional / additional reading (at the time of proposing study programme)

- Cushman-Roisin, B., Gačić, M., Poulain, P.-M., Artegiani, A., 2001. Physical Oceanography of the Adriatic Sea. Kluwer Academic Publishers, Dordrecht, 320 pp.
- Aktualni radovi iz područja istraživanja Jadrana (npr. Supić, N., Orlić, M., Degobbi, D., 2000. Istrian Coastal Countercurrent and its year-to-year variability. Estuarine, Coastal and Shelf Science, 50, 385-397.; Krajcar, V., 2003. Climatology of geostrophic currents in the Northern Adriatic. Geofizika, 20, 105-114.; Jeffries, M.A., Lee, C.M., 2007. A climatology of the northern Adriatic Sea's response to bora and river forcing. J. Geophys. Res. – Oceans. 112, C03S02)
- Mala internet škola oceanografije, link: <http://skola.gfz.hr/>

### 1.12. Number of assigned reading copies with regard to the number of students currently attending the course

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

### 1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences

Implementation of the system of quality control of the Department of Physics. Continuous interaction with students and discussions on quality of teaching process.



| Basic description                |   |           |
|----------------------------------|---|-----------|
| <b>Course coordinator</b>        | Ivica Orlić                                 |           |
| <b>Course title</b>              | Practicals in Nuclear Physics               |           |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |           |
| <b>Course status</b>             | optional                                    |           |
| <b>Year</b>                      | 1.  |           |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 2         |
|                                  | <b>Number of hours (L+E+S)</b>              | 0 + 0 + 2 |

| 1. COURSE DESCRIPTION  |
|--|
| <b>1.1. Course objectives</b>  |
| Acquiring skills in using complex nuclear data acquisition instrumentation. Gaining knowledge and experience in the application of nuclear experimental techniques. Training students for individual work on data analysis and the presentation and interpretation of results of measurements on the basis of previously acquired theoretical knowledge in the courses of Nuclear and Modern physics.  |
| <b>1.2. Course enrolment requirements</b>  |
| Course in Nuclear Physics . Also, it is assumed that students are familiar with general and theoretical physics corresponding to the study program, especially to be familiar with the <i>Modern physics I</i> and <i>Nuclear physics</i> , as well as with the probability theory and statistical physics.  |
| <b>1.3. Expected course learning outcomes</b>  |
| Upon completion of this course, students will be able to:<br>a) describe the experimental techniques and instruments used in Nuclear physics;<br>b) explain the theoretical principles underlying the experimental techniques and measuring devices used in exercises;<br>c) properly interpret X-ray and Gamma spectra obtained by measuring devices;<br>d) perform the data analysis and presentation of measured results;<br>e) discuss cause-effect relationships within a given experimental set-up.  |
| <b>1.4. Course content</b>   |
| Within this practicals, students will get acquainted with some of the applications of nuclear physics and techniques available at the Department of Physics, Laboratory for Elemental Microanalysis. They will have hands-on experience on the following .. acquainted with:<br><ol style="list-style-type: none"> <li>1. X-ray and Gamma detectors and the corresponding data acquisition techniques (amplifiers, MCA-s, as well as the corresponding software for data analysis),</li> <li>2. Spectrum acquisition and analysis by means of available professional software for spectrum fitting and data analysis,</li> <li>3. Energy calibration of X-ray and Gamma spectra,</li> <li>4. Introduction to the Roentgen apparatus as a source of X-ray spectra and measuring some of its characteristic such as spectrum analysis and its dependence on the anode voltage and current.</li> <li>5. Theoretical and experimental aspects of the quantitative XRF analysis by means of empirical and fundamental parameter methods,</li> <li>6. Energy loss of Alpha particles in air and various thin metal foils,</li> <li>7. Measuring mass absorption coefficients for various metal foils in the X-ray energy range (familiarisation with the K and L absorption edge and the corresponding physics behind these effects)</li> <li>8. PIXE and RBS (Particle induced X ray Emission and Rutherford Back Scattering): in collaboration with the Laboratory for Ion Beam Interactions (LIBI) from the Ruđer Bošković Institute, and with the help of the developed</li> </ol> |



|   |     |   |     |  |   |                   |     |
|---|-----|---|-----|--|---|-------------------|-----|
| <p>hardware and software for remote control of their Tandatron accelerator (based at the LIBI) students will be able to run PIXE and RBS experiments from our laboratory at the Department of Physics. They will collect and analyse PIXE and RBS spectra and perform qualitative and quantitative analysis of selected samples by means of professional software packages such as AXIL, GUPIX, TRIM, etc..</p>   |     |   |     |  |   |                   |     |
| <b>1.5. Teaching methods</b>  |     | <input type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork                         |     | <input checked="" type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input checked="" type="checkbox"/> other |   |                   |     |
| <b>1.6. Comments</b>  |     | <p>Students are required to be prepared for each exercise, to independently perform measurements and express them in tables, and finally to complete and report statistical analysis of measured data with a discussion of results and conclusions.</p> |     |  |   |                   |     |
| <b>1.7. Student's obligations</b>   |     |   |     |  |   |                   |     |
| <p>Students are required to regularly attend lab exercises and perform all the planned exercises. For each exercise students are required to write a short work plan (description of equipment, technique and quantities to be measured) and study the theory behind the experiment. Following the instructions for the use of measuring devices, students will perform all the required measurements, analyze data (spectra), interpret the results, formulate conclusions and write the final report. If the report for the particular exercise is not satisfactory, the student will have individual consultation. Only two absences during the lab course are tolerated, and the missed exercises will have to be executed before the end of the semester.</p>                  |     |   |     |  |   |                   |     |
| <b>1.8. Evaluation of student's work</b>  |     |   |     |  |   |                   |     |
| Course attendance   | 0.2 | Activity/Participation  |     | Seminar paper  |   | Experimental work | 0.3 |
| Written exam  |     | Oral exam   | 0.3 | Essay  |   | Research          |     |
| Project   |     | Sustained knowledge check   | 0.2 | Report   | 1 | Practice          |     |
| Portfolio   |     |   |     |  |   |                   |     |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |     |   |     |  |   |                   |     |
| <p>During the lab class students can earn up to 20 points. These points are awarded for each laboratory exercise separately. The structure of points is as follows:</p> <p>a) For each exercise, students will have to prepare oral explanation of the planned procedures and the underlying theory. In this way, students can collect up to 5 points.</p> <p>b) hands-on measurements will bring maximum of 5 points.</p> <p>c) Report with data analysis and interpretation of results will bring up to 5 points to student. This report will have to be submitted within 7 days after the experimental work.</p> <p>The remaining 5 points student can obtain through the final oral exam. Students are allowed to have final exam once they acquire a minimum of 10 points.</p> |     |   |     |  |   |                   |     |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>   |     |   |     |  |   |                   |     |
| <ol style="list-style-type: none"> <li>1. Handouts for Laboratory exercises in the structure of matter,</li> <li>2. S.A.E. Johansson, J.L. Campbell, C.G. Malmqvist, Particle Induced X-Ray Emission Spectroscopy, J. Wiley &amp; Sons, 1995.</li> <li>3. H. R. Verma,, Atomic and Nuclear Analytical Methods, Springer, 2007</li> </ol>  |     |   |     |  |   |                   |     |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>   |     |   |     |  |   |                   |     |
| <ol style="list-style-type: none"> <li>1. B. Beckhoff B. Kanngießner, N. Langhoff R.Wedell H.Wolff, Handbook of Practical X-Ray Fluorescence Analysis, Spriger, 2006.</li> <li>2. C. Leroy and PG Rancoita, Principles of Radiation Interaction in Matter and Detection, World Scientific, 2009.</li> </ol> <p>Additional literature for this course are all the references listed in the general and theoretical physics courses</p>   |     |   |     |  |   |                   |     |



(undergraduate study-physics), especially those for Modern Physics, nuclear Physics and the statistical methods in physical sciences.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title   | Number of copies                | Number of students |
|---|---------------------------------|--------------------|
| Handout for the course <i>Structure of matter lab</i>   | equal to the number of students |                    |
| S.A.E. Johansson, J.L. Campbell, C.G. Malmqvist, Particle Induced X-Ray Emission Spectroscopy, J. Wiley & Sons, 1995. | 1                               |                    |
| Kenneth S. Krane, <i>Modern Physics</i> , John Wiley, New York, 1995.   | 1                               |                    |
| H. R. Verma,, Atomic and Nuclear Analytical Methods, Springer, 2007   | 1                               |                    |
|   |                                 |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

The quality will be monitored through consultations, surveys and interviews after the exam.



| Basic description                |   |         |
|----------------------------------|---|---------|
| <b>Course coordinator</b>        | Goran Kniewald                                    |         |
| <b>Course title</b>              | Protection of the marine and coastal environments |         |
| <b>Study programme</b>           | Graduate study programme PHYSICS                  |         |
| <b>Course status</b>             | Optional  |         |
| <b>Year</b>                      | 2.  |         |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b>       | 6       |
|                                  | <b>Number of hours (L+E+S)</b>                    | 30+30+0 |

| 1. COURSE DESCRIPTION   |   |   |  |               |  |                   |  |
|---|---|---|--|---------------|--|-------------------|--|
| <b>1.1. Course objectives</b>   |   |   |  |               |  |                   |  |
| Students will gain a fundamental knowledge of the issues pertaining to the environmental protection of marine and coastal environments  |   |   |  |               |  |                   |  |
| <b>1.2. Course enrolment requirements</b>   |   |   |  |               |  |                   |  |
|   |   |   |  |               |  |                   |  |
| <b>1.3. Expected course learning outcomes</b>   |   |   |  |               |  |                   |  |
| Students will gain a fundamental knowledge of the issues pertaining to the environmental protection of marine and coastal environments. They will also acquire requisite competencies to participate in establishing strategies for the control of pollution as well as in designing environmental monitoring plans.  |   |   |  |               |  |                   |  |
| <b>1.4. Course content</b>  |   |   |  |               |  |                   |  |
| Fundamental concepts of physical, chemical, biological and geological oceanography – Ecology of marine populations and habitats – Ecosystem of the Adriatic sea – Environmental issues pertaining to coastal ecosystems – Sources and types of pollution of coastal areas – Action plans for environmental accidents in the sea – Integrated coastal zone management – Urbanization of coastal areas – Protection strategies of marine and coastal environments (preservation of biodiversity, sustainability, risk assessment, monitoring plans) |   |   |  |               |  |                   |  |
| <b>1.5. Teaching methods</b>  |   | <input checked="" type="checkbox"/> lectures<br><input type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |  |               | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratory work<br><input checked="" type="checkbox"/> mentorship<br><input checked="" type="checkbox"/> consultations |                   |  |
| <b>1.6. Comments</b>  |   |   |  |               |  |                   |  |
| <b>1.7. Student's obligations</b>   |   |   |  |               |  |                   |  |
| Course attendance and timely completion of term tasks/papers  |   |   |  |               |  |                   |  |
| <b>1.8. Evaluation of student's work</b>  |   |   |  |               |  |                   |  |
| Course attendance   | 1 | Activity/Participation  |  | Seminar paper |  | Experimental work |  |
| Written exam  | 5 | Oral exam   |  | Essay         |  | Research          |  |
| Project   |   | Sustained knowledge check   |  | Report        |  | Practice          |  |
| Portfolio   |   |   |  |               |  |                   |  |



**1.9. Assessment and evaluation of student's work during classes and on final exam**

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. Clark R.B. (2002) Marine pollution, 5<sup>th</sup> edition, Oxford University Press, Oxford.
2. Cicin-Sain B. and Knecht R.W. (1998) Integrated coastal and ocean management – concepts and practices, Island press, Washington DC.

**1.11. Optional / additional reading (at the time of proposing study programme)**

Additional reading and web-resources will be discussed with the course coordinator

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| <i>Title</i> | <i>Number of copies</i> | <i>Number of students</i> |
|--------------|-------------------------|---------------------------|
|              |                         |                           |
|              |                         |                           |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Quality monitoring methods will include the final grading of students exam papers. Student will have the possibility of an anonymous evaluation of the quality of the course, including the competencies and coursework standards of the teaching staff, appropriateness of assigned literature and optional reading.



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Predrag Dominis Prester                     |              |
| <b>Course title</b>              | Quantum Field Theory                        |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | optional                                    |              |
| <b>Year</b>                      | 1. or 2. year (depending on modul)          |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |   |  |
|--|---|--|
| <b>1.1. Course objectives</b>  |   |  |
| This is a course on the Quantum Field Theory on an introductory/medium level. An aim is to describe formalism in a general way so that it can be used in different disciplines in which QFT is an important tool. It is an obligatory course for students wanting to take a course <i>Elementary Particle Physics 2</i> on the second year.  |   |  |
| <b>1.2. Course enrolment requirements</b>  |   |  |
| None.  |   |  |
| <b>1.3. Expected course learning outcomes</b>  |   |  |
| Students should achieve understanding of Quantum Field Theory at the level which should enable them to apply the formalism on phenomena and processes in broad contexts, ranging from condensed matter up to elementary particle physics. Students will acquire knowledge and competences needed for understanding advanced applications of QFT, such as those developed in the courses <i>Elementary Particle Physics 2</i> and <i>Physical Cosmology</i> , or later during PhD studies and scientific research. This course also stimulates and develops general competences connected with analytical thinking and solving of complex problems by using advanced mathematical techniques.   |   |  |
| <b>1.4. Course content</b>   |   |  |
| 1. Bosonic fields – classical fields, Noether's theorem, canonical quantization, free Klein-Gordon field, particles as excitations of fields, antiparticles, nonrelativistic quantum fields and Landau-Ginzburg theory, quantization of electromagnetic field, quantum fluctuations, Casimir effect.<br>2. Fermionic fields – Dirac equation, problems with single particle interpretation, quantization of the free Dirac field, discrete symmetries, spin-statistics theorem, anions.<br>3. Interacting fields – processes, S-matrix, cross sections, Feynman diagrams, some elementary processes in the Quantum Electrodynamics.<br>4. Functional methods – path integrals, connection with statistical mechanics, symmetries.<br>5. Spontaneous symmetry breaking – global SSB and Goldstone bosons, local SSB and Higgs mechanism, superconductivity.<br>6. Brief introduction to the renormalization theory – loops and infinities, field and coupling constant renormalization, critical exponents and phase transitions. |   |  |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |
| <b>1.6. Comments</b>   |   |  |



**1.7. Student's obligations**

Active participation, home and class assignments and tests, preparing one seminar with presentation, passing final exam.

**1.8. Evaluation of student's work**

|                   |  |                           |     |               |   |                   |  |
|-------------------|--|---------------------------|-----|---------------|---|-------------------|--|
| Course attendance |  | Activity/Participation    | 0.5 | Seminar paper | 1 | Experimental work |  |
| Written exam      |  | Oral exam                 | 1.5 | Essay         |   | Research          |  |
| Project           |  | Sustained knowledge check | 3   | Report        |   | Practice          |  |
| Portfolio         |  |                           |     |               |   |                   |  |

**1.9. Assessment and evaluation of student's work during classes and on final exam**

Students will be evaluated and valued continuously during the course through home assignments and periodic tests. They have to write one seminar, which should be publicly presented. The course finishes with a final exam. Activities during the course bring at least 70% of the total mark.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory* (Westview Press; 1995)

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. A. Zee: *Quantum Field Theory in a Nutshell* (2. izdanje, Princeton University Press; 2010)
2. S. Weinberg: *The Quantum Theory of Fields 1 and 2* (Cambridge University Press; 2005)
3. N. Nagaosa: *Quantum Field Theory in Condensed Matter Physics* (Springer; 2010)
4. W. Siegel: *Fields* (<http://insti.physics.sunysb.edu/~siegel/Fields3.pdf>)

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Consultations, standard anonymous student questionnaires, discussions after the final exam.



| Basic description         |                                       |          |
|---------------------------|---------------------------------------|----------|
| Course coordinator        | Zoran Kaliman                         |          |
| Course title              | Quantum theory of Atoms and Molecules |          |
| Study programme           | Graduate Study Programme PHYSICS      |          |
| Course status             | compulsory                            |          |
| Year                      | 1.                                    |          |
| ECTS credits and teaching | ECTS student 's workload coefficient  | 6        |
|                           | Number of hours (L+E+S)               | 30+15+15 |

| 1. COURSE DESCRIPTION   |  |  |   |  |                                    |   |  |
|---|--|--|---|--|------------------------------------|---|--|
| <b>1.1. Course objectives</b>   |  |  |   |  |                                    |   |  |
| The goal of this course is to explain the most modern methods of quantum theory of atoms and molecules that are used in the understanding of their electronic structure. Special emphasis will be given on computational side of the issue.   |  |  |   |  |                                    |   |  |
| <b>1.2. Course enrolment requirements</b>   |  |  |   |  |                                    |   |  |
| There are no formal prerequisites for entering this course, but it assumes knowledge of general and theoretical physics and mathematical methods of physics.  |  |  |   |  |                                    |   |  |
| <b>1.3. Expected course learning outcomes</b>   |  |  |   |  |                                    |   |  |
| Knowledge of modern quantum theory of atoms and molecules. Understanding the theory and creation foundation for independent application of basic models to concrete examples.   |  |  |   |  |                                    |   |  |
| <b>1.4. Course content</b>  |  |  |   |  |                                    |   |  |
| Hartree - Fock model, canonical equations, interpretation of HF solutions of equations (Koopmans, Brillouin and virial theorem), polycentric molecules and Roothaan equations, Feynmann theorem, closed and open shell, computational realization: the basis set, electron correlation problem, the configuration interaction, natural orbitals, MCSCF methods, perturbation correlation treatment, Moeller-Plesset approach, CASSCF theory, the difference between static and dynamic correlation, CASSCF + PT2 procedure, "multireference configuration interaction" methods, density functional theory, time independent B3LYP DFT method. |  |  |   |  |                                    |   |  |
| <b>1.5. Teaching methods</b>  | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input checked="" type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment | <input checked="" type="checkbox"/> multimedia and network |
|   |  |  |   |  |                                    | <input type="checkbox"/> laboratories                     | <input type="checkbox"/> mentorship                        |
|   |  |  |   |  |                                    | <input type="checkbox"/> other                            |  |
| <b>1.6. Comments</b>  |  |  |   |  |                                    |   |  |
| <b>1.7. Student's obligations</b>   |  |  |   |  |                                    |   |  |
| Students must attend lectures and seminar in accordance with the Rules of the study.  |  |  |   |  |                                    |   |  |
| <b>1.8. Evaluation of student's work</b>  |  |  |   |  |                                    |   |  |
| Course attendance   | 0.5  | Activity/Participation                                     | 0.5   | Seminar paper                                    | 1.0                                | Experimental work   |  |
| Written exam  |  | Oral exam  | 2.5   | Essay  |                                    | Research  |  |
| Project   |  | Sustained knowledge  | 1.5   | Report   |                                    | Practice  |  |



|   |       |                  |  |                    |  |  |
|---|-------|------------------|--|--------------------|--|--|
|   | check |                  |  |                    |  |  |
| Portfolio   |       |                  |  |                    |  |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |       |                  |  |                    |  |  |
| Students will be evaluated during lectures and on final exam. Maximum percentage during lectures is 70%, and on final exam 30%. On final exam student should have at least 50% point to pass.<br>Detailed elaboration will be given in executive program.   |       |                  |  |                    |  |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>   |       |                  |  |                    |  |  |
| A.Szabo and N.S.Ostlund, "Modern Quantum Chemistry", Sec.Ed. McGraw-Hill, New York, 1989.   |       |                  |  |                    |  |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>   |       |                  |  |                    |  |  |
| <ol style="list-style-type: none"> <li>1. T.Helgaker, P.Joergensen and J.Olsen, "Molecular Electronic Structure Theory", Wiley, Chichester, 2000.</li> <li>2. Christopher Cramer, "Essentials of Computational Chemistry – Theories and Models", Wiley, Chichester, 2004.</li> <li>3. Z.B.Maksić, "Theoretical Models of Chemical Bonding", Springer-Verlag, Berlin-Heidelberg, Vol. 1-3, 1990-1991.</li> </ol> |       |                  |  |                    |  |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>   |       |                  |  |                    |  |  |
| Title   |       | Number of copies |  | Number of students |  |  |
| A.Szabo and N.S.Ostlund, "Modern Quantum Chemistry", Sec.Ed. McGraw-Hill, New York, 1989.   |       | 2                |  |                    |  |  |
|   |       |                  |  |                    |  |  |
|   |       |                  |  |                    |  |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>  |       |                  |  |                    |  |  |
| The quality will be monitored through consultations, surveys and interviews after the exam.   |       |                  |  |                    |  |  |



| Basic description                |  |          |
|----------------------------------|--|----------|
| <b>Course coordinator</b>        | Nada Orlić   |          |
| <b>Course title</b>              | Selected topics of Atomic and Molecular Spectroscopy |          |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS                     |          |
| <b>Course status</b>             | compulsory   |          |
| <b>Year</b>                      | 2.   |          |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b>          | 6        |
|                                  | <b>Number of hours (L+E+S)</b>                       | 30+15+15 |

| 1. COURSE DESCRIPTION  |   |   |
|--|---|---|
| <b>1.1. Course objectives</b>  |   |   |
| To introduce students to the latest techniques and applications of laser spectroscopy. Set quality theoretical foundation for later work of students in spectroscopic laboratories.  |   |   |
| <b>1.2. Course enrolment requirements</b>  |   |   |
| There are no formal prerequisites for entering this course, but it assumes knowledge of general and theoretical physics, mathematical methods of physics and that the students attended the course Atomic and molecular physics, or as part of undergraduate studies in physics, or at the first year of graduate study.   |   |   |
| <b>1.3. Expected course learning outcomes</b>  |   |   |
| Students after passing the exam will be able to: <ul style="list-style-type: none"> <li>• describe the absorption and emission of light;</li> <li>• list and describe what affects the width of the spectral line profiles;</li> <li>• describe the spectrographs and monochromators;</li> <li>• describe the various types of interferometers;</li> <li>• compare the spectrometers and interferometers;</li> <li>• describe the precise measurement of wavelengths;</li> <li>• list and describe the types of light detectors;</li> <li>• describe the fundamentals of lasers;</li> <li>• describe the differences between the so-called. single-mode lasers and tunable lasers;</li> <li>• enumerate the different types of absorption and emission spectroscopy;</li> <li>• describe and differentiate types of nonlinear spectroscopy;</li> <li>• describe and distinguish Raman spectroscopy techniques - linear and nonlinear Raman spectroscopy;</li> <li>• describe the formation and measurement of short laser pulses;</li> <li>• list and analyze the application of spectroscopy in various fields of science.</li> </ul> |   |   |
| <b>1.4. Course content</b>   |   |   |
| Absorption and emission of light. Widths and profiles of spectral lines: natural linewidth, Doppler, collisional, homogenous and inhomogenous broadening. Spectroscopic instrumentation: spectrographs and monochromators, interferometers, detectors. Fundamentals of lasers. Laser types. Absorption and emission spectroscopy. Nonlinear spectroscopy. Raman spectroscopy. Time-resolved spectroscopy. New developments in laser spectroscopy. Applications of laser spectroscopy in chemistry, environmental research, medicine.   |   |   |
| <b>1.5. Teaching methods</b>   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |



|  |     |                           |     |                  |     |                    |  |
|--|-----|---------------------------|-----|------------------|-----|--------------------|--|
| <b>1.6. Comments</b>   |     |                           |     |                  |     |                    |  |
| <b>1.7. Student's obligations</b>  |     |                           |     |                  |     |                    |  |
| Students must attend lectures and seminar in accordance with the Rules of the study.   |     |                           |     |                  |     |                    |  |
| <b>1.8. Evaluation of student's work</b>   |     |                           |     |                  |     |                    |  |
| Course attendance  | 0.5 | Activity/Participation    | 0.5 | Seminar paper    | 1.5 | Experimental work  |  |
| Written exam   |     | Oral exam                 | 2.5 | Essay            |     | Research           |  |
| Project  |     | Sustained knowledge check | 1.0 | Report           |     | Practice           |  |
| Portfolio  |     |                           |     |                  |     |                    |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |     |                           |     |                  |     |                    |  |
| Students will be evaluated during lectures and on final exam. Maximum percentage during lectures is 70%, and on final exam 30%. On final exam student should have at least 50% point to pass. Detailed elaboration will be given in executive program. |     |                           |     |                  |     |                    |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |     |                           |     |                  |     |                    |  |
| 1. W. Demtröder, <i>Laser spectroscopy, Volume 1, Basic principles</i> , Springer, 2008.   |     |                           |     |                  |     |                    |  |
| 2. W. Demtröder, <i>Laser spectroscopy, Volume 2, Experimental techniques</i> , Springer, 2008.  |     |                           |     |                  |     |                    |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |     |                           |     |                  |     |                    |  |
| 1. W.T. Silfvast, <i>Laser Fundamentals</i> , Cambridge University Press, 2004.  |     |                           |     |                  |     |                    |  |
| 2. A.P. Thorne, U. Litzen, S. Johansson, <i>Spectrophysics</i> , Springer, 1999.   |     |                           |     |                  |     |                    |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |     |                           |     |                  |     |                    |  |
| Title  |     |                           |     | Number of copies |     | Number of students |  |
| W. Demtröder, <i>Laser spectroscopy, Volume 1, Basic principles</i> , Springer, 2008.  |     |                           |     | 1                |     |                    |  |
| W. Demtröder, <i>Laser spectroscopy, Volume 2, Experimental techniques</i> , Springer, 2008.   |     |                           |     | 1                |     |                    |  |
|  |     |                           |     |                  |     |                    |  |
|  |     |                           |     |                  |     |                    |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |     |                           |     |                  |     |                    |  |
| The quality will be monitored through consultations, surveys and interviews after the exam.  |     |                           |     |                  |     |                    |  |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Mladen Petravić                             |              |
| <b>Course title</b>              | Semiconductors: Principles and Applications |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |   |  |     |               |   |                   |     |
|--|---|--|-----|---------------|---|-------------------|-----|
| <b>1.1. Course objectives</b>  |   |  |     |               |   |                   |     |
| To gain knowledge and develop understanding of principles and applications of semiconducting electronic materials.   |   |  |     |               |   |                   |     |
| <b>1.2. Course enrolment requirements</b>  |   |  |     |               |   |                   |     |
| Pass exams of Fundamentals of Physics and Solid State Physics.   |   |  |     |               |   |                   |     |
| <b>1.3. Expected course learning outcomes</b>  |   |  |     |               |   |                   |     |
| To gain knowledge about fundamental properties of semiconducting materials and techniques for tailoring these properties for specific applications and design of electronic devices.   |   |  |     |               |   |                   |     |
| <b>1.4. Course content</b>   |   |  |     |               |   |                   |     |
| 1. Introduction-Survey of Semiconducting Materials and Growth Techniques<br>2. Intrinsic and Extrinsic Semiconductors, Defects in Semiconductors<br>3. Electronic Structure, Conductivity and Transport Phenomena<br>4. Optical Properties of Semiconductors<br>5. Semiconductor Devices- from Diode and Transistor to Solar Cells and Lasers    |   |  |     |               |   |                   |     |
| <b>1.5. Teaching methods</b>   |   | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork |     |               | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input checked="" type="checkbox"/> mentorship<br><input type="checkbox"/> other |                   |     |
| <b>1.6. Comments</b>   |   |  |     |               |   |                   |     |
| <b>1.7. Student's obligations</b>  |   |  |     |               |   |                   |     |
| Active participation of students in classes and project work, with presentations of seminars. Acquirement, analysis and synthesis of competences in topics being taught via readings of bibliographical references. Discussion of these topics on lectures and exercises as well as via written and oral presentations, partial and final exams. |   |  |     |               |   |                   |     |
| <b>1.8. Evaluation of student's work</b>   |   |  |     |               |   |                   |     |
| Course attendance  |   | Activity/Participation   | 0.5 | Seminar paper | 1   | Experimental work |     |
| Written exam   | 1 | Oral exam  | 1   | Essay         |   | Research          | 0.5 |
| Project  | 1 | Sustained knowledge check  | 1   | Report        |   | Practice          |     |
| Portfolio  |   |  |     |               |   |                   |     |



**1.9. Assessment and evaluation of student's work during classes and on final exam**

Tuitions will be in form of lectures, project work and students' seminar work. Knowledge checking during classes will be performed via two partial exams and seminars.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

1. P.Y.Yu i M.Cardona, Principles of Semiconductors, Springer, Berlin, 2005.
2. S.O.Kasap, Principles of Electronic Materials and Devices, McGraw-Hill, New York, 2002

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. J.W.Mayer i S.S.Lau, Electronic Materials Science, Macmillan, New York, 1990.

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Interaction with students and discussions on quality of teaching process. Anonymous questionnaires on quality of teaching. Analysis of passing rates.



| Basic description                |   |           |
|----------------------------------|---|-----------|
| <b>Course coordinator</b>        | Željka Bošnjak                              |           |
| <b>Course title</b>              | Seminar in Physics on English               |           |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |           |
| <b>Course status</b>             | compulsory                                  |           |
| <b>Year</b>                      | 2. year                                     |           |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 2         |
|                                  | <b>Number of hours (L+E+S)</b>              | 0 + 0 + 1 |

| 1. COURSE DESCRIPTION  |  |   |   |               |   |                   |  |
|--|--|---|---|---------------|---|-------------------|--|
| <b>1.1. Course objectives</b>  |  |   |   |               |   |                   |  |
| Several courses on the first year of the study require preparation of a seminar. As research in physics necessarily assumes dissemination of results on English language, one of these seminars students must prepare and publicly present on English. The aim of this course is to offer help in preparation of the seminar, and secure space and time for discussions and questions. |  |   |   |               |   |                   |  |
| <b>1.2. Course enrolment requirements</b>  |  |   |   |               |   |                   |  |
| None.  |  |   |   |               |   |                   |  |
| <b>1.3. Expected course learning outcomes</b>  |  |   |   |               |   |                   |  |
| Developing communication and presentation skills on English language.  |  |   |   |               |   |                   |  |
| <b>1.4. Course content</b>   |  |   |   |               |   |                   |  |
| Time is shared between meetings, on which student is helped in preparation of the seminar and which are conducted in English, and public presentations.  |  |   |   |               |   |                   |  |
| <b>1.5. Teaching methods</b>   |  | <input type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |   |               | <input type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |                   |  |
| <b>1.6. Comments</b>   |  |   |   |               |   |                   |  |
| <b>1.7. Student's obligations</b>  |  |   |   |               |   |                   |  |
| Preparation and public presentation of a seminar on English language.  |  |   |   |               |   |                   |  |
| <b>1.8. Evaluation of student's work</b>   |  |   |   |               |   |                   |  |
| Course attendance  |  | Activity/Participation  |   | Seminar paper | 1   | Experimental work |  |
| Written exam   |  | Oral exam   |   | Essay         |   | Research          |  |
| Project  |  | Sustained knowledge check   |   | Report        |   | Practice          |  |
| Portfolio  |  | Public presentation   | 1 |               |   |                   |  |



|   |                         |                           |
|---|-------------------------|---------------------------|
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>                            |                         |                           |
| There is no separate mark for this course. Student is evaluated as a part of a course from which seminar is taken.  |                         |                           |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>                           |                         |                           |
| None.   |                         |                           |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>                               |                         |                           |
| None.   |                         |                           |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b> |                         |                           |
| <i>Title</i>  | <i>Number of copies</i> | <i>Number of students</i> |
|   |                         |                           |
|   |                         |                           |
|   |                         |                           |
|   |                         |                           |
|   |                         |                           |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>        |                         |                           |
| Consultations, standard anonymous student questionnaires, discussions after completion of the course.               |                         |                           |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Zdravko Lenac                               |              |
| <b>Course title</b>              | Solid State Physics I                       |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 8            |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 30 + 15 |

| 1. COURSE DESCRIPTION   |     |   |     |               |   |                   |  |
|---|-----|---|-----|---------------|---|-------------------|--|
| <b>1.1. Course objectives</b>   |     |   |     |               |   |                   |  |
| Acquiring common knowledge about the properties and applications of different materials, particularly regarding the basic properties of the crystal structure.  |     |   |     |               |   |                   |  |
| <b>1.2. Course enrolment requirements</b>   |     |   |     |               |   |                   |  |
| Completed the bachelor study with the passed course related to a basic knowledge of the quantum mechanics on a bachelor study.  |     |   |     |               |   |                   |  |
| <b>1.3. Expected course learning outcomes</b>   |     |   |     |               |   |                   |  |
| After completing the course, the student will be able to: understand the basic properties of materials, particularly crystals; make the synthesis of different fields of physics and understand their role in the complex model of a crystal structure.   |     |   |     |               |   |                   |  |
| <b>1.4. Course content</b>  |     |   |     |               |   |                   |  |
| Crystal structure (direct and reciprocal lattice). Diffraction of waves by crystals. Crystal binding. Crystal vibrations. Electron gas, Fermi surface. Dielectric properties (electrical and thermal conductivity; conductors, semi-conductors and isolators). Magnetic properties (diamagnetism, paramagnetism, ferromagnetism). |     |   |     |               |   |                   |  |
| <b>1.5. Teaching methods</b>  |     | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |     |               | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |                   |  |
| <b>1.6. Comments</b>  |     | Students are evaluated regarding their activity on lectures and exercises. Two written midterm exams. Final exam: oral.   |     |               |   |                   |  |
| <b>1.7. Student's obligations</b>   |     |   |     |               |   |                   |  |
| Regular attending the lectures, seminars and exercises; in-time delivering required homework; passing two midterms (writing part of the exam) with numerical tasks within the semester; passing the oral exam.  |     |   |     |               |   |                   |  |
| <b>1.8. Evaluation of student's work</b>  |     |   |     |               |   |                   |  |
| Course attendance   | 0.5 | Activity/Participation  | 0.5 | Seminar paper | 1.0   | Experimental work |  |
| Written exam  | 2.4 | Oral exam   | 2.4 | Essay         |   | Research          |  |



|  |  |                           |     |  |     |                         |  |                           |  |
|--|--|---------------------------|-----|--|-----|-------------------------|--|---------------------------|--|
| Project  |  | Sustained knowledge check | 0.6 | Report   | 0.6 | Practice                |  |                           |  |
| Portfolio  |  |                           |     |  |     |                         |  |                           |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |                           |     |  |     |                         |  |                           |  |
| Students are evaluated during the lectures and on the final exam. According to given Table 1.8, the student can get 70% of the total score during the lectures and 30% on the final (oral) exam.                 |  |                           |     |  |     |                         |  |                           |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |  |                           |     |  |     |                         |  |                           |  |
| V. Šips, <i>Uvod u fiziku čvrstog stanja</i> , Školska knjiga, Zagreb, 2003.<br>C. Kittel, <i>Introduction to Solid State Physics</i> , 8. izdanje, Wiley, New York, 2005.                                       |  |                           |     |  |     |                         |  |                           |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |  |                           |     |  |     |                         |  |                           |  |
| N. W. Ashcroft, N. D. Mermin, <i>Solid State Physics</i> , Holt, Rinehart and Winston, New York, 1976.<br>I. Kupčić, <i>Fizika čvrstog stanja, Zbirka riješenih zadataka</i> , HINUS, Zagreb, 1998.              |  |                           |     |  |     |                         |  |                           |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |  |                           |     |  |     |                         |  |                           |  |
|  |  |                           |     | <i>Title</i>   |     | <i>Number of copies</i> |  | <i>Number of students</i> |  |
|  |  |                           |     | V. Šips, <i>Uvod u fiziku čvrstog stanja</i> , Školska knjiga, Zagreb, 2003.               |     | 5                       |  | 5                         |  |
|  |  |                           |     | C. Kittel, <i>Introduction to Solid State Physics</i> , 8. izdanje, Wiley, New York, 2005. |     | 2                       |  | 5                         |  |
|  |  |                           |     |  |     |                         |  |                           |  |
|  |  |                           |     |  |     |                         |  |                           |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |  |                           |     |  |     |                         |  |                           |  |
| The continuous interaction with students. The anonymous questionnaires about the quality of teaching. Flexible adaptation of teaching according to students requirements. Evaluation of a success-rate on exams. |  |                           |     |  |     |                         |  |                           |  |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Zdravko Lenac                               |              |
| <b>Course title</b>              | Solid state physics 2                       |              |
| <b>Study programme</b>           | Graduate study programme PHYSICS            |              |
| <b>Course status</b>             | compulsory                                  |              |
| <b>Year</b>                      | 2.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6            |
|                                  | <b>Number of hours (L+E+S)</b>              | 30 + 15 + 15 |

| 1. COURSE DESCRIPTION  |     |   |     |               |   |                   |  |
|--|-----|---|-----|---------------|---|-------------------|--|
| <b>1.1. Course objectives</b>  |     |   |     |               |   |                   |  |
| Understanding the complex procedures in the application of the quantum mechanics to the atomic/molecular behavior in the crystal structure as well as the understanding the important experimental results that can be explained in that way.  |     |   |     |               |   |                   |  |
| <b>1.2. Course enrolment requirements</b>  |     |   |     |               |   |                   |  |
| Passed the exam of the course Solid state physics 1 on the Graduate study programme Physics.   |     |   |     |               |   |                   |  |
| <b>1.3. Expected course learning outcomes</b>  |     |   |     |               |   |                   |  |
| After completing the course, the student will be able to: make the synthesis of different fields of physics and understand their role in the complex model of a crystal structure; understand and apply the knowledge about relevant condensed matter properties acquired in this course as well as in the course Solid state physics 1. |     |   |     |               |   |                   |  |
| <b>1.4. Course content</b>   |     |   |     |               |   |                   |  |
| Many body theory. Collective excitations in crystals (phonons, plasmons). Fermi liquid (Hartree-Fock approximation). Electron-phonon interaction. Superconductivity. Optical properties of crystals (cyclotron resonance, excitons, polaritons; laser). Nano-structures.   |     |   |     |               |   |                   |  |
| <b>1.5. Teaching methods</b>   |     | <input checked="" type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input checked="" type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork |     |               | <input checked="" type="checkbox"/> individual assignment<br><input checked="" type="checkbox"/> multimedia and network<br><input type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> other |                   |  |
| <b>1.6. Comments</b>   |     | The students are evaluated regarding their activity on lectures and exercises. Two written midterm exams. Final exam: oral.   |     |               |   |                   |  |
| <b>1.7. Student's obligations</b>  |     |   |     |               |   |                   |  |
| Regular attending the lectures, seminars and exercises; in-time delivering required homework; passing two colloquiums (writing part of the exam) with numerical tasks within the semester; passing the oral exam.  |     |   |     |               |   |                   |  |
| <b>1.8. Evaluation of student's work</b>   |     |   |     |               |   |                   |  |
| Course attendance  | 0.3 | Activity/Participation  | 0.3 | Seminar paper | 0.8   | Experimental work |  |
| Written exam   | 1.8 | Oral exam   | 1.8 | Essay         |   | Research          |  |
| Project  |     | Sustained knowledge check   | 0.5 | Report        | 0.5   | Practice          |  |



|  |  |  |                         |                           |  |  |
|--|--|--|-------------------------|---------------------------|--|--|
| Portfolio  |  |  |                         |                           |  |  |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>   |  |  |                         |                           |  |  |
| The students are evaluated during the lectures and on the final exam. According to given Table 1.8, the student can get 70% of the total score during the lectures and 30% on the final (oral) exam.             |  |  |                         |                           |  |  |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>  |  |  |                         |                           |  |  |
| C. Kittel, <i>Introduction to Solid State Physics</i> , 8. Izdanje, Wiley, New York, 2005.<br>C. Kittel, <i>Quantum Theory of Solids</i> , 2. izdanje, Wiley, 1987.  |  |  |                         |                           |  |  |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>  |  |  |                         |                           |  |  |
| N. W. Ashcroft, N. D. Mermin, <i>Solid State Physics</i> , Holt, Rinehart and Winston, New York, 1976.<br>M. P. Marder, <i>Condensed Matter Physics</i> , 2. Izdanje, Wiley, 2010.                               |  |  |                         |                           |  |  |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>  |  |  |                         |                           |  |  |
|  |  | <i>Title</i>   | <i>Number of copies</i> | <i>Number of students</i> |  |  |
|  |  | V. Šips, <i>Uvod u fiziku čvrstog stanja</i> , Školska knjiga, Zagreb, 2003.               | 5                       | 5                         |  |  |
|  |  | C. Kittel, <i>Introduction to Solid State Physics</i> , 8. Izdanje, Wiley, New York, 2005. | 2                       | 5                         |  |  |
|  |  |  |                         |                           |  |  |
|  |  |  |                         |                           |  |  |
|  |  |  |                         |                           |  |  |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>   |  |  |                         |                           |  |  |
| The continuous interaction with students. The anonymous questionnaires about the quality of teaching. Flexible adaptation of teaching according to students requirements. Evaluation of a success-rate on exams. |  |  |                         |                           |  |  |



| Basic description                |   |              |
|----------------------------------|---|--------------|
| <b>Course coordinator</b>        | Željka Bošnjak                              |              |
| <b>Course title</b>              | Statistical Mechanics                       |              |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |              |
| <b>Course status</b>             | Compulsory                                  |              |
| <b>Year</b>                      | 1.  |              |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 8            |
|                                  | <b>Number of hours (L+E+S)</b>              | 45 + 15 + 15 |

| 1. COURSE DESCRIPTION   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
|---|--|--|--|---|--|------------------------------------|---|---|---------------------------------------|-------------------------------------|--------------------------------|
| <b>1.1. Course objectives</b>   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| Explanation of methods and applications of the statistical mechanics. Though the main emphasis is on applications in physics, through a number of examples also from different fields and disciplines (biology, finance, etc.) it will be explained how the methods and mathematical formalism could be in the broader context.   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.2. Course enrolment requirements</b>   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| None.   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.3. Expected course learning outcomes</b>   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| To achieve deep and thorough understanding of the statistical mechanics, which is a base for many other courses on this study. To develop broad and general competences which will enable student to independently apply methods and mathematical formalism for modeling and solving complex problems inside the realm of statistical mechanics, regardless of a context. |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.4. Course content</b>  |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
|   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.5. Teaching methods</b>  |  | <input checked="" type="checkbox"/> lectures | <input checked="" type="checkbox"/> seminars and workshops | <input checked="" type="checkbox"/> exercises | <input type="checkbox"/> long distance education | <input type="checkbox"/> fieldwork | <input checked="" type="checkbox"/> individual assignment | <input type="checkbox"/> multimedia and network | <input type="checkbox"/> laboratories | <input type="checkbox"/> mentorship | <input type="checkbox"/> other |
| <b>1.6. Comments</b>  |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.7. Student's obligations</b>   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| Active participation, home and class assignments and tests, passing final exam.   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.8. Evaluation of student's work</b>  |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| Course attendance   |  | Activity/Participation                       | 0.5  | Seminar paper                                 | 1  | Experimental work                  |   |   |                                       |                                     |                                |
| Written exam  |  | Oral exam                                    | 2.5  | Essay   |  | Research                           |   |   |                                       |                                     |                                |
| Project   |  | Sustained knowledge check                    | 4  | Report  |  | Practice                           |   |   |                                       |                                     |                                |
| Portfolio   |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |  |  |  |   |  |                                    |   |   |                                       |                                     |                                |



Students will be evaluated and valued continuously during the course through home assignments and periodic tests. The course finishes with a final exam. Activities during the course bring at least 70% of the total mark.

**1.10. Assigned reading (at the time of the submission of study programme proposal)**

J. P. Sethna, *Statistical Mechanics: Entropy, Order parameters and Complexity* (Oxford University Press; 2006), cijela knjiga slobodno dostupna na web-u na adresi: <http://pages.physics.cornell.edu/~sethna/StatMech/>

**1.11. Optional / additional reading (at the time of proposing study programme)**

1. R. K. Pathria and P. D. Beale, *Statistical Mechanics*, 3. edition (Academic Press; 2011)
2. R. Kubo, H. Ichimura, T. Usui, N. Hashitsume, *Statistical Mechanics* (North-Holland; 1990)
3. R. Balian, *From Microphysics to Macrophysics: Method and Applications of Statistical Physics, Vol. 1 and 2* (Springer; 2006)

**1.12. Number of assigned reading copies with regard to the number of students currently attending the course**

| Title | Number of copies | Number of students |
|-------|------------------|--------------------|
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |
|       |                  |                    |

**1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences**

Consultations, standard anonymous student questionnaires, discussions after the final exam.



| Basic description                |   |        |
|----------------------------------|---|--------|
| <b>Course coordinator</b>        | Nada Orlić                                  |        |
| <b>Course title</b>              | Structure of Matter Lab                     |        |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |        |
| <b>Course status</b>             | compulsory                                  |        |
| <b>Year</b>                      | 2.  |        |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6      |
|                                  | <b>Number of hours (L+E+S)</b>              | 0+0+60 |

| 1. COURSE DESCRIPTION   |   |
|---|---|
| <b>1.1. Course objectives</b>   |   |
| Acquiring skills in using complex measuring instruments. Gaining knowledge and experience in the application of experimental techniques for measuring physical quantities and phenomena at the atomic level. Training students for individual work on data analysis and the presentation and interpretation of measurement results on the basis of previously acquired theoretical knowledge in modern physics courses.   |   |
| <b>1.2. Course enrolment requirements</b>   |   |
| There are no formal prerequisites for entering this course, but it assumes knowledge of general and theoretical physics corresponding to the study program, especially the knowledge of the courses <i>Modern physics I</i> and <i>Modern physics II</i> , as well as basic knowledge of probability theory and mathematical statistics.  |   |
| <b>1.3. Expected course learning outcomes</b>   |   |
| Upon completion of this course, students will be able to:<br>a) describe the experimental techniques and instruments used to measure a phenomenon / physical quantity at the atomic level;<br>b) explain the theoretical principles underlying the experimental techniques and measuring devices used in exercises;<br>c) properly interpret the spectra obtained by measuring devices;<br>d) perform the data analysis and presentation of measurement results (tabular accounts, graphics) by their own;<br>e) discuss cause-effect relationships in the given content.   |   |
| <b>1.4. Course content</b>  |   |
| Fundamentals of atomic physics. Line spectrum of hydrogen. Balmer series/ determination of Rydbergs constant. Recording and interpretation of line spectra of inert gases and metal vapors. Electron diffraction. The critical potential. Measuring the diameter of the diffraction rings at different anode voltages. Determination of the wavelength of electrons at different voltages using the Bragg conditions. Confirmation of de Broglie wavelength. Parahelium and orthohelium. Rutherford experiment - measuring the number of particles scattered into certain angles and comparison with the theoretically expected values. Fundamentals of X-ray spectroscopy. Helium neon laser. Optical pumping. |   |
| <b>1.5. Teaching methods</b>  | <input type="checkbox"/> lectures<br><input checked="" type="checkbox"/> seminars and workshops<br><input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input type="checkbox"/> fieldwork<br><input checked="" type="checkbox"/> individual assignment<br><input type="checkbox"/> multimedia and network<br><input checked="" type="checkbox"/> laboratories<br><input type="checkbox"/> mentorship<br><input checked="" type="checkbox"/> other |
| <b>1.6. Comments</b>  | Students are required to be prepared for each exercise, to independently perform measurements and express them in tables, and finally to complete and report statistical analysis of measured data with a discussion of results and conclusions.  |
| <b>1.7. Student's obligations</b>   |   |



Students are required to regularly attend lab exercises and perform all the planned exercises. For each exercise students are required to write a short preparation for its implementation (description of equipment, technique and quantities to be measured) and prepare themselves for verbal explanation of the same content. Following the instructions for the use of measuring devices, students have to measure all the required data, analyze those data, interpret the results and formulate conclusions. Reports for already performed exercises and preparation for the next exercise are conditions for accession to the next exercise. If the report for the particular exercise in the opinion of teacher is not satisfactory, the student must come to the individual consultation. Only two absences during the lab course are allowed, and these exercises make up for in due course.

### 1.8. Evaluation of student's work

|                   |     |                           |     |               |     |                   |  |
|-------------------|-----|---------------------------|-----|---------------|-----|-------------------|--|
| Course attendance | 0.5 | Activity/Participation    | 0.5 | Seminar paper |     | Experimental work |  |
| Written exam      |     | Oral exam                 | 1.0 | Essay         |     | Research          |  |
| Project           |     | Sustained knowledge check | 2.0 | Report        | 2.0 | Practice          |  |
| Portfolio         |     |                           |     |               |     |                   |  |

### 1.9. Assessment and evaluation of student's work during classes and on final exam

During the lab class students can earn up to 70 grade points. These points are awarded partially, by each laboratory exercise separately. The structure of these points is as follows: a) For each exercise, students are preparing for verbal explanation of the planned procedures and underlying theory. In this way, students can collect up to 30 grade points. b) by self-activity in performing measurements students can earn up to 10 grade points. c) For reports (homework) containing successful data analysis and correct interpretation of results, the teacher can assign up to 30 grade points to student. The particular report has to be submitted within 7 days after the exercise was held.

The remaining 30 grade points on the course the student can gather demonstrating adequate knowledge on the final exam, which is of verbal type and aimed to recap all of applied methods and underlying theories in a lab course as a whole. Students access the final exam with a minimum of 40 grade points collected during the lab class.

### 1.10. Assigned reading (at the time of the submission of study programme proposal)

1. Handout for Laboratory exercises in the structure of matter
2. R. Barlow, *Statistics-A Guide to the Use of Statistical Methods in the Physical Sciences*, John Wiley, New York, 1989.
3. Kenneth S. Krane, *Modern Physics*, John Wiley, New York, 1995.

### 1.11. Optional / additional reading (at the time of proposing study programme)

Additional readings for this course may be all references listed in the general and theoretical physics courses (undergraduate study-physics), especially those for Modern Physics II and the use of statistical methods in the physical sciences.

### 1.12. Number of assigned reading copies with regard to the number of students currently attending the course

| Title   | Number of copies                | Number of students |
|---|---------------------------------|--------------------|
| Handout for the course <i>Structure of matter lab</i>   | equal to the number of students |                    |
| R. Barlow, <i>Statistics-A Guide to the Use of Statistical Methods in the Physical Sciences</i> , John Wiley, New York, 1989. | 1                               |                    |
| Kenneth S. Krane, <i>Modern Physics</i> , John Wiley, New York, 1995.   | 1                               |                    |
|   |                                 |                    |

### 1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences

The quality will be monitored through consultations, surveys and interviews after the exam.



| Basic description                |   |           |
|----------------------------------|---|-----------|
| <b>Course coordinator</b>        | Boštjan Surina                              |           |
| <b>Course title</b>              | Terrestrial Ecology                         |           |
| <b>Study programme</b>           | Graduate Study Programme PHYSICS            |           |
| <b>Course status</b>             | optional                                    |           |
| <b>Year</b>                      | 2.  |           |
| <b>ECTS credits and teaching</b> | <b>ECTS student 's workload coefficient</b> | 6         |
|                                  | <b>Number of hours (L+E+S)</b>              | 30P + 30V |

## 1. COURSE DESCRIPTION

### 1.1. Course objectives

The main objective is to present students the principles of terrestrial ecology, which regards living organisms, including people, and the elements of their environment as components of a single integrated system. The wild field coverage of the course will examine the central processes at work in terrestrial ecosystems, including their freshwater components. It will trace the flow of energy, water, carbon, and nutrients from their abiotic origins to their cycles through plants, animals, and decomposer organisms. As well as detailing the processes themselves, the course will try to integrate them at various scales of magnitude—those of the ecosystem, the wider landscape and the globe. The course will synthesize recent advances in ecology with established and emerging ecosystem theory to offer a wide-ranging survey of ecosystem patterns and processes in our terrestrial environment. Additionally, course aims at understanding the Mediterranean environment in past and present.

### 1.2. Course enrolment requirements

### 1.3. Expected course learning outcomes

Students will be able to understand and recognize principles of basic processes in terrestrial ecosystems from lowlands to the mountains, their change in time, as well as nutrients cycling in natural environments. To that end, they will recognize and understand human impact on Mediterranean landscape as well as importance of anthropogenic habitats on patterns of biodiversity in the Mediterranean. Students will get acquainted with various approaches and research methods in the field of ecology which will enable them to integrate knowledge through a development of scientific thinking. Due to the pronounced multidisciplinary of the course, students will get a general overview on the field of ecology.

### 1.4. Course content

#### General part

Context The Ecosystem Concept.- Earth's Climate System.- Geology, Soils, and Sediments. Mechanisms Water and Energy Balance.- Carbon Inputs to Ecosystems.- Plant Carbon Budgets.- Decomposition and Ecosystem Carbon Budgets.- Plant Nutrient Use.- Nutrient Cycling.- Trophic Dynamics.- Species Effects on Ecosystem Processes Patterns Temporal Dynamics.- Landscape Heterogeneity and Ecosystem Dynamics Integration Changes in the Earth System. Managing and Sustaining Ecosystem

#### Special part

Mediterranean climates in the World (Mediterranean, South Africa, Australia, Chile, California); Climatology of the Mediterranean in present and past; Geology and geomorphology of the Mediterranean; Mediterranean vegetation in time and space; First humans and their impact on the Mediterranean landscape; Mediterranean ecosystems; Patterns of biodiversity in the Mediterranean; Nature conservation in the Mediterranean; Mediterranean in Croatia.

### 1.5. Teaching methods

lectures

seminars and workshops

individual assignment

multimedia and network



|   |     |   |     |   |                           |
|---|-----|---|-----|---|---------------------------|
|   |     | <input type="checkbox"/> exercises<br><input type="checkbox"/> long distance education<br><input checked="" type="checkbox"/> fieldwork |     | <input type="checkbox"/> laboratory work<br><input type="checkbox"/> mentorship<br><input type="checkbox"/> consultations |                           |
| <b>1.6. Comments</b>  |     |   |     |   |                           |
| <b>1.7. Student's obligations</b>   |     |   |     |   |                           |
| Presence at the field work is mandatory   |     |   |     |   |                           |
| <b>1.8. Evaluation of student's work</b>  |     |   |     |   |                           |
| Course attendance   | 0.3 | Activity/Participation  | 0.3 | Seminar paper   | Experimental work         |
| Written exam  | 5.4 | Oral exam   |     | Essay   | Research                  |
| Project   |     | Sustained knowledge check   |     | Report  | Practice                  |
| Portfolio   |     |   |     |   |                           |
| <b>1.9. Assessment and evaluation of student's work during classes and on final exam</b>  |     |   |     |   |                           |
| Following and tagging student's presence (5% of the total mark) and activit participation at lectures (5% of the total mark); written exam (90% of the total mark)  |     |   |     |   |                           |
| <b>1.10. Assigned reading (at the time of the submission of study programme proposal)</b>   |     |   |     |   |                           |
| Chapin, F., Matson, P. & Mooney, H. 2002: Principles of Terrestrial Ecosystem Ecology. Springer-Verlag.<br>Grove, A.T. & Rackham, O. 2003: The Nature od Mediterranean Europe. An Ecological History. New Haven & London, Yale University Press.  |     |   |     |   |                           |
| <b>1.11. Optional / additional reading (at the time of proposing study programme)</b>   |     |   |     |   |                           |
| Allen, H. D. 2001: Mediterranean Ecography. Prentice-Hall.<br>Dallman, P.R. 1998: Pant Life in the World's Mediterranean Climates. Oxford, Oxford University Press.<br>Bolle, H.J. 2003: Mediterranean Climate. Springer-Verlag.<br>Conacher, A.J. & Sala, M. 1998: Land Degradation in Mediterranean Environments of the World. John Wiley and Sons.<br>King, R., de Mas, P. & Beck, J.M. 2000: Geography, Environment and Developmnet in the Mediterranean. Sussex Academic Press.<br>King, R., Proudfoot, L. & Smith, B. 1997: The Mediterranean. Hodder Arnold. |     |   |     |   |                           |
| <b>1.12. Number of assigned reading copies with regard to the number of students currently attending the course</b>   |     |   |     |   |                           |
|   |     | <i>Title</i>  |     | <i>Number of copies</i>   | <i>Number of students</i> |
|   |     | Chapin, F., Matson, P. & Mooney, H. 2002: Principles of Terrestrial Ecosystem Ecology. Springer-Verlag.                                 |     | 1   | 5                         |
|   |     | Grove, A.T. & Rackham, O. 2003: The Nature od Mediterranean Europe. An Ecological History. New Haven & London, Yale University Press.   |     | 1   | 5                         |
| <b>1.13. Quality monitoring methods which ensure acquirement of output knowledge, skills and competences</b>  |     |   |     |   |                           |
| Stimulation of interdisciplinary approach through frontal and individual course presentation as well as consultations with students; understanding principles of terrestrial ecology while searching for solutions in contemporary problems;  |     |   |     |   |                           |