Sveučilište u Rijeci • University of Rijeka
Trg braće Mažuranića 10 • 51 000 Rijeka • Croatia
T: (051) 406-500 • F: (051) 216-671; 216-091
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Basic description		
Course coordinator		
Course title	Advanced computational physics	
Study programme	Graduate Study Programme PHYSICS	
Course status	Optional	
Year	1., 2.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	6
	Number of hours (L+E+S)	30 + 15 + 15

1. COURSE DESCRIPTION

1.1. Course objectives

Learning of methods for solving complex physical problems using numerical methods. Learing and application of different optimization methods. Training programming skills. Preparing for future application of numerical methods in scientific research.

1.2. Course enrolment requirements

Operational knowledge of programming in FORTRAN or C++.

1.3. Expected course learning outcomes

Students will be expected to describe numerical methods in physics and mathematics, write simple computer codes using simulations, use existing packages for simulationa, animation and visualization, define optimization, distinguish different optimization methods, describe genetic algorithms, write a computer code which optimizes a non-liner problem using a chosen optimization methods, and perform a computational analysis of simulated and measured data.

1.4. Course content

Numerical methods in physics and mathematics. Monte Carlo simulation. Animation and visualisation of computer simulations. Numerical optimization methods of solving multidimenzional physical problems. Simplex algorithm. Neural networks. Genetic algorithms. Simulations in high-energy physics and astrophysics. Computationl analysis of simulated and measured physical data.

1.5. Teaching methods	☒ lectures ☒ seminars and workshops ☒ exercises ☒ long distance education ☐ fieldwork	☒ individual assignment ☒ multimedia and network ☐ laboratories ☐ mentorship ☐ other
1.6. Comments	The course will be subject to changes and continuous improvements, depending on the availability of new software and hardware.	

1.7. Student's obligations

Course attendance, homework, individual project.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		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

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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

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.

1.3. Expected course learning outcomes

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.

1.4. Course content

1. Introduction
2. Maxwell's equations
3. Wavegudes, resonant cavites and optical fibers
4. Diffraction and scattering
5. Collisions and radiation of charged particles
6. Cerenkov and Bremsstrahlung radiation
7. Quantization of electromagnetic field
8. Cavity QED

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

It is expected that the student will follow the course activly and write an seminar paper. Furthermore the student will take the final exam.

1.8. Evaluation of student's work

Course attendance	2.5	Activity/Participation	1.5	Seminar paper	1	Experimental work	
Written exam		Oral exam	1	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

The seminar paper will be evaluated during the term. At the end, final exam will be evaluated.

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

J. D. Jackson, *Classical Electrodyanamics* (3. edition, John Wiley & Sons, Inc.)

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

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 anonymous polls.

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Basic description		
Course coordinator		
Course title	Advanced Experimental Laboratory	
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)	0 + 0 + 60

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

Solid State Physics, Experimental Methods in Physics and Physics of Semiconductors

1.3. Expected course learning outcomes

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.

1.4. Course content

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:

-XPS (X-ray Photoelectron Spectroscopy)
-SIMS (Secondary Ion Mass Spectrometry)
-AFM (Atomic Force Microscopy)
-SEM (Scanning Electron Microscopy)
-XRF (X-ray Fluorescence)

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.

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

Active participation in experimental work, data acquisition, analysis and interpretation and oral presentation of experiments.

1.8. Evaluation of student's work

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Course attendance	2	Activity/Participation		Seminar paper	1.5	Experimental work	1
Written exam		Oral exam		Essay		Research	1.5
Project		Sustained knowledge check		Report		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.Woodrruff and T.A.Delchar, Modern Tecniques 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.

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Basic description		
Course coordinator		
Course title	Advanced Quantum Physics	
Study programme	Graduate study programme PHYSICS	
Course status	compulsory	
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

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.

1.2. Course enrolment requirements

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.

1.3. Expected course learning outcomes

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.

1.4. Course content

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.

1.5. Teaching methods	☒ lectures ☒ seminars and workshops ☒ exercises ☐ long distance education ☐ fieldwork	☒ individual assignment ☒ multimedia and network ☐ laboratories ☐ mentorship ☐ other
1.6. Comments	Students are evaluated regarding their activity on lectures and exercises. Two written midterm exams. Final exam: oral.	

1.7. Student's obligations

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.

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1.8. Evaluation of student's work

Course attendance	3	Activity/Participation		Seminar paper	0.5	Experimental work	
Written exam		Oral exam	2.5	Essay		Research	
Project		Sustained knowledge check	2	Report		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, *Teorijska fizika i struktura materije*, 1. i 2. dio, Školska knjiga, Zagreb, 1977.	4	15
D. J. Griffiths, *Introduction to Quantum Mechanics*, 2nd ed., Prentice-Hall, New Jersey, 2005.	3	15
W. A. Harrison, *Applied quantum mechanics*, 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		
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 γ- 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 flesh 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

- ☒ 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

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	3	Activity/Participation		Seminar paper	0.5	Experimental work	
Written exam		Oral exam	2.5	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 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-Vitensee: 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.

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Basic description		
Course coordinator		
Course title	Astronomy and astrophysics II	
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)	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, metalicity, 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 – Eliptical 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	☒ 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

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	2	Activity/Participation		Seminar paper	1	Experimental work	
Written exam		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

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-Vitensee: 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
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.

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Basic description		
Course coordinator		
Course title	Astroparticle Physics	
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)	30+15+15

1. COURSE DESCRIPTION

1.1. Course objectives

To give a broad overview of astrophysics – expose students to current developments in physics.

1.2. Course enrolment requirements

Elementary Particle Physics 1 ; Astronomy and Astrophysics 1

1.3. Expected course learning outcomes

Training students to apply physics in understanding of the Universe. Preparation for the research work in modern physics.

1.4. Course content

Broad survey: overview of astroparticle physics. EM signal from stars and galaxies, inetrestellar 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 radiaton. Examples in astrophysics where synchrtornon radiation is observed (gamma ray bursts, quasars, SN remnants, microquasars). Gravitational waves . Dark matter (evidence; laboratory searches).

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

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	2	Activity/Participation		Seminar paper	0.8	Experimental work	
Written exam		Oral exam	1.2	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

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.

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Basic description		
Course coordinator		
Course title	Astrophysics lab	
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)	0+0+60

1. COURSE DESCRIPTION

1.1. Course objectives

Gaining practial knowledge and skills in experimental (observational) astrophysics and data reduction. Preparing for scientific research in astrophysics.

1.2. Course enrolment requirements

Mandatory: Courses „Astronomy and Astrophysics I“ and „Observational astrophysics“.

1.3. Expected course learning outcomes

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 independance in solving particular scientific problems.

1.4. Course content

1) Optical telescopes reflector and refractor.
   CCD camera.
   Spectrometer.
2) Data reduction of photometric CCD images.
   Determining stellar photometric colors.
   Determining width of the spectral lines.
   Spectral classification.
   Simulating atmospheric showers (CORSIKA).
   Visualisation of analysis results in astrophysics. (ROOT, SuperMongo)
3) Observing atmospheric showers using Cherenkov telescope (*)

1.5. Teaching methods	☐ lectures ☐ seminars and workshops ☒ exercises ☐ long distance education ☒ fieldwork	☒ individual assignment ☒ multimedia and network ☒ laboratories ☒ mentorship ☐ other
1.6. Comments	Part 1) of this lab will be performed at the Astronomical center (observatory for public and outreach) at Sv. Kriz, Rijeka. Part 2) will be performed in the computing lab at the Department of physics of the University of Rijeka.	

	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.

1.7. Student's obligations

Course attendance, labs, preparing labs, lab reports, final exam.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper		Experimental work	1
Written exam		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

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. CORSIKA manual
4. ROOT manual

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. Complex laboratory exercise will include consultatory work, and develop creativity through active learning.

Basic description		
Course coordinator		
Course title	Atmospheric Physics	
Study programme	Graduate study programme PHYSICS	
Course status	compulsory	
Year	1.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	7
	Number of hours (L+E+S)	30+15+15

1. COURSE DESCRIPTION

1.1. Course objectives

To gain knowledge and develop understanding of principles of atmospheric physics, basic thermodynamic model, weather formation, global worming and aerosol pollution and its effect on human health.

1.2. Course enrolment requirements

Diploma

1.3. Expected course learning outcomes

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.

1.4. Course content

1. Introduction to the physics of atmosphere: A brief survey of the atmosphere
2. The Earth System: Oceans, atmosphere, the earth's crust and mantle, a brief history of climate,
3. Atmospheric Thermodynamics: gas laws, hydrostatic equation, thermodynamic laws, water vapour in the air.
4. Radiative transfer: blackbody radiation, scattering and absorption, radiative transfer and balance
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.
6. Atmospheric dynamics: general circulation, weather systems, weather prediction.
7. Climate dynamics: climate monitoring and predictions, recent climate changes, greenhouse warming, projections of future climate.

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

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	2	Activity/Participation		Seminar paper	0.5	Experimental work	
Written exam	1	Oral exam	1	Essay		Research	
Project		Sustained knowledge check	2.5	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, 2001Dana 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.

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Basic description		
Course coordinator		
Course title	Atomic and molecular physics	
Study programme	Graduate Study Programme PHYSICS	
Course status	compulsory	
Year	1.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	8
	Number of hours (L+E+S)	45+15+15

1. COURSE DESCRIPTION

1.1. Course objectives

The acquisition of advanced knowledge of atomic and molecular physics. Introduction to modern theoretical and experimental methods in physics research.

1.2. Course enrolment requirements

There are no formal prerequisites for entering this course, but it assumes knowledge of general and theoretical physics and mathematical methods of physics.

1.3. Expected course learning outcomes

Students after passing the exam will be able to:
- describe atoms, their size, electronic structure, mass, cross section and the distribution of electrons in the atom;
- provide a complete quantum-mechanical description of the hydrogen atom;
- describe and analyze the spectrum of helium and alkali atoms;
- describe the theoretical models for multielectron atoms;
- define and distinguish between ground and excited states of atoms;
- describe and analyze the transition probabilities, selection rules, lifetimes of excited states of atoms and profiles of spectral lines;
- describe diatomic molecules, molecular orbitals and electronic states of these molecules;
- apply the fundamentals of group theory to determine the symmetry of molecules;
- explain and analyze the spectra of polyatomic molecules;
- describe and analyze the molecules in the excited state and the associated dynamic processes;
- give examples of applications of atomic and molecular physics and the role of atomic and molecular physics in modern research.

1.4. Course content

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.

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

Students must attend lectures and seminar in accordance with the Rules of the study.

1.8. Evaluation of student's work

Course attendance	2.5	Activity/Participation		Seminar paper	1	Experimental work	
Written exam		Oral exam	2.5	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 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.

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

1. W. Demtröder, *Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics*, Springer , 2011.
2. W. Demtröder, *Molecular Physics: Theoretical Principles and Experimental Methods*, John Wiley&Sons, 2008.

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

1. B. H. Bransden, C. J. Joachain, *Physics of Atoms and Molecules*, Pearson Education, 2003.
2. L. Klasinc, Z. Maksić, N. Trinajstić, *Simetrija molekula*, Školska knjiga, Zagreb, 1979.
3. G. Herzberg, *Atomic Spectra and Atomic Structure*, Dover Publications, 2010.

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
W. Demtröder, *Atoms, Molecules and Photons: An Introduction to Atomic-, Molecular- and Quantum Physics*, Springer , 2011.	1	
W. Demtröder, *Molecular Physics: Theoretical Principles and Experimental Methods*, John Wiley&Sons, 2008.	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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

General Ecology

1.3. Expected course learning outcomes

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.

1.4. Course content

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.

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

Course attendance, Activity/Participation, Practice, Written exam

1.8. Evaluation of student's work

Course attendance	1	Activity/Participation		Seminar paper		Experimental work	
Written exam	1.5	Oral exam		Essay		Research	
Project		Sustained knowledge check		Report		Practice	0.5
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: Introductionary questionnaire on the course's expectations. Final anonymus questionnaire on the quality of the performed class.

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Basic description		
Course coordinator		
Course title	Electrodynamics	
Study programme	Graduate Study Programme PHYSICS	
Course status	compulsory	
Year	1.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	7
	Number of hours (L+E+S)	45 + 45 + 0

1. COURSE DESCRIPTION

1.1. Course objectives

- Giving the basic knowledge of classical electrodynamics and special theory of relativity
- Connecting the exact theoretical results with the relevant objects from electricity and magnetism that students have learned in earlier courses (Physics I-III)

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

- Understanding the idea how simple and basic equations for the electromagnetic field, with the help of mathematical methods, can explain complex physical phenomena.
- Understanding the significance of the exact definition of physical quantities for their correct interpretation.

1.4. Course content

1. Electrostatics
Coulomb law. Electric field. Scalar potential. Equations of electrostatics. Energy. Multipole expansion. Electrostatics in media. Dielectrics. Boundary conditions.
2. Magnetostatics
Electric current. Continuity equation. Magnetic field and force. Vector potential. Equations of magnetostatics. Magnetostatics in media. Diamagnetism. Paramagnetism. Ferromagnetism.
3. Maxwell equations
Faraday law of induction. Energy of magnetic field. Maxwell equations. 4-potential. Gauge transformations. Poynting theorem. Conservation laws. Electrodynamics in the media.
4. Radiation
Retarded and advanced potentials. Dipole approximation. Radiation reaction force.
5. Special relativity
Kinematics and dynamics. 4-vectors and tensors. Lorenz transformations of fields, charge density and currents. Covariant formulation of electrodynamics.

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

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

1.8. Evaluation of student's work

Course attendance	3	Activity/Participation		Seminar paper		Experimental work	
Written exam		Oral exam	1.5	Essay		Research	
Project		Sustained knowledge check	2.5	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. 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., *Introduction to Electrodynamics*	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.

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Basic description		
Course coordinator		
Course title	Electronics	
Study programme	Graduate Study Programme PHYSICS	
Course status	optional	
Year	1.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	6
	Number of hours (L+E+S)	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 – pasive and active. Multivibrators. Digital circuits.

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

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	2	Activity/Participation	0.5	Seminar paper		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. Seeger: Semiconductor physics, Springer 1991
http://wnt.cc.utexas.edu/~wlh/index.cfm

http://viper.hep.princeton.edu/~mcdonald/examples/

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*
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.

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Basic description		
Course coordinator		
Course title	Electronics laboratory	
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)	0+0+60

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

Students must have passed the exam in Electronics.

1.3. Expected course learning outcomes

By completing the practical laboratory exercises the students should achieve the following skills and knowledge:
- 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,
- develop specific skills in planning and carrying out experiment in order to solve specific physical problem,
- perform measurements of specific physical entities using appropriate measuring techniques and instruments in order to investigate the physical phenomena or/and hypothesis,
- gaining competence in statistical analysis, display and interpretation of experimental results,
- acquire practical knowledge in application of basic electronic elements, circuits, devices and systems.
- independently construct simpler electronic devices and circuits, such as transistor amplifier, operational amplifier in analog circuits, active filters, electronic oscillator, multivibrators, digital circuits.

1.4. Course content

Students perform individually and independently the following laboratory exercises:
1. Characteristics of bipolar transistor
2. Low-signal transistor amplifier
3. Operational amplifier
4. Active electronic filters
5. Oscillator
6. Multivibrators (bistable, monostable, astable)
7. Digital circuits (OR, AND, NOT, NOR, NAND)

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

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.

1.8. Evaluation of student's work

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

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

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:
- sustained knowledge check required to successfully finish the laboratory exercise – 50 points,
- report on performed measurements, with their statistical analysis and interpretation – 50 points.

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.

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
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

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

D.V. Hall: Digital circuits and systems, Mc Graw-Hill, 1989
D.L. Schilling, C.Belove: Electronic circuits, Mc Graw-Hill, 1989
K. Seeger: Semiconductor physics, Springer 1991
B. Juzbašić: Elektronički elementi, 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*
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

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

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.

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Basic description		
Course coordinator		
Course title	Elementary Particle Physics 1	
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

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.

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

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.

1.4. Course content

1. "Fundamental" forces – ranges (scales) and strength, coupling constants
2. Quantum field theories – particles as excitations of fields, importance of symmetries, antiparticles
3. Particle processes – decays, scattering, cross sections, bound states, Feynman diagrams
4. Quantum electrodynamics – gauge invariance, Compton scattering, positronium
5. Strong force – quark model, confinement, basics of Quantum Chromodynamics
6. Weak force – beta-decay, basics of electroweak unification (spontaneous symmetry breaking, Higgs bosons)
7. Brief introduction to the Standard model of elementary particle physics
8. Experiments and connections with astrophysics and cosmology

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

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	3	Activity/Participation		Seminar paper	1	Experimental work	
Written exam		Oral exam	2	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)

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* (Hinus, 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, *Fizika elementarnih čestica*	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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

This course builds on the course *Elementary Particle Physics 1* 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.

1.2. Course enrolment requirements

Completed courses: *Advanced Electrodynamics*, *Advanced Quantum Mechanics*, *Elementary Particle Physics 1*, *Quantum Field Theory*

1.3. Expected course learning outcomes

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.

1.4. Course content

Quantization of nonabelian gauge field theories – unitary gauges, nonunitary gauges and Faddeev-Popov method, ghosts.
Quark interactions and Quantum Chromodynamics – partons, running coupling constant, asymptotic freedom, parton distribution functions.
Higher-order processes – elementary one-loop calculations.
Effective theories – pions as Goldstone bosons, effective theories and renormalisation, Fermi theory.
Weak interactions – generalisation of the Fermi theory, heavy bosons, GIM mechanism, CP violation in neutral meson systems.
Standard Model – Glashow-Weinberg-Salam theory.
Anomalies – chiral anomaly, global and local anomalies.
Beyond Standard Model physics – 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.

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

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	2	Activity/Participation		Seminar paper	1	Experimental work	
Written exam		Oral exam	1	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)

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.

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Basic description		
Course coordinator		
Course title	Environmental impact assessment	
Study programme	Graduate Study Programme PHYSICS	
Course status	optional	
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

Gaining competence in working on environmental impact assessment studies

1.2. Course enrolment requirements

One course in ecology or environmental protection.

1.3. Expected course learning outcomes

Students will be able to work productively on environmental impact assessment studies..

1.4. Course content

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.

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

Attendance to lectures and participation in a seminar with a project. Independent problem solving.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper	0.5	Experimental work	
Written exam	1.5	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

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 Imapct assessment of Development Projects, A Handbook for practicioners, Elsevier , London, 1992

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*
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.

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Basic description		
Course coordinator		
Course title	Environmental Microbiology	
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)	30+20+10

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 exames 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 Croatian; 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	☒ lectures ☐ seminars and workshops ☒ exercises ☐ long distance education ☒ fieldwork	☐ individual assignment ☐ multimedia and network ☒ laboratories ☐ mentorship ☐ 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.

1.7. Student's obligations

Attendance on lectures and exercises and passing the exam.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper	1	Experimental work	1
Written exam	1	Oral exam		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

In accordance with the Regulations on the Assessment of the University of Rijeka.

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

Duraković S, Redžepović S. Uvod u opću mikrobiologiju – knjiga prva. Kugler, Zagreb, 2002.

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

Hurst CJ, Crawford RL, Garland JL, Lipson DA, Mills AL, Stetzenbach LD. Manual of Environmental Microbiology – Third edition. ASM Press, Washington D.C., 2007.

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*
Duraković S, Redžepović S. Uvod u opću mikrobiologiju – knjiga prva. Kugler, Zagreb, 2002.	?	?

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

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.

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Basic description		
Course coordinator		
Course title	Experimental methods in Physics I	
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

1.1. Course objectives

Teach the students about basic optical methods and devices used in moder day experiments.

1.2. Course enrolment requirements

none

1.3. Expected course learning outcomes

The student should be capable of autonomously performing experiments and solving problems. Understanding of experiments is expected,

1.4. Course content

1. Light source – LASER
2. Optics (basics of Geometrical Optics, Gaussian beam propagation, notions of Fourier optics)
3. Wave nature of light – interference
4. Interferometers – Optical, Atom
5. Resonators – Fabry – Perot resonator
6. Particle nature of light – photoelectric effect
7. Detectors, PD, SiPM, APD, PMT, SQUID + TES (Superconductivity basics)

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

Students should write a seminar paper and take the final exam.

1.8. Evaluation of student's work

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

		check					
Portfolio							

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

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.

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

G.S. Landsberg, Optika

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

M. Born, E. Wolf, Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light
E. Hecht, Optics
M.Thinkham, Superconductivity
A.E. Siegman, Lasers

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*
G.S. Landsberg, Optika	1	

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

Quality will be monitored by anonymous polls.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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).

1.2. Course enrolment requirements

Experimental Physics I

1.3. Expected course learning outcomes

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.

1.4. Course content

1. Introduction: Accelerators, Interaction of charged particles with matter, Scattering and coincidence measurements, Measurements of cross sections,
2. Introduction to nuclear analytical techniques: theoretical and experimental aspects of: XRF, PIXE, PIGE, RBS, NRA, AMS, XPS, SIMS. Quantitative analysis and Tomographic imaging,
3. Applications of experimental methods in medicine, environmental and material science, geochronology.
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.

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

Attending lectures, success in continuous assessment, active participation in project work

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper	1	Experimental work	
Written exam		Oral exam	1	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

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, Analytica 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, UCLPress, 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.

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Basic description		
Course coordinator		
Course title	General Relativity	
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

1.1. Course objectives

This is a course of General Relativity on a beginning/medium level, in which nature of gravitatational 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.

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

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.

1.4. Course content

Equivalence principle. Gravitation as a curvature of the space-time. Basics of the differential geometry. Geodesics and particle trajectories. Einstein-Hilbert equation. Schwartzschild 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.

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

Active participation, home and class assignments and tests, passing final exam.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper		Experimental work	
Written exam		Oral exam	1.5	Essay		Research	
Project		Sustained knowledge check	2.5	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. 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)

H. C. Ohanian, R. Ruffini: *Gravitation and Spacetime* (2. edition, W. W. Norton & Co., 1994.)

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

1. P. A. M. Dirac: *General Theory of Relativity* (Princeton University Press; 1996.)
2. S. Weinberg: Gravitation and Cosmology (John Wiley & Sons, Inc; 1972.)
3. C. W. Misner, K. S. Thorne, J. A. Wheeler: *Gravitation* (W. H. Freeman, 1973.)

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.

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Basic description		
Course coordinator		
Course title	Instrumental methods in environmental phyiscs	
Study programme	Graduate study programme PHYSICS	
Course status	Compulsory	
Year	1.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	7
	Number of hours (L+E+S)	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	☒ lectures ☐ seminars and workshops ☒ exercises ☐ long distance education ☐ fieldwork	☒ individual assignment: ☐ multimedia and network ☐ laboratory work ☐ mentorship ☐ consultations
1.6. Comments	Generally, most of the presented instruments are soficticated (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	2	Activity/Participation		Seminar paper		Experimental work	
Written exam		Oral exam	3	Essay	2	Research	
Project		Sustained knowledge check		Report		Practice	

Portfolio							

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

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.

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

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

Title	*Number of copies*	*Number of students*

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

Portfolio of the student: Continuous monitoring of student's activities during the course, information on success and advance.
Questionaires: introdictory questionaire about student's expectations. Final (anonymous) questionaire 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 imrpovments.

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Basic description		
Course coordinator		
Course title	Master Thesis Seminar	
Study programme	Graduate Study Programme PHYSICS	
Course status	compulsory	
Year	2. year	
ECTS credits and teaching	**ECTS student 's workload coefficient**	6
	Number of hours (L+E+S)	0 + 0 + 15

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

- Ability to read, present and discuss relevant literature.
- Ability to criticaly think and to reflect on different approaches during a research.
- Ability towork both in an analytical and synthetic mode.
- Developing communication skills and abilities for presenting work and results to scientific community.
- Gain insight into the field and scientific culture of respective fields and research questions.
- Understanding and awareness of problems in processes of writing a master thesis.

1.4. Course content

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 coordinatore should stimulate interaction between students. The rest of the time is reserved for student's public presentations.

1.5. Teaching methods		
	☐ lectures	☐ individual assignment
	☒ seminars and workshops	☒ multimedia and network
	☐ exercises	☒ laboratories
	☐ long distance education	☒ mentorship
	☐ fieldwork	☐ other

1.6. Comments	

1.7. Student's obligations

Active participation in discussions. Preparation of a seminar, based on the master thesis research, which must be publicly presented.

1.8. Evaluation of student's work

Course attendance	0.5	Activity/Participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		Essay		Research	1.5

Project		Sustained knowledge check		Report		Practice	
Portfolio		Public presentation	2				

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

Evaluation is based on an assesment of quality of the research work and presented results, seminar and public presentation.

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

None.

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

None.

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 completion of the course.

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Basic description		
Course coordinator		
Course title	Nuclear Physics	
Study programme	Graduate study programme PHYSICS	
Course status	optional	
Year	**1.**	
ECTS credits and teaching	***ECTS student 's workload coefficient***	6
	Number of hours (L+E+S)	30+15+15

1. COURSE DESCRIPTION

1.1. Course objectives

To gain broad knowledge of nuclear physics with it's various applications in other sciences and technologies.

1.2. Course enrolment requirements

Bachelor degree in Physics

1.3. Expected course learning outcomes

1.4. Course content

1. Introduction – Nuclear cross section, Rutherford scattering, measuring cross sections,
2. Nuclear Phenomenology – Properties of nuclei, Nuclear force,
3. Nuclear models – Liquid drop model, Fermi-gas model, Shell model, Square well and harmonic oscillator, Collective model,
4. Nuclear Radiation – Tunnelling, Alpha, Beta and Gamma Decay,
5. Applications of Nuclear Physics – Fission and Fusion, Natural radioactivity and dating, interactions of particles with matter, Energy loss, Particle accelerators and Particle detectors,
6. Applications in medicine and elemental analysis – Nuclear imaging and diagnosing, Radioisotopes and radiotherapy, Nuclear analytical techniques such as PIXE, RBS, ERDA, AMS

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

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	2	Activity/Participation	1	Seminar paper	1	Experimental work	
Written exam		Oral exam	2	Essay		Research	
Project		Sustained knowledge check		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.

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Basic description		
Course coordinator		
Course title	Observational astrophysics	
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)	30+15+15

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

Mandatory: Course „Astronomy and Astrophysics I".
Recommended: enrolling courses „Astroparticle physics" and „Astrophysics Lab".
This course is a prerequisite for „Astrophysics Lab".

1.3. Expected course learning outcomes

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.

1.4. Course content

Observational (experimental) methods and instruments:
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 satelites. Sky surveys. Application of the experimental methods developed in astrophysics in the public sector.

Selected chapters:
Gravitational microlensing. Searching for extrasolar planets. Active galatic nuclei (AGN). Observing the whole electromagnetic spectrum and determining of the spectral energy distribution (SED). Correlations between light curves in different energy bands.

1.5. Teaching methods	☒ lectures ☒ seminars and workshops ☒ exercises ☐ long distance education ☒ fieldwork	☒ individual assignment ☒ multimedia and network ☐ laboratories ☐ mentorship ☐ other
1.6. Comments	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	2	Activity/Participation		Seminar paper	1	Experimental work	
Written exam	1	Oral exam	2	Essay		Research	
Project		Sustained knowledge check		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.

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Basic description		
Course coordinator		
Course title	Physical chemistry	
Study programme	Graduate study programme PHYSICS	
Course status	elective	
Year	1., 2.	
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

Obtaining new knowledge in the field of physical chemistry
Obtaining knowledge in some advanced areas in of physical chemistry
Application of obtained knowledge to independent problem-solving
Understanding experimental and analytical methods needed for investigation of physico-chemical properties of environmental systems and processes.

1.2. Course enrolment requirements

Passed exams in Physics 1 and 2, attended lectures in Mathematical Methods in Physics 1

1.3. Expected course learning outcomes

After completing the final exam, students will be able to:
- Explain the structure and changes in substances at the molecular level.
- Independently solve numerical and theoretical problems in chemical thermodynamics, electrochemistry and chemical kinetics.

- - Analyse chemical systems and processes in the environment in light of the laws of physical chemistry.

1.4. Course content

Chemical thermodynamics. Basic ideas. First, second and third law of thermodynamics. State functions. Heat capacity. Chemical composition. Chemical processes. Partial molar quantities. Entropy. Perfect gas equation. Ideal mixtures. Real gases. Intermolecular interactions. Liquids. Chemical potential. Relative activity. Fugacity and its dependence on the mixture composition. Triple point. The phase rule. Real solutions. Coligative properties. Limits of the phenomenological method. Chemical kinetics. Definition of the reaction rate and the rate of change of concentration. Chemical equilibrium. Reaction constant. Reaction kinetics formalism. First order reactions. Second order reactions. Simultaneous reactions. Chain reactions. Dependence of the reaction rate on temperature. Collision theory. Thermodynamic properties of ions in solution. Activity of ions. Electrochemistry. Electrochemical cell. Electrode reactions. Types of electrodes. Types of electrochemical cells. Reactions in electrochemical cells. Nernst equation. Standard potential.

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

Seminares – mandatory presence with the absence policy according to the University statute
The presence at lectures is being evidented, however it is not mandatory

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper		Experimental work	
Written exam	2	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

Attendance of lectures and especially tutorials, as well as active course participation, will be monitored regularly. Taking part in two written exams and in the final oral exam is compulsory. In order to pass, it is necessary to to obtain at least half of the available points at each step of the examination process.

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

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.

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*
P.W. Atkins, Physical Chemistry, 5th Ed., Oxford University Press, 1994.	1	5
V. Simeon, Termodinamika, Školska knjiga, Zagreb 1980.	1	5
P. W. Atkins, The Elements of Physical Chemistry, 3rd Ed., Oxford University Press, 2000.	1	5

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

Regular monitoring of students' participation in lectures and tutorials, with feedback about perceived progress and achievement. At the start of the course, a questionnaire about each student's expectations from the course. Final anonymous questionnaire about the quality of the course. After the final exam, the teacher will ask feedback about the goals reached in the course: the teaching method, difficulties in understanding parts of the curriculum and suggestions for improvement.

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

1. COURSE DESCRIPTION

1.1. Course objectives

Course objectives comprise:

1. Familiarizing students with the modern observational data on structure and dynamics of the universe
2. Developing understanding of the principles of modern cosmology and their connection with the fundamental theoretical and experimental results in other areas of physics.
3. Achieving understanding and quantitative elaboration of General theory of relativity in the cosmological context.
4. Gaining insight into the theory of Big Bang and the thermal evolution of the universe
5. Getting familiar with the theory of cosmic inflation, onset and evolution of inhomogeneities in the universe and the formation of observed cosmic structures.
6. Adoption of analytical and numerical approaches to solving main equations of the global evolution of the universe.
7. Development of the unified picture and chronology of the evolution of the universe and dominant physical effects in particular epochs of its development.

1.2. Course enrolment requirements

Passed courses: Statistical mechanics, General relativity, Elementary particle physics 1.

1.3. Expected course learning outcomes

Expected course learning outcomes comprise:

1. An insight into modern observational results on dynamics and structure of the universe
2. An operational application of the Theory of general relativity in the quantitative description of the homogeneous and isotropic universe
3. Experience of the application of knowledge from high-energy physics and statistical physics to understanding of the thermal history of the universe
4. Qualitative understanding of the process of cosmic inflation, phase transitions in the early universe and formation of observed cosmic structures
5. Completed project of the numerical solution of the model of the evolution of the universe

1.4. Course content

Introduction

- historical development of concepts about universe
- 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, ...)
- observational basis of the Standard cosmological model (averaging of matter and energy density, homogeneity and isotropy at large scales)
- cosmological principle and alternative approaches

- 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 (mechnaisms 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	2	Activity/Participation	0.4	Seminar paper		Experimental work	
Written exam	2	Oral exam	1	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.

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Basic description		
Course coordinator		
Course title	Physical modelling of the environment	
Study programme	Graduate Study Programme PHYSICS	
Course status	optional	
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

Enable understanding of reasons for model construction and application, prediction and control.

1.2. Course enrolment requirements

One course in ecology or environmental protection. Mathematics (differential and integral calculus, differential equations)

1.3. Expected course learning outcomes

Using obtained knowledge, students will be able to assess when a model is needed, how to build it, analyze and use it.

1.4. Course content

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.

1.5. Teaching methods	X lectures ☐ seminars and workshops X exercises ☐ long distance education ☐ fieldwork	☐ individual assignment X multimedia and network ☐ laboratory work X mentorship ☐ consultations
1.6. Comments		

1.7. Student's obligations

Attendance to lectures and exercises. Independent problem solving.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper		Experimental work	
Written exam	1.5	Oral exam	1.5	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

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

Title	*Number of copies*	*Number of students*
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.

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Basic description		
Course coordinator		
Course title	Physical oceanography	
Study programme	Graduate Study Programme PHYSICS	
Course status	compulsory	
Year	2.	
ECTS credits and teaching	***ECTS student 's workload coefficient***	7
	Number of hours (L+E+S)	30+30+0

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

/

1.3. Expected course learning outcomes

Students should
- recognize the subject of physical oceanography,
- recognize the basic parameters of physical oceanography and methods of their derivation,
- get the basic knowledge on data analysis in physical oceanograpy (i. e. analysis of time series and spatial distribution charts),
- recognize the role of physical oceanography in understanding global and regional climatic changes,
and
- relate different processes in sea environment to changes in sea dynamic.

1.4. Course content

- Subject of physical oceanography,
- Sea conditions (temperature, salinity, density, sea pressure, water masses),
- air-sea fluxes and their impact on sea conditions,
- forces drawing sea dynamics, equations of state and methods of their solving,
- geostrophic currents, wind induced currents, inertial currents,
- waves,
- air-sea interaction and climatic changes,
- equipment in physical oceanography,
- data analysis in physical oceanography,
and
- impact of physical processes on sea ecosystem.

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	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

Sudent's obligations are to attend the courses.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper	1	Experimental work	
Written exam	1	Oral exam	1	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

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)

1. Gill, A.E., 1982. Atmosphere Ocean Dynamics. Academic Press, Orlando, 662 pp.
2. Oceanography Course Team, 1989. Seawater: Its Composition, Properties and Behaviour. Pergamon Press, Oxford, 165 pp.
3. Oceanography Course Team, 1989. Ocean Circulation. Pergamon Press, Oxford, 165 pp.
4. Oceanography Course Team, 1989. Waves, Tides and Shallow Water Processes. Pergamon Press, Oxford, 165 pp.
5. Stewart, R., 2008. Introduction to physical oceanography, Texas A&M University, 353 pp. (udžbenik dostupan na web-u)
6. Penzar, B., Penzar, I., Orlić, M., 2001. Vrijeme i klima hrvatskog Jadrana. Nakladnička kuća "Dr. Feletar", Zagreb, 258 pp.
7. Cushman-Roisin, B., 1994. Introduction to Geophysical Fluid Dynamics. Prentice Hall, New Jersey, 318 pp.
8. 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)

1. Cushman-Roisin, B., Gačić, M., Poulain, P.-M., Artegiani, A., 2001. Physical Oceanography of the Adriatic Sea. Kluwer Academic Publishers, Dordrecht, 320 pp.
2. Aktualni radovi iz područja istraživanja Jadrana (npr. Supić, N., Orlić, M., Degobbis, 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)
3. 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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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 *Elementary Particle Physics 2* on the second year.

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

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 *Elementary Particle Physics 2* and *Physical Cosmology*, 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.

1.4. Course content

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.
2. Fermionic fields – Dirac equation, problems with single particle interpretation, quantization of the free Dirac field, discrete symmetries, spin-statistics theorem, anions.
3. Interacting fields – processes, S-matrix, cross sections, Feynman diagrams, some elementary processes in the Quantum Electrodynamics.
4. Functional methods – path integrals, connection with statistical mechanics, symmetries.
5. Spontaneous symmetry breaking – global SSB and Goldstone bosons, local SSB and Higgs mechanism, superconductivity.
6. Brief introduction to the renormalization theory – loops and infinities, field and coupling constant renormalization, critical exponents and phase transitions.

1.5. Teaching methods	☒ lectures ☒ seminars and workshops ☒ exercises ☐ long distance education ☐ fieldwork	☒ individual assignment ☐ multimedia and network ☐ laboratories ☐ mentorship ☐ other
1.6. Comments		

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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	2	Activity/Participation		Seminar paper	0.5	Experimental work	
Written exam		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. 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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

There are no formal prerequisites for entering this course, but it assumes knowledge of general and theoretical physics and mathematical methods of physics.

1.3. Expected course learning outcomes

Knowledge of modern quantum theory of atoms and molecules. Understanding the theory and creation foundation for independent application of basic models to concrete examples.

1.4. Course content

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.

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

Students must attend lectures and seminar in accordance with the Rules of the study.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation	0.25	Seminar paper	1.0	Experimental work	
Written exam		Oral exam	2.5	Essay		Research	
Project		Sustained knowledge check	0.25	Report		Practice	

Portfolio							

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

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.

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

A.Szabo and N.S.Ostlund, "Modern Quantum Chemistry", Sec.Ed. McGraw-Hill, New York, 1989.

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

1. T.Helgaker,P.Joergensen and J.Olsen, "Molecular Electronic Structure Theory", Wiley,Chichester, 2000.
2. Cristopher Cramer, "Essentials of Computational Chemistry – Theories and Models", Wiley, Chichester, 2004.
3. Z.B.Maksić, "Theoretical Models of Chemical Bonding", Springer-Verlag, Berlin-Heidelberg, Vol. 1-3, 1990-1991.

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
A.Szabo and N.S.Ostlund, "Modern Quantum Chemistry", Sec.Ed. McGraw-Hill, New York, 1989.	2	

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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

To introduce students to the latest techniques and applications of laser spectroscopy. Set quality theoretical foundation for later work of students in spectroscopic laboratories.

1.2. Course enrolment requirements

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.

1.3. Expected course learning outcomes

Students after passing the exam will be able to:
- describe the absorption and emission of light;
- list and describe what affects the width of the spectral line profiles;
- describe the spectrographs and monochromators;
- describe the various types of interferometers;
- compare the spectrometers and interferometers;
- describe the precise measurement of wavelengths;
- list and describe the types of light detectors;
- describe the fundamentals of lasers;
- describe the differences between the so-called. single-mode lasers and tunable lasers;
- enumerate the different types of absorption and emission spectroscopy;
- describe and differentiate types of nonlinear spectroscopy;
- describe and distinguish Raman spectroscopy techniques - linear and nonlinear Raman spectroscopy;
- describe the formation and measurement of short laser pulses;
- list and analyze the application of spectroscopy in various fields of science.

1.4. Course content

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.

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

Students must attend lectures and seminar in accordance with the Rules of the study.

1.8. Evaluation of student's work

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

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

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.

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

1. W. Demtröder, *Laser spectroscopy, Volume 1, Basic principles*, Springer, 2008.
2. W. Demtröder, *Laser spectroscopy, Volume 2, Experimental techniques*, Springer, 2008.

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

1. W.T. Silfvast, *Laser Fundamentals*, Cambridge University Press, 2004.
2. A.P. Thorne, U. Litzen, S. Johansson, *Spectrophysics,* Springer, 1999.

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
W. Demtröder, *Laser spectroscopy, Volume 1, Basic principles*, Springer, 2008.	1	
W. Demtröder, *Laser spectroscopy, Volume 2, Experimental techniques*, Springer, 2008.	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.

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Basic description		
Course coordinator		
Course title	Semiconductors: Principles and Applications	
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

1.1. Course objectives

To gain knowledge and develop understanding of principles and applications of semiconducting electronic materials.

1.2. Course enrolment requirements

Pass exams of Fundamentals of Physics and Solid State Physics.

1.3. Expected course learning outcomes

To gain knowledge about fundamental properties of semiconducting materials and techniques for tailoring these properties for specific applications and design of electronic devices.

1.4. Course content

1. Introduction-Survey of Semiconducting Materials and Growth Techniques
2. Intrinsic and Extrinsic Semiconductors, Defects in Semiconductors
3. Electronic Structure, Conductivity and Transport Phenomena
4. Optical Properties of Semiconductors
5. Semiconductor Devices- from Diode and Transistor to Solar Cells and Lasers

1.5. Teaching methods

☒ lectures	☒ individual assignment
☒ seminars and workshops	☒ multimedia and network
☒ exercises	☒ laboratories
☐ long distance education	☒ mentorship
☒ fieldwork	☐ other

1.6. Comments

1.7. Student's obligations

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	2	Activity/Participation	0.5	Seminar paper		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

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.

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Basic description		
Course coordinator		
Course title	Seminar in Physics on English	
Study programme	Graduate Study Programme PHYSICS	
Course status	compulsory	
Year	2. year	
ECTS credits and teaching	***ECTS student 's workload coefficient***	2
	Number of hours (L+E+S)	0 + 0 + 15

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

Developing communication and presentation skills on English language.

1.4. Course content

Time is shared between meetings, on which student is helped in preparation of the seminar and which are conducted in English, and public presentations.

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

Preparation and public presentation of a seminar on English language.

1.8. Evaluation of student's work

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

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

There is no separate mark for this course. Student is evaluated as a part of a course from which seminar is taken.

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

None.

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

None.

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 completion of the course.

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Basic description		
Course coordinator		
Course title	Solid State Physics I	
Study programme	Graduate Study Programme PHYSICS	
Course status	compulsory	
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

Acquiring common knowledge about the properties and applications of different materials, particularly regarding the basic properties of the crystal structure.

1.2. Course enrolment requirements

Completed the bachelor study with the passed course related to a basic knowledge of the quantum mechanics on a bachelor study.

1.3. Expected course learning outcomes

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.

1.4. Course content

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).

1.5. Teaching methods	☒ lectures ☒ seminars and workshops ☒ exercises ☐ long distance education ☐ fieldwork	☒ individual assignment ☒ multimedia and network ☐ laboratories ☐ mentorship ☐ other
1.6. Comments	Students are evaluated regarding their activity on lectures and exercises. Two written midterm exams. Final exam: oral.	

1.7. Student's obligations

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	3	Activity/Participation	0.5	Seminar paper		Experimental work	
Written exam	2	Oral exam	2	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

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)

V. Šips, *Uvod u fiziku čvrstog stanja*, Školska knjiga, Zagreb, 2003.
C. Kittel, *Introduction to Solid State* Physics, 8. izdanje, Wiley, New York, 2005.

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

N. W. Ashcroft, N. D. Mermin, *Solid State Physics*, Holt, Rinehart and Winston, New York, 1976.
I. Kupčić, Fizika čvrstog stanja, *Zbirka riješenih zadataka*, HINUS, Zagreb, 1998.

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*
V. Šips, *Uvod u fiziku čvrstog stanja*, Školska knjiga, Zagreb, 2003.	5	5
C. Kittel, *Introduction to Solid State Physics*, 8. Izdanje, Wiley, New York, 2005.	2	5

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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

Passed the exam of the course Solid state physics 1 on the Graduate study programme Physics.

1.3. Expected course learning outcomes

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.

1.4. Course content

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.

1.5. Teaching methods	☒ lectures ☒ seminars and workshops ☒ exercises ☐ long distance education ☐ fieldwork	☒ individual assignment ☒ multimedia and network ☐ laboratories ☐ mentorship ☐ other
1.6. Comments	The students are evaluated regarding their activity on lectures and exercises. Two written midterm exams. Final exam: oral.	

1.7. Student's obligations

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.

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation	0.5	Seminar paper		Experimental work	
Written exam		Oral exam	3	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 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)

C. Kittel, *Introduction to Solid State Physics*, 8. Izdanje, Wiley, New York, 2005.
C. Kittel, *Quantum Theory of Solids*, 2. izdanje, Wiley, 1987.

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

N. W. Ashcroft, N. D. Mermin, *Solid State Physics*, Holt, Rinehart and Winston, New York, 1976.
M. P. Marder, *Condensed Matter Physics*, 2. Izdanje, Wiley, 2010.

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*
V. Šips, *Uvod u fiziku čvrstog stanja*, Školska knjiga, Zagreb, 2003.	5	5
C. Kittel, *Introduction to Solid State Physics*, 8. Izdanje, Wiley, New York, 2005.	2	5

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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

None.

1.3. Expected course learning outcomes

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.

1.4. Course content

1.5. Teaching methods

☒ lectures	☒ individual assignment
☒ seminars and workshops	☐ multimedia and network
☒ exercises	☐ laboratories
☐ long distance education	☐ mentorship
☐ fieldwork	☐ other

1.6. Comments

1.7. Student's obligations

Active participation, home and class assignments and tests, passing final exam.

1.8. Evaluation of student's work

Course attendance	2.5	Activity/Participation	0.5	Seminar paper	0.5	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. 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.

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

1. COURSE DESCRIPTION

1.1. Course objectives

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.

1.2. Course enrolment requirements

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 *Modern physics I* and *Modern physics II*, as well as basic knowledge of probability theory and mathematical statistics.

1.3. Expected course learning outcomes

Upon completion of this course, students will be able to:
a) describe the experimental techniques and instruments used to measure a phenomenon / physical quantity at the atomic level;
b) explain the theoretical principles underlying the experimental techniques and measuring devices used in exercises;
c) properly interpret the spectra obtained by measuring devices;
d) perform the data analysis and presentation of measurement results (tabular accounts, graphics) by their own;
e) discuss cause-effect relationships in the given content.

1.4. Course content

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.

1.5. Teaching methods	☐ lectures ☒ seminars and workshops ☐ exercises ☐ long distance education ☐ fieldwork	☒ individual assignment ☐ multimedia and network ☒ laboratories ☐ mentorship ☒ other
1.6. Comments	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.	

1.7. Student's obligations

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	2	Activity/Participation		Seminar paper	2	Experimental work	
Written exam		Oral exam		Essay		Research	
Project		Sustained knowledge check	1	Report		Practice	1
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 *Structure of matter lab*	equal to the number of students	
R. Barlow, *Statistics-A Guide to the Use of Statistical Methods in the Physical Sciences*, John Wiley, New York, 1989.	1	
Kenneth S. Krane, *Modern Physics*, 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.

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Basic description		
Course coordinator		
Course title	Terrestrial Ecology	
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)	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. Additionaly, 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 multidisciplinarity 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

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	☐ exercises ☐ long distance education ☒ fieldwork	☐ laboratory work ☐ mentorship ☐ consultations
1.6. Comments		

1.7. Student's obligations

Presence at the field work is mandatory

1.8. Evaluation of student's work

Course attendance	2	Activity/Participation		Seminar paper		Experimental work	
Written exam	4	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

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)

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

Chapin, F., Matson, P. & Mooney, H. 2002: Principles of Terrestrial Ecosystem Ecology. Springer-Verlag.
Grove, A.T. & Rackham, O. 2003: The Nature od Mediterranean Europe. An Ecological History. New Haven & London, Yale University Press.

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

Allen, H. D. 2001: Mediterranean Ecography. Prentice-Hall.
Dallman, P.R. 1998: Pant Life in the World's Mediterranean Climates. Oxford, Oxford University Press.
Bolle, H.J. 2003: Mediterranean Climate. Springer-Verlag.
Conacher, A.J. & Sala, M. 1998: Land Degradation in Mediterranean Environments of the World. John Wiley and Sons.
King, R., de Mas, P. & Beck, J.M. 2000: Geography, Environment and Development in the Mediterranean. Sussex Academic Press.
King, R., Proudfoot, L. & Smith, B. 1997: The Mediterranean. Hodder Arnold.

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*
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

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

Stimulation of interdisciplinary apporach through frontal and individual course presentation as well as consultations with students; understanding principles of terrestrial ecology while searching for solutions in contemporary problems;