UNIVERSITY OF ZAGREB
FACULTY OF SCIENCE
DEPARTMENT OF PHYSICS
Bijenička cesta 32, Zagreb

PROPOSAL
University study bachelor and master of physics

Zagreb, January/February 2005.

University study bachelor and master of physics

According to Instructions of Croatian Rectors Conference, January 14, 2004

1. INTRODUCTION

1.1.   The students who complete their university study and obtain the degree *Master of physics* can find positions with medical institutions, nuclear power stations, metallurgy and shipbuilding industry, as well as with financial institutions (banks, insurance companies), with geophysical institutions, governmental offices etc.
        The students who obtain the degree *Master of physics* are competent to be assistants with all faculties, in which physics is included in the study programmes.
        They can also join the scientific institutions in Croatia as research assistants.
        The (best) students who are graduated in research physics and obtain the degree *Master of physics* are competent to continue their postgraduate study, ending with the PhD degree in physics, in Croatia and abroad.

1.2.   Physics is fundamental natural science and is the basis for understanding and explanation of natural phenomena and processes which take place in our environment, as well as at most distant points of the Universe. Therefore, all universities, scientific and research institutions all round the world, as well as industrial enterprises have physicists as their employees.

        The beginning of higher education of (college-level) physics in Zagreb dates back to the 17th century. Within the frames of the Faculty of Arts, the programme of physics was introduced in 1874. The Faculty of Science was founded in 1946, consisting of some departments which were separated from the Faculty of Arts. Therefore, the university programme of physics has a long and worthwhile tradition for the education of masters of physics in the future.

1.3.   The study of research physics, which ends with the degree *Master of physics,* is open to students of related studies, but the differential exams should be passed. The study lasts for five years and demands a thorough knowledge of physics, as one of the natural sciences, and the indispensable basic knowledge of mathematics and informatics. That is, the undergraduate study, lasting for three years, is not sufficient to achieve the competence in physics. A full expertise can be achieved only in the integral five-years study.

1.4.   All prominent universities in Europe and in the world include the study programmes for education of Master of physics. We believe that a two-way exchange of students is quite possible on the basis of the collected ECTS credits/points.

1.5.   We do consider the university study programme of research physics to be indispensable, as there is a great need for the Masters of physics and it will be so in the future.

2. GENERAL

2.1. The term of study:	The University study of research **PHYSICS**
2.2. The institution performing the study:	University of Zagreb, Faculty of Science, Department of Physics
2.3. The duration of study:	Five years
2.4. Conditions for enrolment:	Secondary school, chemical vocational school, related schools with at least three-year programmes of mathematics, physics and chemistry. It is expected that, in line with the new law regulating educational matters, the enrolment condition will be the secondary school certificate. The priority enrolment list will be defined by the classification procedure.
2.5. Undergraduate study:	No diploma will be issued for the undergraduate study, because there is no need for such personnel. There is a possibility of the transfer to similar related studies, after completion of any year of study with a condition of passing differential exams.
2.6. Graduate study:	The graduate study for the degree *Master of physics* is an integral five-year study, demanding a full competence in physics and the basic knowledge of mathematics and informatics. No diploma will be issued after three years of study, as the full expertise can be achieved in the integral five-year study.
2.7. The graduation degree achieved at the end of study:	Master of physics

SVEUČILIŠTE U ZAGREBU
PRIRODOSLOVNO-MATEMATIČKI FAKULTET
Fizički odsjek
Ul. kralja Zvonimira 8
10000 Zagreb

CURRICULA FOR MASTER OF PHYSICS

UNIVERSITY STUDY OF RESEARCH PHYSICS
Master of physics

YEAR 1

P = lectures, V = tutorial, S=seminar, L = lab
** obligatory

COURSE	WINTER SEMESTER		SUMMER SEMESTER	
	CONTACT HOURS (P +V+S+L)	ECTS CREDITS	CONTACT HOURS (P +V+S+L)	ECTS CREDITS
General Physics 1	4+2+1+0	11		
Mathematical Analysis 1	3+2+0+0	8		
Linear Algebra	4+3+0+0	8		
Computing Laboratory	1+3+0+0	3		
General Physics 2			4+2+1+0	11
Mathematical Analysis 2			3+2+0	8
Statistics and Basic Measurements			2+3+0	6
Numerical Methods			2+2+0	5
	12+10+1+0		11+9+1+0	
Physical and Health Education**	0+2+0+0		0+2+0+0	
TOTAL HOURS PER WEEK AND TOTAL ECTS CREDITS:	23+(2)	30	21+(2)	30

YEAR 2

COURSE	WINTER SEMESTER		SUMMER SEMESTER	
	CONTACT HOURS (P +V+S+L)	ECTS CREDITS	CONTACT HOURS (P +V+S+L)	ECTS CREDITS
General Physics 3	**4+2+1+0**	**8**		
Introductory Physics Lab 1	0+0+0+4	3		
Mathematical Methods in Physics 1	**3+2+0+0**	9		
Classical Mechanics 1	**3+2+0+0**	8		
Elective Seminar 1	**0+0+2+0**	1		
Elective Seminar 2	**0+0+2+0**	1		
General Physics 4			**4+2+1+0**	7
Introduction to Quantum Physics			2+2+0+0	5
Mathematical Methods in Physics 2			3+2+0+0	8
Classical Mechanics 2			3+2+0+0	7
Introductory Physics Lab 2			**0+0+0+4**	3
	10+6+4+4		**12+8+2+4**	
Physical and Health Education **	**0+2+0+0**		0+2+0+0	
TOTAL HOURS PER WEEK AND TOTAL ECTS CREDITS:	**24**	**30**	**25**	**30**

YEAR 3

COURSE	WINTER SEMESTER		SUMMER SEMESTER	
	CONTACT HOURS (P +V+S+L)	ECTS BODOVI	CONTACT HOURS (P +V+S+L)	ECTS CREDITS
Classical Electrodynamics	3+2+0+0	6		
Quantum Physics	2+1+2+0	6		
Statistical Physics	2+1+0+0	5		
Advanced Physics Lab 1	0+0+0+4	4		
Microelectronics	2+1+0+0	3		
Elective courses: **Two of the following**	2+1 2+1	3 3		
Physics of Materials	2+0+1+0			
General and Inorganic Chemistry	2+1+0+0			
Mathematical Analysis in Space	2+1+0+0			
Group Theory	2+1+0+0			
Nonlinear Phenomena	2+1+0+0			
Symbolic Programming	2+0+0+2			
Vector Spaces	2+1+0+0			
Development of Physics	2+0+1+0			
Classical Electrodynamics			3+2+0+0	6
Quantum Physics			2+1+2+0	6
Statistical Physics			2+1+0+0	5
Advanced Physics Lab 2			0+0+0+4	4
Experimental Techniques in Physics			2+1+0+0	3
Elective courses: **Two of the following**			2+1+0+0 2+1+0+0	3 3
General and Inorganic Chemistry Lab			0+0+0+3	
Differential Geometry in Physics			2+1+0+0	
Numerical Methods and Mathematical Modeling			2+1+0+0	
Symmetries in Physics			2+0+0+1	
Overview of Modern Experimental Research			2+0+1+0	
Modern Physics and Philosophy			2+0+1+0	
Hydrodinamics			2+1+0+0	
	13+7+0+4		**13+7+2+4**	

COURSE	TOTAL HOURS PER WEEK AND TOTAL ECTS CREDITS:			
TOTAL HOURS PER WEEK AND TOTAL ECTS CREDITS:	24	30	26	30

YEAR 4

COURSE	WINTER SEMESTER		SUMMER SEMESTER	
	CONTACT HOURS (P +V+S+L)	ECTS CREDITS	CONTACT HOURS (P +V+S+L)	ECTS CREDITS
Elementary Particle Physics	**2+1+0+0**	**5**		
Nuclear Physics	**2+1+0+0**	5		
Solid State Physics	**2+1+0+0**	5		
Modern Physics Lab	0+0+0+3	4		
Experimental Methods of Modern Physics	2+0+0	3		
Elective courses: **Two** of the following	2+1 2+1	4 4		
Quantum Physics of Finite Systems	**2+1+0+0**			
Astronomy and Astrophysics	2+1+0+0			
Relativistic Quantum Physics	2+1+0+0			
Irreversible Thermodynamics	2+1+0+0			
Electrodynamics of Continuum	2+1+0+0			
Electromagnetic Waves and Optics	2+1+0+0			
Advanced Quantum Physics	2+1+0+0			
Methods of Material Characterization	2+1+0+0			
Biophysics	2+1+0+0			
Elementary Particle Physics			**2+1+0+0**	5
Nuclear Physics			**2+1+0+0**	5
Solid State Physics			**2+1+0+0**	5
Experimental Methods of Modern Physics			2+0+0+0	5
Elective courses: **Two** of the following			2+1 2+1	5 5
Theory of Fields 1			2+1+0+0	
Physical Cosmology			2+1+0+0	
Physics of the Stars			2+1+0+0	
Electronics Lab			0+0+0+3	
Energetics			2+1+0+0	
Medical Physics			2+1+0+0	
Selected Topics in Optics			2+1+0+0	

			2+1+0+0	
Atomic and Molecular Physics			2+1+0+0	
Quantum Statistical Physics			**2+1+0+0**	
Physics of Disordered Systems			**2+1+0+0**	
	12+5+0+3		**12+5+0+0**	
TOTAL HOURS PER WEEK AND TOTAL ECTS CREDITS:	**20**	**30**	**17**	**30**

YEAR 5

Course	WINTER SEMESTER		SUMMER SEMESTER	
	CONTACT HOURS (P +V+S+L)	ECTS CREDITS	CONTACT HOURS (P +V+S+L)	ECTS CREDITS
OBLIGATORY COURSE:				
Seminar in Physics	**0+0+4+0**	9		
ELECTIVE COURSES:				
REMARK: student chooses elective courses . Depending on thesis subject: **a) One of the labs** **and one elective course** **or** **b) Three elective courses** **Student can also take, if his (her) mentor agrees, elective courses from the 4th year of study or graduate studies or other courses from the University of Zagreb.**	**0+0+0+4** **2+1+0+0** **2+1+0+0** **2+1+0+0** **2+1+0+0**	14 7 7 7 7		
Thesis research			**20**	
TOTAL HOURS PER WEEK AND TOTAL ECTS CREDITS:	**11(13)**	**30**	**20**	**30**
ELECTIVE COURSES				
Solid State Phyisics Lab	0+0+0+4			
Nuclear Physics Lab	0+0+0+4			
Particle Physics Lab	0+0+0+4			
Atomic Physics Lab	0+0+0+4			
Gravity and Cosmology	2+1+0+0			
Theory of Fields 2	2+1+0+0			
Topology in Physics	2+1+0+0			
Introduction in Supersymmetries	2+1+0+0			
Flavour Physics and CP Violation	2+1+0+0			

Advanced Gravity	2+1+0+0			
Physics Beyond the Standard Model	2+1+0+0			
Nuclear Structure	2+1+0+0			
Structure of Nucleons	2+1+0+0			
Nuclear Astrophysics	2+1+0+0			
Galaxies	2+1+0+0			
Physics of Hadrons	2+1+0+0			
Experimental Techniques in Subatomic Physics	2+1+0+0			
Reactor Physics	2+1+0+0			
Quantum Fluids	2+1+0+0			
Structure of Surfaces	2+1+0+0			
Low Temperature Physics and Superconductivity	2+1+0+0			
Modern Methods in Electron Microscopy	2+1+0+0			
Nanomaterial Physics	2+0+1+0			
Physics of Semiconductors	2+1+0+0			
Magnetism and Magnetic Materials	2+1+0+0			
Introduction in Bioinformatic of the Centromere of Human Genome	2+1+0+0			
Data Analysis and Corelations in Biology	2+1+0+0			
Cell Biophysics	2+1+0+0			
Selected Topics of Theoretical Atomic Physics	2+1+0+0			
Experimental Methods of Atomic Physics	2+1+0+0			
Selected Topics of Molecular Physics	2+1+0+0			
Selected Topics of Atomic Spectroscopy	2+1+0+0			
Laser Physics	2+1+0+0			
REMARK: Elective courses above which are too advanced for master of physics degree will be included only in curricula for PhD degree.				

COURSE TITLE: General Physics 1

COURSE TEACHER/TEACHERS: Professors of Physics: M. Furić and E. Babić, Faculty of Sciences and Mathematics

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 1

SEMESTER: 1

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	4	teacher
Exercises	2	assistant
Seminars	1	teacher

ECTS credits: 11

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Foundation of notions and their relationships upon which physics, sciences and the material world are described. Introduction of Newtonian Mechanics. Use of the conservation laws. How to solve standard problems in Mechanics. Illustrate the need for the relativistic generalization and demonstrate the realization. In parallel we demonstrate the applications in topics such as engineering and elementary particles.

DESCRIPTION OF THE COURSE:

Mathematical introduction 1: derivatives, integrals, addition of vectors.

Mathematical introduction 2: scalar multiplication of vectors, products of vectors, position velocity and acceleration vectors.

Physics and measurement: time length and mass standards, dimensional analysis, units conversion, significant figures.

Newton's laws and their applications in simple cases

Systems of reference and Galilean transformations: inertial and accelerated systems, pseudoforces, transfomations between systems.

Conservation of energy: idea of conservation laws, work, kinetic energy, conservative forces and potential energy, conservative force and gradient of the potential energy.

Momentum conservation: forces within the system and momentum conservation, center of mass, collisions, transformations between the laboratory and center of mass systems.

Torque and motion of rigid bodies: angular momentum and torque, conservation of angular momentum, moment of inertia, equations for the rigid body motion, energy in rotational motion

Equilibrium of the rigid body: equilibrium conditions for forces and torques, d' Alambert principle, solutions to some eqililbrium cases.

Harmonic oscillator: free oscillations, friction, damped oscillations, forced oscillations, resonance, superposition principle.

Motion for the central force proportional to the inverse squarre of distance: solving the general case, Kepler's laws in gravitational field.

Fluids mechanics: buoyancy, Pascal's law, hydrostatic pressure, Bernoulli's equation, viscosity, surface (tension) effect.

Speed of light measurement and constancy: measurement methods, Michelson-Morley experiment, relativity of simultaneity, relativity of time.

Relativistic effects and generalizations: length contraction, time dilation, relativistic momentum, relativistic energy.

STUDENT OBLIGATIONS DURING THE COURSE: Course attendance is controlled, three colloquia are offered during the semester; students' results on colloquia are included into the final written exam. Students receive homework problems. During seminars students ask explanations of the more complex problems. Also they prepare own presentations.

METHODS TO EVALUATE STUDENT PERFORMANCE: Evaluation includes results of written colloquia, final written exam and oral examination.

EXAMINATION METHODS: Final written exam includes also the results of the three colloquia. Oral exam is in front large audience. Student draws four questions. By answering very well student may improve his/her written exam grade by one grade.

COURSE(s) NEEDED FOR THIS COURSE:None

COMPULSORY LITERATURE: H.D. Young and R.A.Freedman, University Physics, Pearson-Addisson Wesley, San Francisco, 2004.

ADDITIONAL READING: C. Kittel, W.D. Knight and M.A. Ruderman: Mehanika (Udžbenik fizike Sveučilišta u Berkeleyu), Tehnička knjiga, Zagreb 1982

COURSE TITLE: MATHEMATICAL ANALYSIS 1

COURSE TEACHER/TEACHERS: Prof. Miljenko Marušić, Ph.D.

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 1

SEMESTER: 1

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*Teacher or assistant*)
Lectures	3	*Teacher*
Exercises	2	*Assistant*
Seminars	0	-

ECTS credits: 8

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction of basic mathematical concepts, adoption of differential calculus and learning mathematical theory.

DESCRIPTION OF THE COURSE: Set. Function. Biection and inverse function. Natural numbers. Axiom of mathematical induction. Real numbers. Upper and lower bounds. Elementary functions.

Sequences and limit of sequences. Function limits and continuity. Continuous functions on a segment.

Derivatives. Rules for derivation. Derivatives of elementary functions. Taylor's Theorem. Extremes.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance on the lectures and passing colloquiums.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Colloquiums.

EXAMINATION METHODS: Colloquiums (80%), final exam (20%)

COURSE(s) NEEDED FOR THIS COURSE:

COMPULSORY LITERATURE:

S. Kurepa, Matematička analiza 1, 2, Tehnička knjiga, Zagreb.

B.P. Demidovič, Zadatci i riješeni primjeri iz više matematike, Tehnička knjiga, Zagreb.

ADDITIONAL READING:

COURSE TITLE: Linear algebra		
COURSE TEACHER/TEACHERS: Professor M. Primc		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 1		
SEMESTER: 1		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	4	
Exercises	3	
Seminars		
ECTS credits: 8		
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:		

DESCRIPTION OF THE COURSE:

Linear maps and matrices. The fields of real and complex numbers. Operations of addition and multiplication of functions and the notion of vector space. Linear maps defined by matrices; composition and matrix multiplication. Vector spaces of matrices and linear maps. Basis of a vector space. Rank of a matrix. **(3 weeks)**

Systems of linear equations. Gauss elimination method. Elementary transformations. Homogeneous and inhomogeneous equations. The rank and defect theorem. A computation of the inverse matrix. **(2 weeks)**

Euclidean plane geometry. Lines and planes in V2 and V3. Hilbert axioms and models of geometry. Scalar product and congruence axioms. **(1 week)**

Scalar product. Cauchy inequality. Norm. Orthonormal bases. Gram-Schmidt orthogonalization. The best aproximation and the least squares method. The projection theorem. The representation theorem for linear functionals. The Hermitian adjoint of an operator. Orthogonal, unitary and Hermitian operators. Coordinates of vectors and matrices of operators in a given basis. The change of coordinates and matrices in different bases. A change of orthonormal bases and unitary similarity. **(3 weeks)**

Determinants. Length, area, volume and multilinear alternating maps. Calculations of determinants by using elementary transformations and the uniqueness of a determinant. The existence of determinant. Binet-Caucy theorem. Cramer's rule. Laplace expansion. **(3 weeks)**

Eigenvectors and eigenvalues. Characteristic polynomial and the matrix spectrum. The diagonalization theorem for normal operators. Nilpotent and semisimple operators. The Jordan decomposition theorem (without proof). Exponential function for operators. Systems of differential equations $y' = Ay$. **(2 weeks)**

STUDENT OBLIGATIONS DURING THE COURSE:
METHODS TO EVALUATE STUDENT PERFORMANCE:
EXAMINATION METHODS:
COURSE(s) NEEDED FOR THIS COURSE: None
COMPULSORY LITERATURE: **N. Elezović, Linearna algebra, Element, Zagreb 1995.**
ADDITIONAL READING: K. Horvatić, Linearna algebra, PMF-Matematički odjel i LPC, Zagreb 1995.

COURSE TITLE: Computing Lab		
COURSE TEACHER/TEACHERS: Doc.dr. sc. Nenad Pavin		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 1		
SEMESTER: 1		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	1	teacher
Exercises	0	teacher
Seminars		
Laboratory	3	assistant
ECTS credits: 3		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

The course is designed for understanding the basics of Computer Scinece.

DESCRIPTION OF THE COURSE:

1.Bits, Storage of Bits, Gates, Flip-Flops, Other Storage Techniques, Hexadecimal Noatation

2.Maim Memory, Mass Storage, Coding Information for Storage, ASCII

3.Representing Numerical Values, The Binary System, Storing Integers, Excess Notation, Two's Complement Notation, Storing Fractions, Floating-Point Notation

4.Data Manupulation, The Central Processing Unit, Registers, CPU/Memory Interface, Machine Instructions, The Stored-Program Concept

5.A Typical Machine Language, Program execution, Other Architectures (CISC and RISC), Pipelining, Multiprocessor Machines

6.Algorthms, Algorithm Representation, Pseudocode, Algorithm Discovery

7.Iterative Structures, The Sequential Search Algorithm, The Insertion Sort Algorithm, Recursive Structures

8.Programming Languages

9.Program Units, Procedures, Parameters, Functions, I/O Statements

10.Data Structures, Arrays, Pointers

11.Lists, Contiguous Lists, Linked Lists, Stacks, Queues

12.Trees, Terminology, Tree Implementation, A Binary Tree

STUDENT OBLIGATIONS DURING THE COURSE:

During laboratory students have to solve ten simple problems.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Students have to solve three more complicated problems, and two coloquia.

EXAMINATION METHODS:

The final mark is consists of laboratory examination (40% of mark) and of two coloquia (2×30% of mark)

COURSE(s) NEEDED FOR THIS COURSE: none

COMPULSORY LITERATURE:

Brookshear, J.G., "Computer Science: An Overview", Addison-Wesley

ADDITIONAL READING:

COURSE TITLE: General Physics 2
COURSE TEACHER/TEACHERS: Professors of Physics: M. Furić and E. Babić, Faculty of Sciences and Mathematics
STUDY PROGRAMME: University study of research physics
YEAR OF STUDY: 1
SEMESTER: 2

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	4	teacher
Exercises	2	assistant
Seminars	1	teacher

ECTS credits: 11
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: On the basis of Mechanics and specific properties of eletric and magnetic phenomena we develop the full description of unified electromagnetism. Through induction, which starts with the Coulomb law and countinues over the effects such as the Faraday effect we arrive at the Maxwell equations as the final description of the topic. We include the description of the real materials through the chapters on the internal electric and magnetic fields. Examples of applications include those in electrical engineering and other modern equipment .
DESCRIPTION OF THE COURSE: Charging and electric charge: electric charge, properties and origin, conductors and insulators, Coulomb's law, flux of the electric field, Gauss law-integral version.

Electric potential: potential energy for two point charges, potential energy for system of charges, continuum aproximation, equipotential surfaces and field's lines.

Calculation of fields and potentials for certain geometries, energy used to create the electric field.

Gauss law in the differential form: divergence of the vector field, expression for the divergence in Cartesi coordinates, application of the Gauss law to calculate electric fields.

Stokes theorem: circulation of the vector field, curl and its physical significance, Stokes theorem, differential formulation of electrostatics.

Capacitors and capacitance: definition, calculations of capacity, energy in capacitor, capacitors in series and parallel.

Current and resistance: current density, electric conductivity, Ohm's law, electromotive force and circuits, Kirchhoff's rules.

Magnetostatics: Oersted experiment, magnetic field, vector potential, charged particle in the

magnetic field, calculations of the magnetic field, Hall effect, differential form of magnetostatics.

Faraday induction: experimental discovery and its formulation, mutual and selfinduction, direct current motors, circuits containing coils.

Maxwell equations: displacement current, integral and differential forms of Maxwell equations.

Alternating currents: various L-R-C circuits, complex resistance, resonance, power and energy in the alternating current circuits.

Electric fields in materials: dielectrics, potential of the dipole, polarization, field of charges inside the dielectrics and Gauss law.

Magnetic fields in materials: diamagnetism, paramagnetism, ferromagnetism, magnetic field inside magnetized material, permanent magnet's magnetic field.

STUDENT OBLIGATIONS DURING THE COURSE: : Course attendance is controlled, three colloquia are offered during the semester; students' results on colloquia are included into the final written exam. Students receive homework problems. During seminars students ask explanations of the more comlex problems. Also they prepare own presentations.

METHODS TO EVALUATE STUDENT PERFORMANCE: : Evaluation includes results of written colloquia, final written exam and oral examination.

EXAMINATION METHODS: Final written exam includes also the results of the three colloquia. Oral exam is in front large audience. Student draws four questions. By answering very well student may improve his/her written exam grade by one grade

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COURSE(s) NEEDED FOR THIS COURSE:General Physics 1

COMPULSORY LITERATURE: H.D. Young and R.A.Freedman, University Physics, Pearson-Addisson Wesley, San Francisco, 2004.

ADDITIONAL READING: E.M. Purcell, Elektricitet i magnetizam (Udžbenik fizike Sveučilišta u Berkeleyu), Tehnička knjiga, Zagreb, 1988

COURSE TITLE: MATHEMATICAL ANALYSIS 2

COURSE TEACHER/TEACHERS: Prof. Miljenko Marušić, Ph.D.

STUDY PROGRAMME: University study of research study

YEAR OF STUDY: 1

SEMESTER: 2

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*Teacher or assistant*)
Lectures	3	*Teacher*
Exercises	2	*Assistant*
Seminars	0	-

ECTS credits: 8

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Adoption of integration calculus and learning mathematical theory.

DESCRIPTION OF THE COURSE: Rieman's integral. Indefinite integral. Integrabilitz of monotone and continuous functions. Newton-Leibniz formula.

Numerical series. Function series. Taylor's expansion.

Function of several variables (continuity, differential, extremes). Multiple integrals.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance on the lectures and passing colloquiums.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Colloquiums.

EXAMINATION METHODS: Colloquiums (80%), final exam (20%)

COURSE(s) NEEDED FOR THIS COURSE:Mathematical analysis 1

COMPULSORY LITERATURE:

S. Kurepa, Matematička analiza 1, 2, Tehnička knjiga, Zagreb.

B.P. Demidovič, Zadatci i riješeni primjeri iz više matematike, Tehnička knjiga, Zagreb.

ADDITIONAL READING:

COURSE TITLE: STATISTICS AND BASIC MEASUREMENTS		
COURSE TEACHER/TEACHERS: Professor dr. sc. Miroslav Požek		
STUDY PROGRAMME: university study of research physics		
YEAR OF STUDY: first		
SEMESTER: second		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	3	assistant
Seminars		

ECTS credits: 6

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Basic theory of probability and statistics; Basic measurements and processing of the results

DESCRIPTION OF THE COURSE: Course is divided into lectures (30 hours), numerical exercises (20 hours) and laboratory exercises (25 hours)

Lectures and numerical exercises: Descriptive statistics; Basic concepts of the theory of probability; Counting methods; Conditional probability, independence; Discrete probability distributions, expected value, variance, moments; Binomial distribution; Poisson distribution; Continous distributions; Normal distribution; Least square principle; Gamma distributions; Two-dimensional distributions; Correlations; Random sample; Central limit theorem; Confidence intervals, standard error, measurement precision; Measurements of different statistical weights; Error propagation; Linear regression and correlation; Nonlinear regressions; Samples of measurement data processing.

Laboratory exercises: Basic physical measurements and processing of measured data:

    - length, mass, time, microscope, voltage, current, resistance, oscilloscope

    - types of errors, mean value, precision, standard error, scatter plot, linear regression, use of computer

STUDENT OBLIGATIONS DURING THE COURSE: Attendance of lectures and numerical exercises. Problems solving. Attendance of laboratory exercises. Colloquium after laboratory exercises.

METHODS TO EVALUATE STUDENT PERFORMANCE: Passed colloquium after laboratory exercises.

EXAMINATION METHODS: Written exam (can be replaced by good results in solving problems). Oral exam.

COURSE(s) NEEDED FOR THIS COURSE:
COMPULSORY LITERATURE: lectures are available on the Internet: www.phy.hr/otvims
ADDITIONAL READING: J. L. Devore, Probability and statistics for engineering and the sciences, Duxbury, Thomson Learning, 2000

COURSE TITLE: Numerical methods		

COURSE TEACHER/TEACHERS: Doc.dr. sc. Nenad Pavin		

STUDY PROGRAMME: University study of research physics		

YEAR OF STUDY: 1		

SEMESTER: 2		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	0	
Seminars	0	
Laboratory	2	assistant

ECTS credits: 5		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

Aim of this coures is accomplishing fundamentals of numeric methods and programming in Fortran 95, and its application in physics and mathematics

DESCRIPTION OF THE COURSE:

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Lectures:
1. Introduction to Computers and the Fortran Language
2. Basic Elements of Fortran
3. Program Design and Branching Structures
4. Loops and Character Manipulation
5. Basic I/O Concepts
6. Introduction to Arrays
7. Introduction to Procedures and Functions
8. Additional Intrinsic Data Types
9. Object Oriented Programming in Fortran 95
10. Pointers and Dynamic Data Structures

Laboratory:
1. Polynomial Roots, Interpolation, Numerical Differentiation, Numerical
Integration
2. Understand the Process of Numerical Integration using Euler's method –
Kinematics of Space Ship
3. Understand some of the other Numerical Integration Methods (Runge-Kutta
method) - oscillators
4. Eigenvalues and Eigenvectors
5. Sort and Search Algorithm
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STUDENT OBLIGATIONS DURING THE COURSE:

Two labs completely done.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Course attendance is controled. During exercises students solve two problems and write an essay.

EXAMINATION METHODS:

Evaluation two essays would provide the final mark.

COURSE(s) NEEDED FOR THIS COURSE: none

COMPULSORY LITERATURE:

1.Stephen J. Chapman, Fortran 90/95 for Scientists and Engineers, McGraw-Hill, 2003
2.P.L. De Vries, A First Course in Computational Physics, John Wiley, 1994

ADDITIONAL READING:

COURSE TITLE: General Physics 3

COURSE TEACHER/TEACHERS: Professors of Physics: M. Furić and E. Babić, Faculty of Sciences and Mathematics

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 2

SEMESTER: 3

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	4	teacher
Exercises	2	assistant
Seminars	1	teacher

ECTS credits: 8

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:Based on Mechanics and Electromagnetism we develop the treatment of oscillations and classical waves. We explain in causal manner propagation of waves from wave equation. We introduce basic concepts of acoustics and optics. Through the concept of superposition and Fourier analysis we prepare students for quantum formalism. We also include applications in acoustics, optics and telecommunications.

DESCRIPTION OF THE COURSE:

Mechanical and electrical oscillations of the simple systems: spring oscillations and various pendelums, superposition principle due to the linearity of differential equations.

Oscillations of the systems with finite number of degrees of freedom: solving the coupled differential equations, eigen-frequencies and corresonding oscillations.

Oscillations of continuum: transversal oscillations of the string, Fourier analysis of the general solution, standing waves.

Forced oscillations: forced damped oscillator, forced oscillations for the system of finite number of degrees of freedom, filtering, wave penetration into the reactive region.

Travelling waves: harmonic travelling waves in one dimension, impedance, phase velocity, energy flux, transmission lines, index of refraction and dispersion.

Reflections: boundary conditions, perfect termination, matching the impedances, reflections on the thin films.

Modulations and the wave packets: group velocity, pulses and Fourier analysis, pulse dimensions, spreading of the travelling wave packet.

Waves in three dimesions: wave vector for the plane wave, electromagnetic waves, radiation of the accelerated point charge.

Polarization of the waves: polarization states, double refraction and optical activity, production and analysis of the state of polarization.

Interference and diffraction: Interference of two coherent point sources, diffraction grating, Huygens principle, angular width of the « parallel beam».

Geometrical optics: laws of geometrical optics, Fermat's principle, thin lense formula, human eye, microscope, telescope.

STUDENT OBLIGATIONS DURING THE COURSE: Course attendance is controlled, three colloquia are offered during the semester, students' results on colloquia are included into the final written exam. Students receive homework problems. During seminars students ask explanations of the more complex problems. Also they prepare own presentations.

METHODS TO EVALUATE STUDENT PERFORMANCE: Evaluation includes results from colloquia, final written exam and the oral examination.

EXAMINATION METHODS:Final written exam grade includes also the results from colloquia. Oral exam is in front of large audience. Student draws four questions. By answering very well student may improve his/her written exam grade by one grade.

COURSE(s) NEEDED FOR THIS COURSE: General Physics 1 and General Physics 2.

COMPULSORY LITERATURE: H.D. Young and R.A. Freedman, University Physics, Pearson-Addisson Wesley, San Francisco, 2004.

ADDITIONAL READING: F.S. Crawford, Waves (Berkeley physics course 3), McGraw-Hill, New York, 1965.

COURSE TITLE: INTRODUCTORY PHYSICS LAB 1

COURSE TEACHER/TEACHERS: Miroslav Požek, Dinko Babić, Gorjana Jerbić Zorc

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: second

SEMESTER: third

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	assistant

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Individual experiments connected to the lectures in physics and processing of the results

DESCRIPTION OF THE COURSE: Laboratory exercises in physics: Student chooses 6 of 9 exercises:

- one of "Mathematical pendulum" or "Maxwell's disk"
- one of "Modulus of elasticity" or "Modulus of torsion and torsional oscillations"
- obligatory "Mechanical harmonic oscillator"
- three of "Measurement bridge for inductance and capacitance", "Magnetic induction", "Transformer" or "Magnetic dipole moment in magnetic field"

STUDENT OBLIGATIONS DURING THE COURSE: Short test on physical foundations of the exercise to be done. Report on the measurements and results after each exercise.

METHODS TO EVALUATE STUDENT PERFORMANCE: Six exercises and reports have to be done.

EXAMINATION METHODS: Each exercise is given a mark (test+performance+report). No final exam unless student is not satisfied with the given final mark.

COURSE(s) NEEDED FOR THIS COURSE: Physics 1, Physics 2, passed colloquium in Statistics and basic measurements.

COMPULSORY LITERATURE: manual for each exercise;

Požek, Miroslav; Dulčić, Antonije: Fizički praktikum I i II, Zagreb : Sunnypress, 1999.

COURSE TITLE: Mathematical methods of physics 1 and 2

COURSE TEACHER/TEACHERS: Denis Sunko

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 2

SEMESTER: 3 and 4

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	3	teacher
Exercises	2	assistant
Seminars	0	

ECTS credits: 9 + 8

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Basic mathematical apparatus required to describe physical phenomena.

DESCRIPTION OF THE COURSE:

1. **Complex numbers. Algebraic and topological completeness. Projective sphere and the point at infinity.**

2. **Functions of complex numbers. Power, root, exponential and logarithmic functions.**

3. **Analytic functions. Cauchy-Riemann conditions. Cauchy's theorem with Goursat's proof. Basic theorem of integral calculus for analytic functions. Cauchy's integral formula. Liouville's theorem and basic theorem of algebra.**

4. **Sequences and series of complex numbers and functions. Absolute and uniform convergence. Cauchy's sequences. Power series. Abel's theorem. Radius of convergence.**

5. **Taylor's and Laurent's series.**

6. **Zeros of analytic function. Uniqueness theorem.**

7. **Singularities of analytic functions. Isolated singularities and their characterization by Laurent series. Residue theorem.**

8. **Gama function.**

9. **Ordinary linear differential equations. Wronskian. Cauchy's problem. First order equations. Inhomogeneous equations. Equations with constant coefficients. Methods of undetermined coefficients and variation of constants. Frobenius' method for second-order equations over complex regions. Fuchs' teorem (without proof).**

10. **Fourier series. Concept of a set of measure zero. The space L^1. The space L^2 as a**

vector space. Distance and orthogonal projection in L^2. Classical Fourier series. Riemann-Lebesgue lema (without proof). Convergence in the mean. Convergence at a point. Inversion formula. Principle of localization. Jordan's theorem.

11. The space ℓ^2. Bessel's and Parseval's equality. Riesz-Fischer theorem (proof assuming topological completeness of L^2).

12. Fourier transforms. Inversion formula. Jordan's theorem for transforms (informally). The transform of a convolution, with dielectric response as an example.

13. Integration and differentiation of Fourier series. Basic concepts of distribution theory. Weak convergence. Examples of delta-sequences. Interpretation of the inversion formula for transforms as a delta-sequence. Dirac's delta-function notation and its use to derive Bessel's and Parseval's equations for transforms.

14. Partial differential equations. Derivation of the wave equation for a string. Method of separation of variables. Method of eigenfunction expansion. Example of a continuous spectrum. Qualitative analysis of the wave equation, D'Alembert's solution, total energy of a wave. Helmholtz equation. Diffusion equation. Derivation of the wave equation for sound in a gas. Example of a wave-guide.

15. Special functions. Legendre polynomials. Associated Legendre functions and spherical harmonics. Sturm-Liouville problem. Bessel functions. Spherical Bessel and Neumann functions. Modified Bessel functions.

16. Asymptotic series. Saddle-point and steepest-descent methods. Examples of factorials and binomial coefficients.

STUDENT OBLIGATIONS DURING THE COURSE: No formal obligations. Colloquia may be organized for the student's own information.

METHODS TO EVALUATE STUDENT PERFORMANCE: Examination.

EXAMINATION METHODS: Written and oral parts, written part should be passed to proceed to oral.

COURSE(s) NEEDED FOR THIS COURSE:Mathematical analysis. Harmonic oscillator and electromagnetism within the framework of general physics.

COMPULSORY LITERATURE: E. Butkov, Mathematical Physics, Addison-Wesley, 1968. ISBN 0-201-00727-4.

ADDITIONAL READING: Prescribed to individual students, adapted to their request.

COURSE TITLE: Classical Mechanics I		
COURSE TEACHER/TEACHERS: Prof. Aleksa Bjeliš, Department of Physics, University of Zagreb		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 2		
SEMESTER: 3		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	3	teacher
Exercises	2	assistant
Seminars	-	-
ECTS credits: 8		
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Conceptual and systematic understanding of classical mechanics		
DESCRIPTION OF THE COURSE: Galilean transformation. Newton's formulation of classical mechanics. Dynamics of a point mass (particle). The Kepler problem. Scattering in classical mechanics. Euler-Lagrange equations. Hamiltonian. Phase space. Mechanics of a rigid body.		
STUDENT OBLIGATIONS DURING THE COURSE: Students should continuously follow lectures and exercises, participate in quiz-tests, and fulfil home-assignments.		
METHODS TO EVALUATE STUDENT PERFORMANCE: Success in the obligations mentioned in the previous point will be evaluated, together with a final written and oral exam.		
EXAMINATION METHODS: Written and oral exam, quiz-tests during the semester		
COURSE(s) NEEDED FOR THIS COURSE: General Physics courses		
COMPULSORY LITERATURE: H. Goldstein, Classical Mechanics L.D. Landau, E.M. Lifshitz, Course of Theoretical Physics (Mechanics, Fluid Mechanics, Theory of Elasticity) Z. Janković, Teorijska mehanika		
ADDITIONAL READING: V. Arnold, Methodes Mathematiques de la Mechanique Classique I. Percival, D. Richards, Introduction to Dynamics		

COURSE TITLE:	Elective seminars 1, 2

COURSE TEACHER/TEACHERS: Professors teaching 2nd year students. The mentors of 1st and 2nd year Prof. Bosnar and Prof. Požek

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 2nd year

SEMESTER: 3 rd semester

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars	2	teacher

ECTS credits: 1+1

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The students are allowed to choose different topics from all regions of physics from scientific journals. In this way the students will complete their knowledge from physics according to their interest.

DESCRIPTION OF THE COURSE: Seminars from all regions of physics.

STUDENT OBLIGATIONS DURING THE COURSE: The course attendance is controlled. The students should give oral presentation.

METHODS TO EVALUATE STUDENT PERFORMANCE: Regular attendance of seminars and oral presentation of their elected topics.

EXAMINATION METHODS: There is no ordinary examination. After succesful oral presentation of seminar topic the student receive the signature and the note.

COURSE(s) NEEDED FOR THIS COURSE: The courses of 1st year.

COMPULSORY LITERATURE: The relevant articles from Physics Today, Scientific American, American Journal of Physics, INTERNET

ADDITIONAL READING: The articles from scientific journals

COURSE TITLE: General Physics 4

COURSE TEACHER/TEACHERS: Professors of Physics: M. Furić and E. Babić, Faculty of Sciences and Mathematics.

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 2

SEMESTER: 4

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	4	teacher
Exercises	2	asistant
Seminars	1	teacher

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Confront the knowledge on wave phenomena with experiments indicating also the corpuscular aspects in the microworld. Introduce the Copenhagen interpretation as a solution to the duality problem and start the quantum physics formulation. With the topics from classical Thermodynamics complete the knowledge on foundations of physics. Applications of thermodynamics and applications in modern physics are also included

DESCRIPTION OF THE COURSE: Basic observations in favour of quantum physics: Planck's constant, photoelectric effect, Franck-Hertz experiments, atomic structure and stability of atoms.

Building the periodic system: Bohr's model for the explanation of the atomic spectra, atomic levels and spectra of selected atoms, Pauli principle.

Transitions between atomic levels: level width, allowed transitions and selection rules.

Photons: wave and corpuscular aspects, Compton effect, Bremsstrahlung and x-ray spectra, indivisibility of photons, Copenhagen interpretation; an exit for duality.

Matter waves: De Broglie waves, diffraction of the matter waves on the periodic structures, wave equation and the superposition principle.

Uncertainty principle: Heisenberg relations, measurement and statistical ansamble, amplitudes and intensities, causality in quantum physics.

Schroedinger wave formulation: Schroedinger equation, potential barrier, potential well, harmonic oscillator, Ehrenfest theorems.

Temperature: zeroth-law of thermodynamics, thermometry, temperature scales (including the international).

Equation of state: ideal gas, P-V-T surface for the real substance, triple point.

First law of thermodynamics: work to heat conversion, internal energy of the system, proper and Pfaff differentials, thermal capacities.

Heat transfers: contact and temperature gradient, convection, laws of thermal radiation.

Second law of thermodymamics: Heat engines, refrigirators, Carnot cycle and its properties.

Irreversible thermodynamic processes: a factor to convert the Pfaff differential into proper differential- entropy, calculations of entropy.

Thermodynamic potentials, Joule-Thompson coefficient, phase transitions, Clausius-Clayperon relation.

STUDENT OBLIGATIONS DURING THE COURSE: Course attendance is controlled, three colloquia are offered during the semester, student's results on colloquia are included into the final written exam. Students receive homework problems. During seminars students ask explanations for the more complex problems. Also they prepare own presentations.

METHODS TO EVALUATE STUDENT PERFORMANCE: Evaluation includes the results from colloquia, final written exam and oral examination.

EXAMINATION METHODS:Final written examination grade includes also the results from colloquia. Oral exam is in front of large audience. Student draws four questions. He may improve his written exam grade by one unit in the final grade by answering very well during the oral examination.

COURSE(s) NEEDED FOR THIS COURSE:General Physics 1, General Physics 2, General physics 3.

COMPULSORY LITERATURE: H.D. Young and R.A. Freedman, University Physics (with Modern Physics), Pearson-Addisson Wesley, San Francisco 2004.

ADDITIONAL READING: E.H. Wichmann Kvantna fizika (Udžbenik fizike Sveučilišta u Berkeleyu 4), Tehnička knjiga, Zagreb, 1988.

F. Reiff Berkeley Physics Course 5 (Statistical Physics) McGraw-Hill, New York, 1967

COURSE TITLE: INTRODUCTION TO QUANTUM PHYSICS		
COURSE TEACHER/TEACHERS: Professor M. Šunjić		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 2		
SEMESTER: 4		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	2	assistant
Seminars		
ECTS credits: 5		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction to the origin and basic principles of quantum physics. Solutions of the simple physicalproblems, and their discussion.

DESCRIPTION OF THE COURSE:

1) Historical introduction, experimental basis

2) Quantum hypothesis, old quantum theory

3) De Broglie hypothesis, particle-wave duality

4) Interpretation and properties of the wave function, superposition principle

5) Uncertainty principle, wave packet

6) Schrodinger equation

7) Statistical interpretation of the wave function, density and current probabilities

8) Representation of observables by operators, average values and measurements

9) Stationary solutions of the Schrodinger equation, energy quantization

10) Fre particle, particle in a (piecewise) constant potential, tunneling

11) Infinite potential well

12) Linear harmonic oscillator

STUDENT OBLIGATIONS DURING THE COURSE: Homework projects and active participation in excercices.

METHODS TO EVALUATE STUDENT PERFORMANCE: Regular delivery of homework.

EXAMINATION METHODS: Written and oral examinations.

COURSE(s) NEEDED FOR THIS COURSE: Physics I-III, Mathematical methods in physics I, Classical mechanics I

COMPULSORY LITERATURE:
 I. Supek: Teorijska fizika i struktura materije II (Školska knjiga, Zagreb, 1977)

ADDITIONAL READING:

 Leonard I. Schiff: Quantum Mechanics (McGraw-Hill 1968)
Eugen Merzbacher: Quantum Mehanics (John Wiley 1970)

COURSE TITLE: Classical Mechanics II		
COURSE TEACHER/TEACHERS: Prof. Aleksa Bjeliš, Department of Physics, University of Zagreb		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 2		
SEMESTER: 4		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	3	teacher
Exercises	2	assistant
Seminars	-	-

ECTS credits: 7
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Conceptual and systematic understanding of classical mechanics
DESCRIPTION OF THE COURSE: Linear systems and linear stability. Normal coordinates. Resonance. Parametric resonance. Canonical transformations. Hamilton-Jacoby formulation of classical mechanics. Action-angle variables. Poisson brackets. Adiabatic invariants.
STUDENT OBLIGATIONS DURING THE COURSE: Students should continuously follow lectures and exercises, participate in quiz-tests, and fulfil home-assignments.
METHODS TO EVALUATE STUDENT PERFORMANCE: Success in the obligations mentioned in the previous point will be evaluated, together with a final written and oral exam.
EXAMINATION METHODS: Written and oral exam, quiz-tests during the semester
COURSE(s) NEEDED FOR THIS COURSE: General Physics courses, Classical mechanics I
COMPULSORY LITERATURE: H. Goldstein, Classical Mechanics
L.D. Landau, E.M. Lifshitz, Course of Theoretical Physics (Mechanics, Fluid Mechanics, Theory of Elasticity)
Z. Janković, Teorijska mehanika
ADDITIONAL READING: V. Arnold, Methodes Mathematiques de la Mechanique Classique
I. Percival, D. Richards, Introduction to Dynamics

COURSE TITLE: INTRODUCTORY PHYSICS LAB 2		

COURSE TEACHER/TEACHERS: Miroslav Požek, Dinko Babić, Gorjana Jerbić Zorc

STUDY PROGRAMME: university study of research physics

YEAR OF STUDY: second

SEMESTER: fourth

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	assistant

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Individual experiments connected to the lectures in physics and processing of the results

DESCRIPTION OF THE COURSE: Laboratory exercises in physics: Student chooses 6 of 11 exercises:

- one of "Density of liquids", "Surface tension" or "Viscosity"
- three of "Lences", "Optical instruments", "Velocity of light", "Light iterference" or "Light diffraction "
- two of "Ideal gas state", "Maxwell-Boltzman distribution of velocity " or "Resistive thermometer"

STUDENT OBLIGATIONS DURING THE COURSE: Short test on physical foundations of the exercise to be done. Report on the measurements and results after each exercise.

METHODS TO EVALUATE STUDENT PERFORMANCE: Six exercises and reports have to be done.

EXAMINATION METHODS: Each exercise is given a mark (test+performance+report). No final exam unless student is not satisfied with the given final mark.

COURSE(s) NEEDED FOR THIS COURSE: Physics 1, Physics 2, passed colloquium in Statistics and basic measurements.

COMPULSORY LITERATURE: manual for each exercise;

Požek, Miroslav; Dulčić, Antonije: Fizički praktikum I i II, Zagreb : Sunnypress, 1999.

ADDITIONAL READING: www.phywe.de

COURSE TITLE: Classical electrodynamics

COURSE TEACHER/TEACHERS: Professor Silvio Pallua

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: third

SEMESTER: fifth and sixth

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	3	teacher
Exercises	2	assistant
Seminars		

ECTS credits: 6 + 6

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The aim of the course is to enable the student to get the the knowledge and understanding of basic concepts of classical electrodynamics.In the same time it is aim of the course to develop the students skill in operative knowledge and capability to solve problems.

DESCRIPTION OF THE COURSE:

Electrostatics

-Concept of electric charge and of electric field.Coulomb law.Electric field of discrete and continous distribution of charges.

-Differential equations of electrostatics.Integral laws of electrostatics.

-Electrostatic potential.Poisson and Laplace equation.Energy of electrostatic field.

-Simple electrostatic systems and corrresponding potentials(Multipoles,surface distribution of charges,surface distribution of dipoles etc.)

-Multipole expansion of electrostatic potential of a localised distribution of charges.

-Electrostatics in dielectrics.Boundary conditions for electrostatic fields on boundary of two media.Energy of electrostatic field in dielectric media

-Theory of polarization with induced dipole moments and permanent dipole moments.

-Uniqueness of solution of electrostatic problem with Neumann or Dirichlet boundary conditions.Solving electrostatic problems with boundary conditions using Green functions.

Magnetostatics

-Historical introduction.Continuity equation.Magnetic induction for a given current distribution.Force on localized currrent in external magnetic induction.

-Lorentz force.Differential equations of magnetostatics.Integral laws of magnetostatics.Vector potential.

-Magnetic field of a localized distribution of currents.Notion of magnetic dipol moment.Magnetic moment of a charged particle and its angular momentum .

Differential equations of magnetostatics in presence of media.Diamagnetism.Paramagnetism.

Time dependent fields

-Maxwell equations

-Energy of magnetostatic field.Conservation of energy and momentum of the system of charged particles and electromagnetic field.

-Formulation of electrodynamics with vector and scalar potential.Gauge invariance of electrodynamics.

-Solutions of homohenous Maxwell eqautions.Plane electromagnetic waves.Polarisation of plane waves.Waves in conducting and dissipative medium.

-Conditions on boundaries between dielectric.Reflection and refraction of plane electromagnetic waves at a plane boundary(Fresnel equations)

-Wave packet and group velocity.

-Retarded and advanced potentials as solutions of nonhomogenous equations for vector and scalar potentials

-Radiation of localised sources.multipole expansion.Electric dipol radiation.Magnetic dipol radiation.Electric quadrupol radiation.Scalar diffraction theory .

-Review of various unit systems in electrodynamics.

Special theory of relativity

Motivation for special theory of relativity.Michelson-Morely experiment.

-Postulates of special theory.Length contraction and time dilation.Synchronisation of clocks.

-Lorentz transformations.Addition of velocities and concept of maximal length.

-Relativistic mechanics.Special theory and relation between mass and energy

Special theory of relativity and electrodynamics.

Equations of electrodynamics in covariant form.

-Transformation of electromagnetic field and application on the field of the point charge.Solution of nonhomogenous wave equations in covariant form Application on Lienard-Wiechert potentials of point charges
-Connection betwen concepts of electrodynamics and mechanics.Action,Lagrangian and Hamiltonian of the system of charged particles and electromagnetic field .Nonrelativistic limit of this hamiltonian and connection with quantum mechanics.Energy momentum tensor.
-Equivalence principle and short introduction to general theory of relativity.

STUDENT OBLIGATIONS DURING THE COURSE:

There are four written colloquia (two per semester).Results of colloquia are included in final written examination.There is in addition an oral examination.

METHODS TO EVALUATE STUDENT PERFORMANCE: Evaluation includes results from colloquia,written examination and oral examination.

EXAMINATION METHODS: colloquia with written problems,written examination and oral examination

COURSE(s) NEEDED FOR THIS COURSE:,Obligatory mathematical courses from the first two years,General Physics courses from the first two years.

COMPULSORY LITERATURE: J.D.Jackson,Classical electrodynamics,John Wiley,3rd ed.1999

David.J.Griffiths,Introduction to Electrodynamics,Prentice Hall 1999

ADDITIONAL READING:Landau L D ,Lifshits E M,The Classical Theory of Fields,Pergamen 1994

COURSE TITLE:	**Quantum physics**

COURSE TEACHER/TEACHERS: Professor M. Šunjić

STUDY PROGRAMME: University study of research pyhsics

YEAR OF STUDY: 3rd

SEMESTER: 5th and 6th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars	2	assistant

ECTS credits: 6 + 6

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Develop understanding of the principles of quantum physics, methods (especially approximative) of solution of physical problems, and apply them to concrete systems.

DESCRIPTION OF THE COURSE:

Winter semester

1) Principles and experimental confirmation of quantum physics

2) Schrodinger equation, separation of variables, quantum numbers

3) Threedimensional problems – quantization in a box, finite well, harmonic oscillator. Degeneracy and the density of states.

4) Spherically symmmetric potentials, angular momentum operator

5) Identical particles, spin and statistics. Bose-Einstein and Fermi-Dirac distributions

6) Hydrogen atom. Periodic system of elements

7) Approximation methods: Stationary perturbation theory

8) Examples, particle interacting with electric and magnetic field, Stark effect, Zeeman effect

9) Approximation methods: Variation method. Examples, ground state of helium atom, twoelectron atoms

10) Approximation methods: WKB approximation

11) Tunneling, alpha-decay, bound state energies in WKB approximation

12) Electron spin, algebra of angular momentum operators

Summer semester

13) Electron in a magnetic field, LS coupling, anomalous Zeeman effect, Paschen-Back

effect

14) Quantization of a harmonic oscillator, axioms of quantum mechanics, states in a Hilbert space, opservables and linear operators

15) Dirac notation. Complementary variables, commutators and uncertainty relations, minimum uncertainty wave packet

16) Scattering theory, cross section, partial wave method, phase shifts, optical theorem, scattering on a finite spherical well, resonances

17) Integral equation for the wave function, Born expansion

18) First Born approximation, bare and screened Coulomb potentials

19) Heisenberg and interaction pictures, time evolution operator, time-dependent perturbation theory, first order processes

20) Adiabatic hypothesis, transition probabilities, Fermi golden rule

21) Particle – radiation interaction: absorption and emission

22) Nucleon states in a nuclear potental, magic numbers

23) Molecules: Born-Oppenheimer approximation, hydrogen ion – binding energy, vibrations, rotations

24) Electrons in a periodic 1–D potential: Bloch theorem, forbidden states, energy bands

STUDENT OBLIGATIONS DURING THE COURSE: Homework; small projects submitted and orally presented.

METHODS TO EVALUATE STUDENT PERFORMANCE: Homework delivered regularly, successful project presentation.

EXAMINATION METHODS: Delivery and presentation of projects, colloquium after winter semester, and final oral exam.

COURSE(s) NEEDED FOR THIS COURSE:Physics I-IV, Mathematical methods in physics I and II, Classical mechanics I and II

COMPULSORY LITERATURE: **I.Supek: Teorijska fizika i struktura materije II (Školska knjiga, Zagreb, 1977)**
Leonard I. Schiff: Quantum Mechanics (McGraw-Hill 1968)

COURSE TITLE: Statistical Physics		

COURSE TEACHER/TEACHERS: Denis Sunko		

STUDY PROGRAMME: University study of research physics		

YEAR OF STUDY: 3		

SEMESTER: 5 and 6		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 5 + 5		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Understanding the relationship of thermodynamics and statistical physics. Acquiring the basic concepts of a statistical description of systems in the thermodynamic limit: entropy, thermodynamic potentials, ensembles, single-particle distributions, fluctuations.**

DESCRIPTION OF THE COURSE:

1. **Thermodynamics as an autonomous discipline**
    1.1. **Introduction. Basic concepts**
    1.2. **First law of thermodynamics. Engines**
    1.3. **Second law of thermodynamics. Reversibility and entropy**
    1.4. **Thermodynamic potentials**
    1.5. **Practical calculations**
2. **Introduction to statistical physics**
    2.1. **Basic considerations**
    2.2. **Ensemble: universal random model**
    2.3. **The connection with thermodynamics**
3. **Canonical and grand canonical ensembles**
    3.1. **Canonical ensemble**
    3.2. **Grand canonical ensemble**
    3.3. **Sums over states as generating functions**
    3.4. **Classical ideal gas**
    3.5. **Maxwell's distribution and the equipartition theorem**
4. **Quantum statistical physics**
    4.1. **Basic considerations**
    4.2. **Ideal Fermi gas**
    4.3. **Ideal Bose gas**
    4.4. **Practical calculations in a finite system**

5. **Examples and models**
   - **5.1. Barometric formula**
   - **5.2. Chemical reactions**
   - **5.3. Diatomic molecules**
   - **5.4. Magnetic fields**
   - **5.5. Paramagnetism**
   - **5.6. Heat capacities of crystals**
   - **5.7. Van der Waals' model of gas liquefaction**
   - **5.8. Macroscopic analysis of stability**
   - **5.9. Ferromagnetism**
6. **Fluctuations and non-equilibrium processes**
   - **6.1. Brownian motion**
   - **6.2. Thermodynamic fluctuations**
   - **6.3. Wiener-Khintchine theorem**
   - **6.4. Nyquist's theorem**
   - **6.5. Return to equilibrium as an irreversible process**
   - **6.6. Onsager's relations**

STUDENT OBLIGATIONS DURING THE COURSE: No formal obligations. Colloquia may be organized for the student's information.

METHODS TO EVALUATE STUDENT PERFORMANCE: Examination.

EXAMINATION METHODS:Written and oral part, written part should be passed to proceed to oral.

COURSE(s) NEEDED FOR THIS COURSE:Thermodynamics within the framework of general physics. Classical mechanics.

COMPULSORY LITERATURE:

C. Kittel, Elementary Statistical Physics, Dover 2004, ISBN 0486435148.

R. Kubo et al., Statistical mechanics: an advanced course with problems and solutions, (North-Holland Personal Library). North-Holland, Amsterdam 1988, ISBN 0444871039.

ADDITIONAL READING: Prescribed to individual students, adapted to their request.

COURSE TITLE: ADVANCED PHYSICS LAB 1		
COURSE TEACHER/TEACHERS: Miroslav Požek, Dinko Babić, Gorjana Jerbić Zorc		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: third		
SEMESTER: fifth		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	assistant
ECTS credits: 4		
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Individual sophisticated experiments connected to the lectures in classical and quantum physics		

DESCRIPTION OF THE COURSE:

I. Sophisticated laboratory exercises in physics to be executed in 2 or 3 sessions each.: Authonomy in preparation and execution of the exercises, as well as result processing and concluding is required. Student chooses exercises (but all exercises should be equally distributed in a generation):

- one of "Mechanical damped and forced oscillator", "Electrical resonant circuit" or "Coupled pendula"

- one of "Interference optical phenomena", "Polarization of light", "Spectrometer with prism and spectra of two-electron systems"

- one of "Planck constant and Heisenberg uncertainty relations", "Frank-Hertz experiment"

II. Seminar in which student presents one of the executed exercises to his colleagues, demonstrating measurements, and showing physical principles, results and discussion. The seminar allow all students to be familiar with all exercises.

STUDENT OBLIGATIONS DURING THE COURSE: Understanding of physical foundations of the exercise to be done. Report on the measurements and results after each exercise. Seminar. Attendance of the seminars given by colleagues.

METHODS TO EVALUATE STUDENT PERFORMANCE: Three exercises and reports have to be done. Seminar

EXAMINATION METHODS: Each exercise is given a mark. No final exam unless student is not

satisfied with the given final mark.
COURSE(s) NEEDED FOR THIS COURSE: Physics 1-4, Basic laboratory exercises 1-2.
COMPULSORY LITERATURE: script with setup for each exercise;
ADDITIONAL READING: Požek, Miroslav; Dulčić, Antonije: Fizički praktikum I i II, Zagreb : Sunnypress, 1999.

COURSE TITLE: Microelectronics

COURSE TEACHER/TEACHERS: Professor A. Hamzić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 5

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Knowledge of the principles, properties, realizations and use of semiconductor elements, integrated circuits and systems of analogue and digital microelectronics.

DESCRIPTION OF THE COURSE:
1. **Principles of semiconductor physics, band structure, conduction, mobility, diffusion;**
2. **Semiconductors under non-equilibrium conditions, recombination processes;**
3. **p-n junction; forward and reverse bias, junction breakdown;**
4. **Bipolar junction transistor (BJT) - physical characteristics, properties, I-V characteristics;**
5. **Junction field-effect transistor (JFET) - physical characteristics, properties, I-V characteristics;**
6. **Surface field-effect transistor with metal-oxide-semiconductor structure (MOSFET) - physical characteristics, properties, I-V characteristics**
7. **Amplifiers, followers and differential amplifiers with FET, MOSFET and BJT;**
8. **RC – amplifiers;**
9. **Feedback;**
10. **Operational amplifier, active and passive filters;**
11. **Basic logic gates (TTL, ECL, NMOS, CMOS versions);**
12. **Combinational and sequential logic circuits;**
13. **Elements of spintronics**

STUDENT OBLIGATIONS DURING THE COURSE:

homework, partial exams (colloquy)

METHODS TO EVALUATE STUDENT PERFORMANCE: positive results at colloquy

EXAMINATION METHODS: written and oral parts of the exam

COURSE(s) NEEDED FOR THIS COURSE: Solid State Physics

COMPULSORY LITERATURE:
A.S.Grove, Physics and Technology of Semiconductor Devices, Wiley, NY 1967.

D.J.Roulston, An Introduction to the Physics of Semiconductor Devices, Oxford University Press, 1999

J .Millman and A.Grabel, Microelectronics, McGraw-Hill, New York, 1988.

ADDITIONAL READING:

S.M. Sze, Physics of Semiconductor Devices, Wiley & Sons Inc., New York, 1981.
A. Sedra, K.C.Smith, Microelectronic circuits, Oxford University Press, 1998

COURSE TITLE: Physics of Materials

COURSE TEACHER/TEACHERS: Dinko Babić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 5

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	teacher

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction to variability, physical properties and applications of materials

DESCRIPTION OF THE COURSE: Hystorical overview. Chemical bonding. Crystal state. Reciprocal space. Disorder in solid state. Amorphous state. X-ray diffraction. Multiphase materials. Processing and performances of materials. Corrosion and the protection. Polymers. Composites. Magnetic properties of materials. Dielectric properties of materials. Superconductors. Semiconductors.

STUDENT OBLIGATIONS DURING THE COURSE: Regular attendance of lectures and seminars (prepared by students)

METHODS TO EVALUATE STUDENT PERFORMANCE: Discussions.

EXAMINATION METHODS: Oral examination. The first part of the examination covers topics of the seminars, the second part of the lectures. The final grade is formed as a combination of these two elements.

COURSE(s) NEEDED FOR THIS COURSE: General physics 1-4

COMPULSORY LITERATURE: L. H. Van Vlack, Elements of Material Science and Engineering, 6th edition, Addison-Wesley, 1989; C. Kittel, Introduction to Solid State Physics, 6th edition, John Wiley & Sons, 1986.

ADDITIONAL READING: Selected diploma theses.

COURSE TITLE: Mathematical analysis in space		
COURSE TEACHER/TEACHERS: Prof. dr. sc. Nenad Antonić, dr. sc. Marko Vrdoljak		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 3		
SEMESTER: 5		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	2	assistant
Seminars	0	
ECTS credits: 3		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Aquire technics of differential and integral calculus in higher dimensions and provide a foundation in differential geometry of surfaces.

DESCRIPTION OF THE COURSE:

[1-3] Translation space of d-dimensional Euclidean space, inner product space. Tensor product of vectors, invariants of operators, axial vector of antisymmetric operator in three dimensions, spectrum of symmetric operator.

[4-7] Differential calculus in Rd: derivative, differential, gradient, Jacobi matrix, derivatives of higher order. Mean value theorems, theorem on implicit and inverse function. Extrema of functions with several arguments and applications.

[8-10] Integral calculus in Rd: Riemann integral on parallelepiped, change of variables and Fubini theorem.

[11-14] Vector fields, divergence and rotation. Derivative of determinant and inverse matrix. Space curves, tangent line and length. Surfaces in space, tangential space, constrained extrema. Line and surface integrals, Stokes and Gauss theorem. Differential forms and some applications.

STUDENT OBLIGATIONS DURING THE COURSE: 20% credit on tests.

METHODS TO EVALUATE STUDENT PERFORMANCE: Homework exercises, two tests.

EXAMINATION METHODS: 50% credit on tests or final written exam, oral exam.

COURSE(s) NEEDED FOR THIS COURSE: Mathematical analysis, Linear algebra.

COMPULSORY LITERATURE:

1. Serge Lang: Undergraduate analysis, Springer, 1997.

2. Christopher T. J. Dodson, Timothy Poston: Tensor geometry, Springer, 1991.

ADDITIONAL READING:

1. Morton E. Gurtin: An introduction to continuum mechanics, Academic Press, 1981.

2. Paul Bamberg, Shlomo Sternberg: A course of mathematics for students of physics, Cambridge, 1991.

3. Šime Ungar: Matematička analiza 3, PMF-Matematički odjel, Zagreb, 1992.

COURSE TITLE: Group Theory		
COURSE TEACHER/TEACHERS: doc. dr. sc. Krešimir Kumerički, PMF, Zagreb		
STUDY PROGRAMME: university study of research physics		
YEAR OF STUDY: 3		
SEMESTER: 5		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars		
Lab	1	assistant
ECTS credits: 3		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction to the methods of group theory and of group representations. Development of the mathematical formalism and application to physical examples. Course also supplements courses in quantum physics, and helps with later courses in solid state, nuclear and particle physics. It mainly treats finite groups. For continuous (Lie) groups, course Symmetries in Physics in the next semester is recommended.

DESCRIPTION OF THE COURSE: 1. Groups. Chrystalographic point groups.2. Subgroups. Homomorphism and isomorphism.3. Group representations. Equivalence of representations.4. Direct sum and product of representations. Reducibility.5. Schur lemmas and orthogonality relations6. Character tables. Decomposition of reducible representations.7. Applications: Dipole moments of christals. Degeneration and splitting of energy levels8. Symmetries in classical and quantum mechanics. Transformations and conservation laws. Notion of tensors.9. Space transformations of QM systems10. Examples: Bloch theorem. Spin.11. Discrete simmetries in QM: space inversion (parity) 12. Time inversion. Permutation symmetry and identical particles

STUDENT OBLIGATIONS DURING THE COURSE: Student must submit solutions to 50 percent of homework problems.

METHODS TO EVALUATE STUDENT PERFORMANCE: Homework problems and oral exam

EXAMINATION METHODS: 50 percent of final grade comes from homeworks and another 50 percent from oral examination

COURSE(s) NEEDED FOR THIS COURSE: Linear algebra. Introduction to Quantum Physics

COMPULSORY LITERATURE:K. Kumericki, Symmetries in Physics, course text available online at http://www.phy.hr/~kkumer

ADDITIONAL READING:H. F. Jones, Groups, Representations and Physics, 2nd ed, IOP Publishing, 1998.W. Greiner and B. Mueller, Quantum Mechanics - Symmetries, Springer Verlag, 1989.J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley, 1994.M. Hamermesh, Group Theory and its Application to Physical Problems, Dover, 1989.J. F. Cornwell, Group Theory in Physics, An Introduction, Academic Press, 1997.

COURSE TITLE: Nonlinear Phenomena

COURSE TEACHER/TEACHERS: Prof. dr. Aleksa Bjeliš, Doc. dr. Hrvoje Buljan

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 5

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

The course serves as an introduction into the modern theory of nonlinear dynamical systems. Emphasis is given to the fact that nonlinear phenomena appear in various fields of science such as physics, biology, engeneering, social studies etc. Some aspects of modelling realistic systems are addressed. Methods used to analyze these models, and their solution(s), are studied.

DESCRIPTION OF THE COURSE:

Dynamical systems, phase space, phase diagrams; fixed points, periodic orbits, structural stability, Lie derivative, stability criteria (Lyapunov, orbital); Poincare cross-section, mappings, invariant measures, symbolic dynamics, topological conjugacy; Logistic map, results of May and Feigenbaum; critical exponents, renormalization group, universality; routes to turbulence in fluids; normal forms, classification of bifurcations, routes to chaos; non-integrabile classical-mechanical systems; Kolmogorov-Arnold-Moser theorem; examples of quantum chaotic systems.

STUDENT OBLIGATIONS DURING THE COURSE: **Students are requested to continuously follow lectures and tutorials, participate in solving quiz-type tests; in addition, during the semester every student is requested to prepare a 1 hour seminar to be presented in front of the student group; students are encouraged to participate in small research projects, in particular the ones associated to numerical analysis of certain models, but in contemporary relevant physical (or other) context.**

METHODS TO EVALUATE STUDENT PERFORMANCE: Successful completion of the assignments listed in the previous point.

EXAMINATION METHODS: Student performance during the semester (quiz, seminar, project) is evaluated and forms about 50% of the grade; the course is completed with a final oral exam.

COURSE(s) NEEDED FOR THIS COURSE: General physics I-IV, Classical mechanics, Mathematical courses from the first two years

COMPULSORY LITERATURE:

M. Tabor, Chaos and Integrability in Nonlinear Systems, John Willey& Sons, 1989.

E. Ott, Chaos in Dynamical Systems, Cambridge Univ. Press, 1993.

H. G. Schuster, Deterministic Chaos, VCH, 1995.

ADDITIONAL READING:

Contemporary review papers from various fields related to the studies of nonlinear phenomena, other scientific papers

A. Katok and B. Hasselblatt, Introduction to the Modern Theory of Dynamical Systems, Cambridge University Press, 1995.

COURSE TITLE: Symbolic Programming
COURSE TEACHER/TEACHERS: doc. dr. sc. Krešimir Kumerički, PMF, Zagreb
STUDY PROGRAMME: University study of research physics
YEAR OF STUDY: 3
SEMESTER: 5

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	1	teacher
Exercises		
Seminars		
Lab	2	assistant

ECTS credits: 3
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Student solves standard problems in mathematics and physics on computer, acquiring skills in symbolic (and functional) programming. After the course he should be competent user of one of the standard Computer Algebra Systems.
DESCRIPTION OF THE COURSE: 1. Basics of Computer Algebra System, basic algebraic manipulations, equation solving2. Mathematical Analysis and Linear Algebra on computer3. Plotting, data processing4. Example: Modeling a trajectory of particle in a force field5. Basics of symbolic prgramming: lists, functions, expressions6. Basics of symbolic prgramming: patterns, transformation rules7. Advanced programming: procedural programing8. Advanced programming: functional programming9. Advanced programming: programming via transformation rules10. Examples from classical mechanics11. Examples from classical electrodynamics and quantum physics12. Linking with other languages (such as C)
STUDENT OBLIGATIONS DURING THE COURSE: Student must submit solutions to 50 percent of homework problems.
METHODS TO EVALUATE STUDENT PERFORMANCE: Homework problems and final project
EXAMINATION METHODS: 60 percent of final grade comes from homeworks and another 40 percent from final project
COURSE(s) NEEDED FOR THIS COURSE:Introduction to programming
COMPULSORY LITERATURE:K. Kumericki, Symbolic programming for physicsists, course text available online at http://www.phy.hr/~kkumer

ADDITIONAL READING:S. Wolfram, The Mathematica Book, available online with the Mathematica package

COURSE TITLE: Vector Spaces

COURSE TEACHER/TEACHERS: Mirko Primc

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 5

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	Teacher
Exercises	1	Assistant
Seminars		

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Acquisition of the more abstract concepts of vector space theory in finite dimensions, and of elements of functional analysis.

DESCRIPTION OF THE COURSE:

1. **Finite-dimensional spaces. Basis and dimension. Subspaces. Sum and direct sum. Direct complement. Quotient subspace. Linear operators. Bases and coordinatisation. Rank and defect. Isomorphisms. Regular operatora. The space L(V,W). Dual space and operator. Eigenvalues and eigenvectors. Characteristic and minimal theorems. Algebraic and geometric multiplicity of eigenvalues. Hamilton-Cayley theorem.**
2. **Nilpotent operators and Jordan's form. Index of a nilpotent operator. Nilpotent operator of maximal index. Fitting's decomposition. Decomposition of a nilpotent operator. Jordan's basis. Jordan's cell and elementary Jordan's cell.**
3. **Functions of operators. Convergence in L(V). Definition of f(A) for whole functions. Representation of f(A) in Jordan's basis. Operator f(A) as a polynomial. Langrange-Sylvester interpolation polynomials.**
4. **Operators on unitary spaces. Basic properties of unitary spaces. Normed spaces and their connection with unitary spaces (parallelogram rule). Concept of orthonormal bases. (Hermitean) adjoint operator. Hermitean and antihermitean operators. Unitary operators. Spectrum of an unitary operator. Normal operators and their diagonalisation.**

STUDENT OBLIGATIONS DURING THE COURSE: Attending exercices.

METHODS TO EVALUATE STUDENT PERFORMANCE: Examination.

EXAMINATION METHODS: Written and oral parts, written is prerequisite for oral.

COURSE(s) NEEDED FOR THIS COURSE: Mathematical methods of physics.

COMPULSORY LITERATURE:

S. Kurepa, Konačnodimenzinalni vektorski prostori i primjene.
S. Mardešić, Matematička analiza u n-dimenzionalnom prostoru 1, glava II: Konvergencija nizova i redova.
S. Kurepa, Funkcionalna analiza, glava I: Normirani prostori.

ADDITIONAL READING: Assigned to individual students on request.

COURSE TITLE: **Development of Physics**

COURSE TEACHER/TEACHERS: **Tihomir Vukelja, Ph.D.**

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 5

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**0**	
Seminars	**1**	**assistant**

ECTS credits**: 3**

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

The objective of the course is to encourage students to ponder about physics and to help them in placing their own profession within a wider historical, philosophical, cultural and social context. The course presents physics, as a human activity, and the physical knowledge, as a product of that activity, as a philosophical problem, i.e. as a subject of a historical, philosophical and sociological investigation.

DESCRIPTION OF THE COURSE:

Week 1: Introduction. The origin of physics – circumstances. Natural philosophy and modern physics.
Week 2: The nature and the achievements of the antic and medieval natural philosophy.
Week 3: The origin of modern physics: changes in the worldview and methodology.
Week 4: Development of the ideas on space and time. Space and time in classical mechanics.
Week 5: Ontology of classical physics: particles and fields.
Week 6: The emergence of the theory of relativity. Philosophical problems of special relativity.
Week 7: Determinism and probability in classical physics. The structure of matter – various theories.
Week 8: The emergence of quantum mechanics.
Week 9: Logical empiricism and the cumulative model of the development of physics.
Week 10: Popper and falsificationism. Duhem – Quine thesis.
Week 11: Kuhn: paradigms and scientific revolutions. Physical knowledge as a social construct.
Week 12: Lakatos: research programmes. Feyerabend and scientific method.
Week 13: Naturalistic and instrumental experience (in classical and quantum physics). The role of technology. The philosophy of experiment.

Week 14: The alternative models of physics development. Realism and instrumentalism.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Classes are organized in lectures (2 hours per week) and seminars (1 hour per week). The intention is to use lectures for the active debate and students' questions regarding the course topics in maximum degree. Students are therefore obliged to prepare beforehanded readings for the lectures. For lectures and seminars students can propose topics not scheduled by the course curriculum. In seminars students present their essays accompanying lectures, in which particular lecture topics are elaborated and commented in more details.

STUDENT OBLIGATIONS DURING THE COURSE:

Student is obliged to attended lectures regularly and to complet an essay.

EXAMINATION METHODS:

The exam is oral. A student is evaluated on the basis of the knowledge demonstrated at the lecture and seminar discussions, knowledge demonstrated at the exam, and on the basis of the essay grade.

COURSE(s) NEEDED FOR THIS COURSE:

COMPULSORY LITERATURE:

J. T. Cushing, *Philosophical Concepts in Physics: The Historical Relation between Philosophy and Scientific Theories*, Cambridge University Press, Cambridge, 1998.

J. Lelas, *Teorije razvoja znanosti*, ArTresor, Zagreb, 2000.

ADDITIONAL READING:

A. F. Chalmers, *What is this thing called Science?*, 3. izdanje, Open University Press, Buckingham, 1999.

R. Torretti, *The Philosophy of Physics*, Cambridge Universitiy Press, Cambridge, 1999.

L. Sklar, *Philosophy of Physics*, Westview Press, Boulder, 1992.

D. C. Lindberg, *The Beginnings of Western Science: The European Scientific Tradition in Philosophical, Religious, and Institutional Context, 600 B.C. to A.D. 1450*, University of Chicago Press, Chicago, 1992.

P. Rossi, *The Birth of Modern Science*, Blackwell, Oxford, 2001.

M. Jammer: *The Conceptual Development of Quantum Mechanics*, McGraw–Hill, New York, 1966.

COURSE TITLE: ADVANCED PHYSICS LAB 2
COURSE TEACHER/TEACHERS: Miroslav Požek, Dinko Babić, Gorjana Jerbić Zorc
STUDY PROGRAMME: University study of research physics
YEAR OF STUDY: third
SEMESTER: sixth

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	assistant

ECTS credits: 4
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Individual sophisticated experiments connected to the lectures in classical and quantum physics

DESCRIPTION OF THE COURSE:

I. Sophisticated laboratory exercises in physics to be executed in 2 or 3 sessions each.: Autonomy in preparation and execution of the exercises, as well as result processing and concluding is required. Student chooses exercises (but all exercises should be equally distributed in a generation):

- one of "Specific electrical charge of electron", "Stefan-Boltzman's law" or "Milliken experiment "

- one of "Electric field", "Characteristic curves of semiconducing elements", "RC amplifier " or "Skin effect"

- one of "Conductivity of electrolytes" "Joule-Thompson's coefficient of N_2 and CO_2", "Magnetic susceptibility of liquids" or "Thermal capacity of metals and gases"

II. Seminar in which student presents one of the executed exercises to his colleagues, demonstrating measurements, and showing physical principles, results and discussion. The seminar allow all students to be familiar with all exercises.

STUDENT OBLIGATIONS DURING THE COURSE: Understanding of physical foundations of the exercise to be done. Report on the measurements and results after each exercise. Seminar. Attendance of the seminars given by colleagues.

METHODS TO EVALUATE STUDENT PERFORMANCE: Three exercises and reports have to be done. Seminar

EXAMINATION METHODS: Each exercise is given a mark. No final exam unless student is not satisfied with the given final mark.

COURSE(s) NEEDED FOR THIS COURSE: Physics 1-4, Basic laboratory exercises 1-2.

COMPULSORY LITERATURE: script with setup for each exercise;

ADDITIONAL READING: Požek, Miroslav; Dulčić, Antonije: Fizički praktikum I i II, Zagreb : Sunnypress, 1999.

COURSE TITLE: Experimental Techniques in Physics

COURSE TEACHER/TEACHERS: Professor of Physics E. Babić, Faculty of Sciences and Mathematics

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3.

SEMESTER: 6.

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	assistant

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Basic principles of the sucessful experimental research in physics are explained. The application of these principles to the construction and operation of original scientific measurement systems is illustrated.

DESCRIPTION OF THE COURSE:

The impact of experiment on the development of modern science and society. Types of experiments.
General principles in planning and design of scientific experiment.
Construction of experimental setup: physical considerations and critical factors.
Variables and signals. Modern sensors, their characteristic, examples and specific applications.
Types of measurements, data acquisition and transmission. The accuracy of the measurement. Origins and reduction of random and systematic arrors.
The natural limits of the measurement accuracy. End of Moore's law in microelectronics?
Intrinsic and transmitted noise; the origins, effects and the methods for their reduction.
The interaction between the sensor/experimental setup and the investigated system.
Dynamical influence on the speed and accuracy of measurements.
Amplification of signals: passive and active amplifiers. Impendance matching. Feedback and stability. Lock-in amplifier and its applications.
The analysis and operation of some original (unique) experimental setups built in Zagreb.

STUDENT OBLIGATIONS DURING THE COURSE: Course attendance is expected. Students receive homework problems.During seminars students ask explanations of the more compex problems and/or visit the laboratories.

METHODS TO EVALUATE STUDENT PERFORMANCE: Evaluation includes results of the written colloquium and oral examination.

EXAMINATION METHODS:Students analyze and discuss recent scientific paper of their choice. Oral exam checks their knowledge and understanding of of the subject.

COURSE(s) NEEDED FOR THIS COURSE:General Physics 1-4. (Some knowledge of Electronics is desirable.)

COMPULSORY LITERATURE:

Jacob Fraden : Handbook of modern sensors, Springer 1996.

ADDITIONAL READING:

H.J.J. Braddick: The Physics of Experimental Method, Chapman and Hall 1974.

COURSE TITLE:	Differential geometry in physics
COURSE TEACHER/TEACHERS:	Prof.dr.Marijan Mileković
STUDY PROGRAMME:	University study of research physics
YEAR OF STUDY:	3
SEMESTER:	6

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		
Laboratory		

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The aim of the course is to provide students with basic techniques and methods of modern differential geometry and exterior differential calculus and their applications in various branches of physics (e.g. classical mechanics,electromagnetism,gauge theories etc.)

DESCRIPTION OF THE COURSE:

Introduction and motivation.Basic concepts of geometry and toplogy.Topological spaces.Riemannian and pseudo-Riemannian spaces.

Manifolds.Differential manifolds.Vector bundles. Tangent and cotangent bundles.

Vector fields.Vector fields and flow.Vector fields as diferential operators.Tangent vectors and mappings.

Tensors.Tensors in linear spaces.Tensor bundles and tensor fields.Lie derivatives-algebraic and dynamical approach.

Differential forms.Algebra of differential forms.Determinants and volume. Hodge star operator.

Integration on manifolds.Definition of integral.Stokes theorem.A short introduction to Hodge-de Rham theory and toplogical application of differential forms.

Physical applications.Hamilton mechanics. Fluid mechanics. Thermodynamics. Electromagnetism (Maxwell equations).

Perspectives.Connections and curvature.Gauge theories of Yang-Mills type.

The general theory of relativity.

STUDENT OBLIGATIONS DURING THE COURSE: Students should attend lectures and excersises and work out 2 homeworks in semester.

METHODS TO EVALUATE STUDENT PERFORMANCE: Regular attendance of lectures and excersises.

EXAMINATION METHODS: Written and oral exams.Students which collect 50% points from homeworks have oral exam only.

COURSE(s) NEEDED FOR THIS COURSE:

Mathematical analysis 1 and 2.

Linear algebra.

COMPULSORY LITERATURE:

M.Nakahara:'Geometry,toplogy and physics' (IOP Publishing,2003).

B.F.Schutz:'Geometrical methods of mathematical physics' (Cambridge University Press, 1980).

H.Flanders:'Differential forms with application to the physical sciences' (Dover, 1989).

ADDITIONAL READING: T.Frankel:'The geometry of physics:an introduction' (Cambridge University Press,2001).

COURSE TITLE: **Numerical Methods and Mathematical Modelling**

COURSE TEACHER/TEACHERS: **Prof. dr. sc. Dario Vretenar**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **3rd**

SEMESTER: **6th**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	**teacher**
Exercises	1	**assistant**
Seminars		

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **The goal is to instruct students how to effectively use numerical techniques and computers in modelling various physical systems. The emphasis is on a series of projects that the student should be able to carry out with minimal help from the instructor. Each project consists in modelling and solving numerically on a computer, a physical problem that the student had already encountered in courses on classical mechanics, quantum physics, statistical physics, and classical electrodynamics. This should also lead to a better understanding of the various physical concepts introduced in courses on classical and quantum physics. The student will submit the project in the form of a seminar thesis and present the results to the class.**

DESCRIPTION OF THE COURSE:

1. **Basic mathematical operations**
2. **Ordinary differential equations**
3. **Two-point boundary value problems**
4. **Gaussian integration and special functions**
5. **Matrix operations**
6. **Elliptic partial differential equations**
7. **Parabolic partial differential equations**
8. **Monte-Carlo methods**
9. **Minimization or maximization of functions**
10. **Fourier transform spectral methods**

STUDENT OBLIGATIONS DURING THE COURSE: **homework assignments and projects**

METHODS TO EVALUATE STUDENT PERFORMANCE: **homework problems and projects**

will be graded, written final examination.

EXAMINATION METHODS: **Several projects must be submitted (modelling a given physical problem, numerical solution, implementation in a computer code) together with a final test at the end of the semester.**

COURSE(s) NEEDED FOR THIS COURSE:**Classical Mechanics, Mathematical Methods in Physics, (partially Quantum Phyiscs, Classical Electrodynamics, Statistical Physics).**

COMPULSORY LITERATURE: **S.E. Koonin, D.C. Meredith: Computational Physics, Addison-Wesley, 1990**

W.H. Press, S.A. Teukolsky, W.T. Vetterling, B.P. Flannery: Numerical Recipes, The Art of Scientific Computing, Cambridge University Press, 2002

ADDITIONAL READING: P.L. De Vries, A First Course in Computational Physics, John Wiley, 1994

COURSE TITLE: Symmetries in Physics		
COURSE TEACHER/TEACHERS: doc. dr. sc. Krešimir Kumerički, PMF, Zagreb		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 3		
SEMESTER: 6		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars		
Lab	1	assistant

ECTS credits: 3
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction to the methods of group theory and of group representations. Development of the mathematical formalism and application to physical examples. Course also supplements courses in quantum physics, and helps with later courses in solid state, nuclear and particle physics.Course supplements course "Group Theory" from last semester with theory of Lie groups, foremost rotation, SU(N) and Lorentz groups.
DESCRIPTION OF THE COURSE: 1. Lie groups. Examples of Lie groups important in physics2. Lie algebras3. Connection of Lie groups and Lie algebras4. Rotations and angular momentum in QM: Irreducible representations of 2D rotation group5. IRREPS of 3D rotation group6. Addition of angular momenta7. Clebsch-Gordan coefficients. Selection rules.8. Tensor operators and Wigner-Eckart theorem9. SU(N) and elementary particle physics. Isospin.10. Lorentz symmetry11. Generators and representations of Lorentz group. Poincare symmetry.12. Advanced subjects
STUDENT OBLIGATIONS DURING THE COURSE: Student must submit solutions to 50 percent of homework problems.
METHODS TO EVALUATE STUDENT PERFORMANCE: Homework problems and oral exam
EXAMINATION METHODS: 50 percent of final grade comes from homeworks and another 50 percent from oral examination
COURSE(s) NEEDED FOR THIS COURSE: Linear algebra. Introduction to Quantum Physics, Group theory
COMPULSORY LITERATURE:K. Kumericki, Symmetries in Physics, course text available online at http://www.phy.hr/~kkumer

ADDITIONAL READING:H. F. Jones, Groups, Representations and Physics, 2nd ed, IOP Publishing, 1998.W. Greiner and B. Mueller, Quantum Mechanics - Symmetries, Springer Verlag, 1989.J. J. Sakurai, Modern Quantum Mechanics, Addison-Wesley, 1994.M. Hamermesh, Group Theory and its Application to Physical Problems, Dover, 1989.J. F. Cornwell, Group Theory in Physics, An Introduction, Academic Press, 1997.

COURSE TITLE: Overview of modern experimental research		
COURSE TEACHER/TEACHERS: professor dr. sc. Antun Tonejc		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 3		
SEMESTER: 6		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	teacher
Laboratory		
ECTS credits: 3		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

  To provide a students with basic concepts of modern experimental techniques

DESCRIPTION OF THE COURSE:
Ones per week the students will visit a particular experimental physical laboratory at Department of Physics, Institute of Physics or Institute Ruđer Bošković where the laboratory staff will give them a short overview of scientific research in the laboratory and describe the instruments used in measurements.

STUDENT OBLIGATIONS DURING THE COURSE: **Students have to attend seminars in different laboratories at Deparment of Physics, Institut Ruđer Bošković and Institute of Physics and to write homework about the scientific research in particular laboratory.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Regulary attendence of seminar in laboratories and rasonable good presentation of scientific work in the laboratories.**

EXAMINATION METHODS: **no exam**

COURSE(s) NEEDED FOR THIS COURSE: Elementary Physics 1 to 4.

COMPULSORY LITERATURE:

     published papers from particular laboratory

ADDITIONAL READING:.

COURSE TITLE: **Modern Physics and Philosophy**

COURSE TEACHER/TEACHERS: **Tihomir Vukelja, Ph.D.**

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 6

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	0	
Seminars	1	assistant

ECTS credits: **3**

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

The objective of the course is to encourage students to ponder about philosophical problems of quantum mechanics. The course offers an overview of the most important interpretations of quantum mechanics and helps students in shaping their own attitude toward the nature of contemporary physics.

DESCRIPTION OF THE COURSE:

Week 1: Introduction: the origin of quantum mechanics and the need for an interpretation. The problem of the nature of 'quanton'– theoretical and experimental aspects of the superposed quantum states and the uncertainty relations: neutron interferometry, the *welcher Weg* experiments.
Week 2: The quantization of the electromagnetic field and photons: semi-classical theories, Hanbury-Brown and Twiss experiment, one-photon interference, the delayed-choice experiment and the wholeness of quantum phenomena. Stationary states and quantum beats.
Week 3: Discussion of the presented experiments. Experiential level: quantum mechanics and technology. Theoretical level: pure states and mixtures. Interpretative level.
Week 4: Quantum-mechanical realism. Probability in quantum mechanics. Epistemic interpretation, ensembles and propensities.
Week 5: Bohr and the Copenhagen interpretation.
Week 6: Bohm's ontological interpretation and hidden variables.
Week 7: Statistical interpretation. Quantum logics.
Week 8: Quantum mechanics and classical physics: discussion between Einstein and Bohr on the nature of theory, the problem of classical limit of quantum mechanics.
Week 9: The problem of time in quantum mechanics: experiments with time interference of neutrons and atoms, decay of unstable state, Franson's experiment and time uncertainty, the time-energy uncertainty relation.
Week 10: The superpostions of macroscopically distinguishable states and the measurement

problem in quantum mechanics: von Neumann's description of the measurement – conditions and consequences, Schrödinger's cat paradox, search for the macroscopic superpositions (SQUID).

Week 11: Solution of the measurement problem based on the alternative quantum mechanical dynamics: dual dynamics – reduction of the wave packet, matter and mind; unique dynamics – stochastic interpretations in general, programmes of the nonlinear stochastic modification of Schrödinger's equation.

Week 12: Solution of the measurement problem based on the alternative interpretation of experience; decoherence by environment, many worlds and many minds. Modal interpretations and decoherent histories.

Week 13: EPR dilemma, Bell's inequality and experiments.

Week 14: GHZ theorem. Quantum nonlocality and relativity theory. Nonseparability of the quantum phenomenon.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Classes are organized in lectures (2 hours per week) and seminars (1 hour per week). The intention is to use lectures for the active debate and students' questions regarding the course topics in maximum degree. Students are therefore obliged to prepare beforehanded readings for the lectures. For lectures and seminars students can propose topics not scheduled by the course curriculum. In seminars students present their essays accompanying lectures, in which particular lecture topics are elaborated and commented in more details.

STUDENT OBLIGATIONS DURING THE COURSE:

Student is obliged to attended lectures regularly and to complete an essay.

EXAMINATION METHODS:

The exam is oral. A student is evaluated on the basis of the knowledge demonstrated at the lecture and seminar discussions, knowledge demonstrated at the exam, and on the basis of the essay grade.

COURSE(s) NEEDED FOR THIS COURSE:

COMPULSORY LITERATURE:

G. Greenstein i A. G. Zajonc, *The Quantum Challenge*, Jones and Bartlett Publishers, Boston, 1997.

ADDITIONAL READING:

M. W. Dickson, *Quantum Chance and Non-Locality*, Cambridge University Press, Cambridge, 1998.

D. Home, *Conceptual Foundations of Quantum Physics: An Overview from Modern Perspectives*, Plenum, New York, 1997.

A. Whitaker, *Einstein, Bohr and the Quantum Dilemma*, Cambridge University Press, Cambridge, 1996.

P. R. Holland, *Quantum Theory of Motion: An Account of the de Broglie-Bohm Causal Interpretation of Quantum Mechanics*, Cambridge University Press, Cambridge, 1995.

M. Jammer: *The Philosophy of Quantum Mechanics*, John Wiley and Sons, New York, 1974.

T. Maudlin: *Quantum Non-Locality and Relativity: Metaphysical Intimations of Modern Physics*, Blackwell, Oxford, 2002.

M. P. Silverman, *More Than One Mystery: Explorations in Quantum Interference*, Springer, New York, 1994.

COURSE TITLE: Hydrodinamics		

COURSE TEACHER/TEACHERS: Professor Ivo Batistić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 3

SEMESTER: 6

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	*teacher*
Exercises	1	*assistant*
Seminars		
Laboratory		

ECTS credits: 3

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Understanding of principal concepts and methods of fluid dynamics: mass conservation, momentum and energy flux. Navier-Stokes equation for viscous flows. Similarity and dimensional analysis. Circular motion and vorticity theorems. Potential flow. Introduction to turbulence. Lift and drag force.

DESCRIPTION OF THE COURSE: 1. The equation of continuity 2. Euler's equation, hydrostatics, Bernoulli's equation 3. The energy flux 4. The momentum flux 5. Circular motion, potential flow 6. Incompressible fluid 7. Drag and lift force in potential flow past a body 8. Waves 9. Navier-Stokes equations, energy dissipation 10. Similarity law 11. Instabilities of the fluid motion and turbulence 12. Period doubling turbulence and Lorenz's attractor

STUDENT OBLIGATIONS DURING THE COURSE: lecture and exercise attendance

METHODS TO EVALUATE STUDENT PERFORMANCE: problem solving
EXAMINATION METHODS: written and oral examination
COURSE(s) NEEDED FOR THIS COURSE: theoretical mechanics and statistical physics
COMPULSORY LITERATURE: XXXX
ADDITIONAL READING: Landau and Lifshitz: Fluid Mechanics

COURSE TITLE:	Elementary Particle Physics	
COURSE TEACHER/TEACHERS:	Prof. Ivica Picek	
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY:	4th	
SEMESTER:	7th and 8th	

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 5 + 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: formulating and solving given problem

DESCRIPTION OF THE COURSE:

A preview of particle physics;

Identification of particles and forces;

Particle detectors and accelerators;

Invariance principles and conservation laws;

Relativistic kinematics;

Hadron-hadron interactions;

Quark model of hadrons;

Electromagnetic interactions;

The Feynman calculus in QED;

Electrodynamics of quarks and hadrons;

Parton model and QCD;

Weak interactions;

Charged and neutral weak currents;

Electroweak interactions;

Gauge symmetries and the electroweak unification;

Quantum flavourdynamics (QFD);

Dynamics of the Standard Model and Beyond Standard Model.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lectures and homeworks

METHODS TO EVALUATE STUDENT PERFORMANCE: Homeworks and written exams

EXAMINATION METHODS: evaluation of homeworks and an exam at the end of the semester

COURSE(s) NEEDED FOR THIS COURSE: Classical electrodynamics and quantum physics

COMPULSORY LITERATURE:

I. Picek, Fizika elementarnih čestica, Sveučilište u Zagrebu, HINUS, Zagreb, 1997

or   D. Griffiths, Introduction to Elementary Particles, Harper&Row, 1987

ADDITIONAL READING:

D.H. Perkins, Introduction to High Energy Physics, Addison Wesley, 1987

F. Halzen, A.D. Martin, Quarks & Leptons, J. Wiley&Sons, 1984.

COURSE TITLE: **Nuclear Physics**

COURSE TEACHER/TEACHERS: **Prof. dr. sc. Dario Vretenar**

STUDY PROGRAMME: **University study of physics**

YEAR OF STUDY: **4th**

SEMESTER: **7th and 8th**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		

ECTS credits: 5 + 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

This course has three principal goals:

1. **Practical application of the concepts and methods of quantum physics (which the students have learned during the second and third year) to microscopic finite systems – aggregates of strongly interacting particles.**

2. **An introduction into one of the most developed branches of modern physics. Nuclear physics is on one hand closely related to many basic scientific disciplines: particle physics, astrophysics, astronomy, cosmology. Its applications, on the other hand, form the basis of modern technologies: energy production, nuclear medicine, material research, ecology, etc.**

3. **Introduces, especially through assigned projects, modern theoretical and experimental research methods. Provides the basis for more specialized courses taught in the eight and ninth semester: Nuclear Astrophysics, Nuclear Structure, Structure of the Nucleon, Hadron Physics, Medical physics, Reactor physics, and connects the master and Ph.D. programs. For those students who complete their study program after five years, Nuclear Physics serves as a preparatory course for the master thesis.**

DESCRIPTION OF THE COURSE:

1. **Nucleosynthesis (concepts of nuclear astrophysics, primordial nucleosynthesis, nucleosynthesis in stars from hydrogen burning to the s-process, nova and supernova nucleosynthesis: r-process and rp-process, white dwarfs, neutron stars).**

2. **Nucleon structure (baryons, quarks and color, leptons and weak interactions, isospin, static quark model of hadrons, magnetic dipole moment of the baryon octet).**

3. **Nucleon-nucleon interaction (deuteron, symmetry and nuclear force, nucleon-nucleon scattering and phase shifts).**

4. **Bulk properties of nuclei (electron scattering, charge radius and charge density, matter density, nuclear shape and electromagnetic moments, ground-state spin and isospin, semi-empirical mass formula, nuclear matter).**

5. **Electromagnetic and weak interactions (nuclear transition matrix elements, electromagnetic transitions, nuclear beta-decay).**

6. **Nuclear structure(nuclear many-body problem, Hartree-Fock, single-particle shell model for spherical and deformed nuclei, nuclear collective motion, vibrations and rotations, high-angular momentum states, algebraic models).**

7. **Nuclear reactions (Coulomb excitation, compound nucleus formation, direct reaction, high-energy collisions).**

STUDENT OBLIGATIONS DURING THE COURSE: **homework assignments, projects**

METHODS TO EVALUATE STUDENT PERFORMANCE: **homework problems and projects will be graded, written and oral final examination.**

EXAMINATION METHODS: **Students will have a choice between: a) standard written and oral exam, or b) four projects (two theoretical and two experimental, investigating and reporting on a given problem in nuclear physics) together with a final test at the end of each semester.**

COURSE(s) NEEDED FOR THIS COURSE: **Quantum Physics, Classical Electrodynamics, Statistical Physics**

COMPULSORY LITERATURE: Samuel S. M. Wong, Introductory Nuclear Physics, Wiley-Interscience, 1999

ADDITIONAL READING: Kenneth S. Krane, Introductory Nuclear Physics, Wiley-Interscience, 1987
Kris Heyde, Basic Ideas and Concepts in Nuclear Physics, Institute of Physics, 2004
Kris Heyde, From Nucleons to the Atomic Nucleus: Perspectives in Nuclear Physics, Springer Verlag, 2002

COURSE TITLE:	Solid State Physics	

COURSE TEACHER/TEACHERS:	Professor Slaven Barišić

STUDY PROGRAMME:	University study of research physics

YEAR OF STUDY:	4

SEMESTER:	7 + 8

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 5 + 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

1. With respect to Solid State Physics, students become acquainted with qualitative and quantitative physical explanations of the phenomena encountered in everyday life, in particular with the origins of the stability of solids and with the related conductive and magnetic properties. Through excersises, the students become operative in solving the corresponding simple problems. In this way they obtain first insights in one of the most developed fields of modern physics, which is also the basis of most of the high technologies used world-wide.

2. >From a more general point of view, the examples from Solid State Physics, amenable to direct intuitive grasp, provide a convenient introduction into the general concepts and procedures used in all branches of physics. The most important is the reduction of the primary degrees of freedom to the few effective ones, relevant for the phenomenon under consideration, and the construction of effective interactions among these effective degrees of freedom. In this spirit the concept of equilibrium states, which break the symmetry of effective hamiltonians, is also discussed.

3. An important aim of the course to acquaint the students with the basic requirements of successful activity in physics: mastering the qualitative and intuitive aspects of physics, the approximate and *ad hoc* way of thinking, using analogies, etc.

In order to emphasize the above aims, only simple mathematical methods are used, which often amount to solving self-consistent single particle problems by low order perturbation theories, using at most 2x2 matrices, etc. In accord with the simplicity of the theoretical methods, the measurement methods are described only in principle, always however emphasizing the quantities which are measurable. In this way the course builds up the space of communication among all physicists regardless of their specialization, which is of key importance for the success of physics as a whole. In all, the course enables the students to define their interests and appreciate their abilities before the choice of their diploma work, and to use the accumulated knowledge after graduation, either in doctoral studies or in professional work.

DESCRIPTION OF THE COURSE: Solid as the equilibrium state which breaks the continuous translational symmetry. Description of basic properties of solids according to the bonding models: van der Waals, ionic, metallic, covalent (tight binding) and hydrogen bondings as the basis of the cohesive, conductive and magnetic properties of crystals. Stability of crystals with respect to small homogeneous and periodic deformations of the crystal lattice. Phonons. Determination of sound velocity. Diffuse scattering of radiation on the periodic deformations of the lattice. Spreading of electromagnetic waves in ionic crystals and infrared activity. Raman effect. Polaritons. Ferroelectricity of ionic crystals. Reduction of the ferroelectric order-disorder transition to the Ising model in a transverse field, self-consistent solution and the resulting dielectric properties. Dielectric properties of insulators in the high frequency range: Thomas-Reiche-Kuhn law. Dielectric properties of metals by self-consistent low order perturbation theory (RPA). Thomas-Fermi static screening and Friedel oscillations, plasmons. Electrical and thermal resistivity of metals as a consequence of static and thermal disorder in the crystal lattice, Drude and Wiedemann-Franz laws, Matthiessen rule. Simultaneous charge and thermal transport, thermoelectric effects. Motion of itinerant electrons in a magnetic field. Cyclotron resonances. Magnetism: Langevin orbital diamagnetism of bound electrons, Landau orbital diamagnetism of itinerant electrons through the Haas-van Alphen effect at small applied magnetic field, Curie paramagnetism of bound spins, van Vleck orbital paramagnetism of bound electrons, Pauli and Stoner paramagnetism of itinerant spins. Heisenberg and Stoner ferro-magnetisms. Application to the magnetic properties of rare-earth salts and of transition metals.

STUDENT OBLIGATIONS DURING THE COURSE: In addition to standard forms of student involvement (lectures and exercises), the students will have the opportunity to pass a colloquium at the end of the first semester; the corresponding grade will contribute to the final grade at the exam.

METHODS TO EVALUATE STUDENT PERFORMANCE: Success in exercises, written and oral colloquium, written and oral examination.

EXAMINATION METHODS: Written and oral.

COURSE(s) NEEDED FOR THIS COURSE: Quantum mechanics, Statistical physics, Classical electrodynamics.

COMPULSORY LITERATURE:

1. C. Kittel, ***Introduction to solid state physics,*** John Wiley and Sons, New York, 2005 (8th edition)

2. N. W. Ashcroft and N. D. Mermin, ***Solid State Physics,*** Saunders College Publ., 1976

ADDITIONAL READING:

1. J. M. Ziman, ***Principles of the Theory of Solids,*** Cambridge University Press, Cambridge, 1998 (2nd edition)

2. C. Kittel, ***Quantum Theory of Solids,*** John Wiley and Sons, New York, 1987

3. P. W. Anderson, ***Concepts in Solids,*** W. A. Benjamin, New York, 1964

COURSE TITLE: **Modern Physics lab**		
COURSE TEACHER/TEACHERS: **Prof. Dr. Sc. Damir Bosnar, doc. dr. sc. Ivan Kokanović**		
STUDY PROGRAMME: **Master of Physics**		
YEAR OF STUDY: **4.**		
SEMESTER: **7.**		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	3	Teacher + assistant
ECTS credits: 4		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Knowledge and skills of measurement methods and techniques in different fields of modern physics obtained by performing selected laboratory exercises in atomic physics, nuclear physics, particle physics and solid state physics.**

DESCRIPTION OF THE COURSE: **Detection of alpha, beta and gamma particles. Measurement of Rutherford scattering. Detection and decay of cosmic muons. Experimental observation of nuclear magnetic resonance. Hall effect. Resistance thermometer. Magnetoresistance.**

STUDENT OBLIGATIONS DURING THE COURSE: **Preparations for the laboratory exercises. Execution of the laboratory exercises. Data analysis and discussion.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Evaluation of each segment of given assignments.**

EXAMINATION METHODS: **Evaluation of student performance during execution of laboratory exercises.**

COURSE(s) NEEDED FOR THIS COURSE: **General Physics. Quantum Physics. Electronics.**

COMPULSORY LITERATURE:
 A.C. Melissinos, J. Napolitano: Experiments in Modern Physics, Academic Press, 2003.

ADDITIONAL READING: **Selected scientific articles.**

COURSE TITLE: Experimental methods of modern physics

COURSE TEACHER/TEACHERS: Professor of Physics, M. Furić, Faculty of Sciences and Mathematics

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4

SEMESTER: 7 , 8

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	0	
Seminars	0	

ECTS credits: 3 + 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduce to the students a wide spectrum of modern research methods and techniques currently in use around the world. Also, as an illustration, a description of a few Nobel-prize experiments is included. Visits to the research laboratories are organized ; students see in this way the real work-places for physicists.

DESCRIPTION OF THE COURSE:

Spectroscopy with emphasis on optical aspects: diffraction grating, molecular dynamics, Raman spectroscopy, infrared spectroscopy, spectroscopy in general.

Nuclear magnetic resonance: basic NMR equipment scheme, saturation and relaxation, magnetization manipulations, relaxation time measurements, structural and position information, human body imaging, fMRI.

Moessbauer effect: resonant scattering of gamma rays, isomeric shift, chemical effects, gravitational red shift observation in laboratory,

Application of diffraction in studying microstructure: single scatterer parameters, combining the scatterers, cross section, atomic scattering factor, scattering function, diffraction by crystals.

Lasers: stimulated radiation, population inversion, resonant cavity, He-Ne laser, solid state lasers, dye lasers, free electron laser.

Holography: hologram recording, reconstruction of the 3D wave front, mathematical description of recording and reconstruction, Denisyuk method, acoustical holography, applications.

Night vision: Solving the problem of the low light intensity by amplification: multichannel plates,

CCD cameras, high voltage electronic tubes.

Vacuum: mechanical pumps, diffusion pumps, turbomolecular pumps, pumps for high and ultrahigh vacuum, vacuum measuring devices, mass spectrometer and its use in leak detection.

Cryogenics: Stirling cooling, adiabatic cooling, Joule-Thompson valve, dillution refrigirator, gas liquifaction, transport of liquids, temperature measurements.

Microwaves: properties of microwaves, waveguides, resonant cavities, microwave sources.

Radioastronomy: radiotelescope's components, temperature scale and calibration, antenna, radiometer, cosmic background radiation, pulsars, indirect proof of gravitational radiation through the orbiting pulsar.

Controlled fusion: basic parameters, criteria for the continuous operation, tokamak, laser induced fusion, muonic catalysis.

Radiopharmaceuticals and their applications: radioisotope production, radioisotope generators, using tracers, gamma cammera, mechanisms for tracer accumulation.

Neutral (non-nuclear) beams: formation of the neutral beam, detection, applications of neutral beam techniques.

Josephson effects: combining tunneling and superconductivity, Josephson junction, SQUID, applications.

Exotic atoms: creation of the exotic atoms, muonic versus hadronic atoms, information from the spectra of exotic atoms, muonic spin rotation.

J/psi particle's discovery through colliding beams: basic parameters for colliding beam experiments, luminosity, detectors, J/psi signal and independent evidence for charm.

CP violation: kaons and strangeness, regeneration, CP violation equipment, high energy data collection and data analysis, CP puzzle.

Experiment on existence of at least two neutrino flavours: the direct radiative muon decay puzzle, kinds of neutrino beams, muonic neutrinos do not produce electrons.

STUDENT OBLIGATIONS DURING THE COURSE: The fourth year students are expected to attend the lectures, however , the relationship is less formal. Their background knowledge is tested during lecturing.

METHODS TO EVALUATE STUDENT PERFORMANCE: During the weekly contacts student responses to questions related to the topic under study.

EXAMINATION METHODS: The final exam includes three aspects: a test checks that a wide spectrum is qualitatively covered, written exam concentrates on four problems, during the oral examination the voids detected in test and written exam are probed in a more detail.

COURSE(s) NEEDED FOR THIS COURSE: General Physics 1-4, Quantum Physics

COMPULSORY LITERATURE: M. Furić Moderne eksperimentalne metode , tehnike i mjerenja u fizici, Školska knjiga, Zagreb 1992

ADDITIONAL READING:Scientific journals such as Physical Rewiev and popular journals such as Physics Today.

COURSE TITLE: **Quantum Physics of Finite Systems**

COURSE TEACHER/TEACHERS: **Prof. dr. sc. Dario Vretenar**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **4th**

SEMESTER: **7th**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		

ECTS credits: 4

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **This intermediate level course will introduce the basic concepts and methods of quantum physics applied to microscopic finite systems. It naturally follows the courses in Quantum Physics from the second and third year, and serves as an introduction to more specialized courses taught in the eight and ninth semester: Quantum Statistical Physics, Atomic and Molecular Physics, Nuclear Structure. The emphasis is on physical concepts: canonical transformations, self-consistent mean-fields, self-consistent and broken symmetries, linear response to an external field, etc. The course includes the necessary mathematical techniques, gives an overview of modern methods which are used in the description of microscopic finite systems, and prepares the student for the master thesis.**

DESCRIPTION OF THE COURSE:

1. **Canonical transformations**
2. **Static mean-field approximations (variational principle, Hartree-Fock, Hartree-Fock-Bogoliubov)**
3. **Symmetries and collective motion associated with broken symmetries (symmetries of the Hamiltonian and broken symmetries, symmetries and transformation of single-particle states, symmetries of the Hartree-Fock field, self-consistent and broken symmetries in the presence of pairing fields, broken symmetries in finite systems)**
4. **Time-dependent self-consistent fields (time-dependent Hartree-Fock for fermions, time-dependent mean-field approximation for bosons, time-dependent Hartree-Fock-Bogoliubov)**
5. **Small-Amplitude vibrations (linear response, sum rules, spurious states)**
6. **Applications: the atomic nucleus**

STUDENT OBLIGATIONS DURING THE COURSE: **homework assignments**

METHODS TO EVALUATE STUDENT PERFORMANCE: **homework problems will be**

graded, written and oral final examination.

EXAMINATION METHODS: **standard written and oral exam**

COURSE(s) NEEDED FOR THIS COURSE: **Quantum Physics, Symmetry in Physics**

COMPULSORY LITERATURE: **J-P. Blaizot and G. Ripka, Quantum Theory of Finite Systems, The MIT Press, 1986**

ADDITIONAL READING:

A. L. Fetter and J. D. Walecka, Quantum Theory of Many-Particle Systems , McGraw-Hill, 1971

J. W. Negele and H. Orland, Quantum Many-Particle Systems, Addison-Wesley, 1988

COURSE TITLE: Astronomy and Astrophysics		
COURSE TEACHER/TEACHERS: Prof. Krešimir Pavlovski		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 4		
SEMESTER: 7		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	assistant
ECTS credits: 4		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction to the basic knowledge of astronomy and astrophysics (fundamental astrophysical quantities and stellar properties, detecteors of EM radiation in astrophysics, stellar formation and evolution, structure of Milky Way galaxy, properties of galaxies, large-scale structure of the Universe, introduction to cosmology (origin and expansion of the Universe). Introductory course to principal astrophysical processes and phenomenology in stars and galaxies. Introduction to cosmology.

DESCRIPTION OF THE COURSE: 1) Fundamental astrophysical quantities; brigtness, colors, and luminosity, 2) Detectors of EM radiation, principes of photometry and spectroscopy, 3) Spectral classification, effective temeprature, 4) Binary stars, stellar masses and radii, 5) Hertzsprung-Russel diagram, 6) Equations of the stellar interiors, 7) Transport of radiation in stars, convection, 8) Stellar models, 9) Thermonuclear processes in stars, nucleosynthesis, 10) Stellar evolution; main-sequence and red giant phases, 11) Degenerate matter and white dwarfs, 12) Evolution of the Sun, 13) Variable stars; role of cepheids, 14) Supernoave and neutron stars, 15) Black holes, 16) Evolution of close binary stars, cataclysmic binaries, 17) Cosmic X-ray sources, 18) Interstellar medium (gas and dust), 19) Formation of stars, 20) Spiral structure of the Milky Way galaxy, 21) Rotation of the Galaxy, dark matter, 22) Classification of galaxies, 23) Properties of spiral and elliptical galaxeis, 24) Formation of galaxies, 25) Active galactic nuclei, quasars, 26) Clusters of galaxies, and large-scale structure of the universe, 27) Observational cosmology, expansion of the Universe, Hubble law, 28) Distance ladder, 29) Origin of the Universe, Big Bang theory, 30) Background radiation, primordial nucleosynthesis

STUDENT OBLIGATIONS DURING THE COURSE: seminar paper

METHODS TO EVALUATE STUDENT PERFORMANCE: seminar paper

EXAMINATION METHODS: written and oral

COURSE(s) NEEDED FOR THIS COURSE: none

COMPULSORY LITERATURE:

D. A. Ostlie & B. W. Carroll, An Introduction to Modern Astrophysics, Addison-Wesley, Reading, 1996

ADDITIONAL READING:

H. Karttunen et al., Fundamental Astronomy, Springer, Berlin, 2000

COURSE TITLE:	Relativistic Quantum Physics	
COURSE TEACHER/TEACHERS: Prof. dr. sc. Dubravko Klabučar		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 4.		
SEMESTER: 7.		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacherrassistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		
ECTS credits: 4		
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Mastering of the basic and easiest concepts of relativistic quantum physics – solutions for a free particle and some bound state cases in relativistic quantum mechanics, free quantum field theory, and the simplest examples of scattering in quantum electrodynamics.		

DESCRIPTION OF THE COURSE:

ↂ Formulation of a relativistic quantum theory. Transition from the non-relativistic to relativistic quantum mechanics.

ↂ Relativistic quantum-mechanical equations: Klein-Gordon and Dirac equation.

ↂ Non-relativistic limit, Pauli equation.

ↂ Covariant form of Dirac equation, gamma matrices.

ↂ Solutions of the free Dirac equation.

ↂ Dirac particle in the central field.

ↂ On motivations for quantum field theory – on Lamb's shift.

ↂ Photons and the electromagnetic field.

ↂ Classical field, harmonic oscillator and quantized radiation field.

ↂ Transition from classical to quantum electrodynamics.

ↂ Dipole interaction. Emission and absoption of photons on atoms.

ↂ Relativistically invarijant Lagrangians and transition to quantized theory.

ↂ Bosons of spin 0 – Klein-Gordon field, second quantization, meson propagator.

ↂ Fermions of spin ½ - Dirac field, second quantization, fermion propagator.

ↂ Covariant quantum theory of photons, photon propagator.

ↂ Scattering in quantum electrodynamics, Feynman rules.

ↂ Some lowest-order processes in electrodynamics, tree graphs.

STUDENT OBLIGATIONS DURING THE COURSE: Handing in at least a minimial number of homeworks (besides attendance).

METHODS TO EVALUATE STUDENT PERFORMANCE: Grading homeworks, colloquia (i.e., quiz-tests), final examinations.

EXAMINATION METHODS: Written (which can be accomplished also by accumulating sufficient number of points on homeworks and quiz-tests/colloquia) and oral.

COURSE(s) NEEDED FOR THIS COURSE: Quantum mechanics, mathematical courses.

COMPULSORY LITERATURE:

- F. Mandl, G. Shaw, Quantum Field Theory, John Wiley & Sons, revised edition (1993).

- W. Greiner, Relativistic Quantum Mechanics: Wave Equations, Springer-Verlag; 3rd edition (2000).

ADDITIONAL READING:

- W. Greiner, J. Reinhardt, Quantum Electrodynamics, Springer-Verlag; 3rd edition (2003).

COURSE TITLE: Irreversible thermodynamics

COURSE TEACHER/TEACHERS: Katarina Uzelac

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4

SEMESTER: 7

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY *(teacher or assistant)*
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 4

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

DESCRIPTION OF THE COURSE: Equilibrium thermodynamics and fluctuations. Space and time correlations. Generalized susceptibility. Fluctuation-dissipation theorem. Fluctuation dominated phenomena. Scale invariance. Processes near equilibrium. Conservation laws. Entropy production. Phenomenological equations. Stationary states. Processes far from equilibrium.

STUDENT OBLIGATIONS DURING THE COURSE: **attending lectures and exercises**

METHODS TO EVALUATE STUDENT PERFORMANCE: examination, student projects

EXAMINATION METHODS:written and oral examination

COURSE(s) NEEDED FOR THIS COURSE: thermodynamics, statistical mechanics

COMPULSORY LITERATURE: Landau and Livshitz: Statistical mechanics, Landau and Livshitz: Fluid mechanics (selected chapiters)

ADDITIONALREADING: S. R. de Groot and P. Mazur: Nonequilibrium thermodynamics (selected chapiters); J. Cardy: Scaling and renormalisation in statistical physics

COURSE TITLE:	Electrodynamics of Continuum

COURSE TEACHER/TEACHERS: Professor Slaven Barišić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4

SEMESTER: 7

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 4

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The course is meant to extend students' knowledge beyond the 3rd year compulsory course on Classical Electrodynamics, towards the electomagnetism of condensed matter, solid state in particular. This knowledge is required for solving numerous concrete electromagnetic problems, which appear in professional or research work.

DESCRIPTION OF THE COURSE: Electrostatics of the dielectrics and conductors. DC current. Constant magnetic field. Quasi-stationary electromagnetic field. Magneto- hydrodynamics. Propagation of the electromagnetic field in anisotropic media: metals, semiconductors, charge density wave systems, superconductors. Behavior of electromagnetic waves at interfaces. Inelastic scattering of the electromagnetic waves by media.

STUDENT OBLIGATIONS DURING THE COURSE: Attending lectures and exercises, solving a number of straightforwardly solvable problems.

METHODS TO EVALUATE STUDENT PERFORMANCE: Written and oral examinations, homework during the semester.

EXAMINATION METHODS: Written and oral, evaluation of progress achieved through exercises and homework.

COURSE(s) NEEDED FOR THIS COURSE:

General Physics, Classical Electrodynamics

COMPULSORY LITERATURE:

1. L.D. Landau, E.M. Lifshitz, L.P. Pitaevskii, Electrodynamics of Continuous Media, Butterworth-Heinemann, 1995;

2. M. Dressel, G. Grüner, Electrodynamics of Solids, Cambridge University Press, 2002.

ADDITIONAL READING:

COURSE TITLE:	**Electromagnetic waves and Optics**

COURSE TEACHER/TEACHERS: Prof. dr. D. Klabučar, Doc. Dr. H. Buljan

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4th

SEMESTER: 7th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY *(teacher or assistant)*
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 4

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

The course is intended to continue elaborating, and also to extend the topics related to electromagnetic (EM) waves that were addressed in the course Classical electrodynamics. The topics include wave propagation in waveguides, optical fibers (apsorption/dispersion in the medium), and related topics such as group/phase velocity, and paraxial wave equation.

DESCRIPTION OF THE COURSE:

- The derivation of wave equations for vector and scalar potential starting from the Maxwell equations. Homogeneous and inhomogeneous plane waves.

- Total reflexion described with inhomogeneous plane wave with complex wave-vector

- Dispersion characteristics of dielectrics, metals, and plasma. Classical model for the description of dispersion.
ଔ Normal and anomalous dispersion, resonant absorption.
ଔ Dielectric constant at low frequencies and electrical conductivity; Dielectric constant at high frequencies up to plasma frequency. Index of refraction and apsorption coefficient of water in dependence of frequency.
- Waves in metals and dissipative media.
- Phase and group velocity, pictorial description of pulse propagation in dispersive medium; split-step Fourier method for solving evolution equations
ଔ Boundary conditions on metal surfaces, waveguides and characteristic modes.
ଔ Optical fibers: modes and dispersion properties, geometrical description, wave description, the affect of nonlinearity on wave propagation.
ଔ Ray equation, paraxial wave equation, application in optic fibers.

- Analogy between paraxial wave equation and Schrodinger wave equation.

STUDENT OBLIGATIONS DURING THE COURSE: Home assignments, quiz-tests

METHODS TO EVALUATE STUDENT PERFORMANCE:

Continuous writing of home assignments and success in quiz tests.

EXAMINATION METHODS: Written exam and oral exam.

COURSE(s) NEEDED FOR THIS COURSE: General physics courses, Classical electrodynamics, general mahematical courses

COMPULSORY LITERATURE:

J. D. Jackson, Classical Electrodynamics, John Wiley and Sons, New York 1999.

G. P. Agrawal, Fiber-Optic Communication Systems, Wiley-Interscience, 2002.

M. P. Silverman, More Than One Mystery: Explorations in Quantum Interference, Springer Verlag 1995.

ADDITIONAL READING:

B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, Wiley-Interscience, 1991.

S. Ramo, J. R. Whinnery, T. Van Duzer, Fields and Waves in Communication Electronics, John Wiley and Sons, 1994.

R.W. Boyd, Nonlinear Optics, Academic press, 1992.

COURSE TITLE:	Advanced quantum physics

COURSE TEACHER/TEACHERS: Professor M. Šunjić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4th

SEMESTER: 7th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 4

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Extend the knowledge of quantum physics and apply it to more complex systems.

DESCRIPTION OF THE COURSE:

1) Quantization of the boson and fermion fields, states and opservables. Field operators for fermions and bosons, particles and antiparticles (holes)

2) Quantization of the electromagnetic field

3) Canonical transformations. Coherent and squeezed states, connection with classical fields (laser)

4) Boson condensation, coherence

5) Quantum mechanical effects in tunneling: coherent and sequential tunneling, resonances

6) Scattering theory – Lippmann-Schwinger equation, T-matrix

7) Born expansion, Green's functions – propagators

8) Description of scattering processes in terms of Feynman diagrams, rules for Feynman diagrams

9) Time-dependent perturbation theory: inelastic processes, two-level systems: exact solution

10) Second order processes, interferences, irreversibility

11) Self-consistent mean field method: many-electron atoms – Thomas-Fermi and Hartree-Fock approximations

12) Quantum mechanical aspects of the electromagnetic fields: gauge invariance, Aharonov-Bohm effect, Casimir and Casimir-Polder energies

STUDENT OBLIGATIONS DURING THE COURSE: Homework; small projects submitted and orally presented.

METHODS TO EVALUATE STUDENT PERFORMANCE: Homework delivered regularly, successful project presentation.

EXAMINATION METHODS: Delivery and presentation of projects, and final oral exam.

COURSE(s) NEEDED FOR THIS COURSE: 1st to 3rd year courses.

COMPULSORY LITERATURE:

I.**Supek: Teorijska fizika i struktura materije II (Školska knjiga, Zagreb, 1977)**
Leonard I. Schiff: Quantum Mechanics (McGraw-Hill 1968)
Eugen Merzbacher: Quantum Mehanics (John Wiley 1970)
J.J.Sakurai: Modern Quantum Mechanics (Addison-Wesley 1985)

ADDITIONAL READING:

Richard W. Robinett : Quantum Mechanics (Oxford UP, 1997)
B.H. Bransden & C.J. Joachain: Quantum Mechanics (Pearson, Prentice Hall, 2000)
R. P. Feynman, R.B.Leighton, M. Sands: The Feynman Lectures on Physics III, Quantum Mechanics (Addison-Wesley 1965)
A.Messiah: Quantum Mechanics (Interscience, 1961)
P.A.M. Dirac: Quantum Mechanics , 4th ed. (Oxford UP, London, 1958)
S. Gasiorowicz: Quantum Physics (Wiley, New York, 1974)
C. Cohen-Tannoudji: Quantum Mechanics (Wiley-Interscience, 1996)

COURSE TITLE: Methods of material characterisation

COURSE TEACHER/TEACHERS: professor dr. sc. Antun Tonejc

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4

SEMESTER: 7

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	teacher
Laboratory		

ECTS credits: 4

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: To provide a students with basic concepts of materials characterisation.

DESCRIPTION OF THE COURSE:
1. DIFFRACTION TECHNIQUES
   a) XRD: X-ray Diffraction
  b) ED: Electron Diffraction

  c) LEED: Low-Energy Electron Diffraction
  d) RHEED: Reflection High-Energy Electron Diffraction

  e) ND: Neutron Diffraction
2. MICROSCOPIC TECHNIQUES

A) optical and electron microscopy
  a) Optical Microscopy
  b) TEM:Transmission Electron Microscopy
    CTEM: Conventional Transmission Electron Microscopy
    AEM:Analytical Electron Microscopy
    EMMA:Analytical Electron Microscopy with Microanalysis
    TEM with EPMA (Electron Probe Microanalysis)
    HRTEM: High-Resolution Transmission-Electron Microscopy
    STEM: Scanning Transmission Electron Microscopy
  c) SEM: Scanning Electron Microscopy
  d) LEEM: Low-Energy Electron Microscopy

B) SURFACE MICROSCOPY
   a) SPM: Scanning Probe Microscopy
  b) AFM: Atomic Force Microscopy

  c) STM: Scanning Tunneling Microscopy
  d) LFM: "Lateral-Force" Microscope
     E) NSOM: Near-field Scanning Optical Microscopy
3. SPECROSCOPIC TECHNIQUES
   a) visible and ultraviolet spectroscopy

  b) ellipsometry

  c) IR: Infrared Spectroscopy

  d) RS: Raman Spectroscopy

  e) Luminiscence

  f) Nonlinear Optical Spectroscopy
  g) Mössbauer Spectroscopy

  h) electron spectroscopies
     ESCA: Electron Spectroscopy for Chemical Analysis

     UPS: Ultraviolet Photoelectron/Photoemission Spectroscopy

     XPS: X-ray Photoelectron/Photoemission Spectroscopy

     AES: Auger Emission Spectrometry
     EELS: Electron Energy Loss Spectrometry
     EXELFS: Extended Energy Loss Fine Structure Spectroscopy
     LEELS: Low-Energy Electron Loss Spectrometry
  i) X-ray spectroscopies
     XRF: X-ray Fluorescence
     AEFS: Absorption Edge Fine Structure
     EXAFS: Extended X-ray Absorption Fine Structure Spect
     EDS: Energy Dispersive X-ray Spectrometry
     XANES: X-ray absorption near edge structure

     EXAFS: Surface Extended X-ray Apsorption Fine Structure Spectroscopy
4. TRANSPORTMEASUREMENTS
   a) electrical resistivity and hall effect
   b) Thermopower, Peltier Coefficient and thermal conductivity
5. MAGNETIC MEASUREMENTS
   a) Foner magnetometer
   b) Faraday balance
   c) AC bridge
   d) SQUID: Superconducting Quantum Interference Device
6. RESONANCE TECHNIQUES
   a) NMR: Nuclear Magnetic Resonance

b) ESR: Electron Spin Resonance
   c) ENDOR: Electron Nuclear Double Resonance
   d) NQR:Nucelar Quadruple Resonance
7. ELEMENBTARY PARTICLES
   a) PAS: Positron-Annihilation Spectrometry

   b) μPS: Muon-Precession Spectrometry
11. THERMAL ANALYSIS
   a) TG: Thermogravimetry

   b) DTA: Differential Thermal Analysis
   c) DSC: Differential Scanning Calorimetry
12. MECHANICAL MEASUREMENTS
   a) Tension Test
   b) Compression Test
   c) Vibration Test
   d) Hardness, Micro-hardness and Nano-hardness Test

STUDENT OBLIGATIONS DURING THE COURSE: **Students have to attend lectures, to give one seminar of a selected topic, and to work out homeworks and colloquia.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Regulary attendence of lectures and exercises. Reasonable good presentation of the seminar.**

EXAMINATION METHODS: **no exam**

COURSE(s) NEEDED FOR THIS COURSE: Solid State physics

COMPULSORY LITERATURE:

   P. E. J. Flewitt, R. K. Wild; Physical Methods for Marterials Characterisation, Institute of Physics Publisching, Bristol, 2003

ADDITIONAL READING:

 A. R. West, Basic Solid State Chemistry, Yohn Wiley&Sons, New York, 1999

COURSE TITLE: **Biophysics**

COURSE TEACHER/TEACHERS: **Dr. sc. Selma Supek, Assistant Professor, Department of Physics, Faculty of Science, University of Zagreb**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **4**

SEMESTER: **7**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises		
Seminars	**1**	**teacher**

ECTS credits: **4**

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **To introduce the students to interdisciplinary biophysics research. To give an insight into the basic concepts of the structure and function of biological systems from molecule to the brain and to give an overview of the latest experimental methods. To emphasize the close connection between biophysics and biotechnologies of the future. To stimulate students to present some of the latest biophysics research in the seminars on the topics of their interest.**

DESCRIPTION OF THE COURSE: **Subject, role, and importance of biophysics. Biophysics – biotechnology. Cellular organization of life. Biosynthesis, structure and functions of nucleic acids and proteins. Protein folding and dynamics. Overview of experimental methods in examining structure and dynamics of biological systems. Solute transport through biological membranes. Ion transport and rest potential. Molecular and cellular imaging. Noninvasive imaging of neurodynamic, hemodynamic, and metabolic brain activity. Neurobiology and biophysics of cognitive processes and emotions. Bio-sensors. Neuroimplants.**

STUDENT OBLIGATIONS DURING THE COURSE: **Lectures, discussions, written exams, seminars.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Participation at lectures and seminars.** **Oral presentation of a seminar.**

EXAMINATION METHODS: **Final written exam.**

In the total grade the final exams contributes with 30%, discussions and written exams with 40% and oral presentation of a seminar with 30%.

COURSE(s) NEEDED FOR THIS COURSE: **General physics.**

COMPULSORY LITERATURE:

PowerPoint presentations of the lectures and selected review articles.

ADDITIONAL READING:

Cotterill R. "Biophysics: An Introduction" John Wiley & Sons, N.Y., 2002

Weiss, T.F. "Cellular Biophysics I" The MIT Press, Cambridge, USA, 1996

COURSE TITLE: Theory of Fields I

COURSE TEACHER/TEACHERS: Prof. Amon Ilakovac

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4th

SEMESTER: 8th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	Teacher
Exercises	1	Assistant
Seminars	0	

ECTS credits: 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:
Students are familiarized with basic notions of regularization and renormalization and application of these methods to quantum electrodynamics and phi^4 theory.

DESCRIPTION OF THE COURSE:
ଔ Recapitulation of basic quantum-field-theory notions through tree-level examples in QED (quantum electrodynamics)
ଔ Soft Bremsstrahlung
ଔ Structure and evaluation of the electron-vertex function.
ଔ Infra-red divergencies of the electron-vertex function.
ଔ Formalism of radiative corrections: A. Field-strength renormalization, electron self-energy,
ଔ B. LSZ reduction formula, C. Optical theorem,
ଔ D. Ward-Takahashi identity, E. Charge renormalization
ଔ Systematics of renormalization: A. Counting of divergencies
ଔ B. Renormalization of phy^4 theory,
ଔ C. Renormalization of QED,
ଔ D. Renormalization beyond the leading order
ଔ Aplications of renormalization and regularization techiques: examples.

STUDENT OBLIGATIONS DURING THE COURSE:
solving homework problems

METHODS TO EVALUATE STUDENT PERFORMANCE:
Solving the homework problems.

EXAMINATION METHODS: oral and written exams

COURSE(s) NEEDED FOR THIS COURSE: Relativistic Quantum Physics

COMPULSORY LITERATURE:

M.E. Peskim, D.V. Schroeder, An Introduction to Quantum Field Theory, Addison Wesley 1995,

ADDITIONAL READING:

S. Weinberg, The Quantum Theory of Fields I, Cambridge, 1995.

S. Weinberg, The Quantum Theory of Fields II, Cambridge, 1996.

COURSE TITLE:	Physical cosmology	

COURSE TEACHER/TEACHERS:	Prof. Ivica Picek

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY:	4th

SEMESTER:	8th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: connections of particle physics and cosmology; formulating and solving a problem

DESCRIPTION OF THE COURSE:

1. **Galactic Universe and the cosmological principle.**
2. **Distances in the Universe and the Hubble expansion.**
3. **Geometry and gravitation – the basics of the general relativity.**
4. **Einstein equations for the Universe and Friedmann cosmological models.**
5. **Solving Einstein-Friedmann equations for different epochs.**
6. **Standard big bang model and the early Universe.**
7. **Primordial nucleosynthesis of light elements.**
8. **Cosmic microwave background and the anisotropy measurements**
9. **Very early Universe as the elementary particle laboratory.**
10. **Bariogenezis, nonbarionic dark matter and dark energy**
11. **Inflationary cosmology, neutrino physics and gravitational waves.**
12. **Large and small inflation and the large scale structures.**

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lectures and homeworks

METHODS TO EVALUATE STUDENT PERFORMANCE: Participation in common projects

EXAMINATION METHODS: : the activity in the course and the final seminar

COURSE(s) NEEDED FOR THIS COURSE:

 Electrodynamics, Quantum physics, Particle physics (1 semester)

COMPULSORY LITERATURE:

J. V. Narlikar, INTRODUCTION TO COSMOLOGY, Cambridge University Press, 2nd ed. 1993.

L. Bergstroem and A. Goobar, COSMOLOGY AND PARTICLE ASTROPHYSICS, John Wiley and Sons Ltd, 1999.

ADDITIONAL READING:

P.J.E. Peebles, PRINCIPLES OF PHYSICAL COSMOLOGY, Princeton Univ. Press, 1993.

J.A. Peacock, COSMOLOGICAL PHYSICS, Cambridge University Press, 1999.

D.H. Perkins, PARTICLE ASTROPHYSICS, Oxford University Press, 2003.

COURSE TITLE: Physics of the stars

COURSE TEACHER/TEACHERS: Prof. Krešimir Pavlovski

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4

SEMESTER: 8

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	assistant

ECTS credits: 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Fundamentals of the stellar physics including radiative transfer in stellar atmospheres and formation of continuum and line spectra. Diagnostics and analysis of stellar spectra as a key for understanding physical processes in stellar interiors and atmospheres.

DESCRIPTION OF THE COURSE: 1) Emirpical stellar data, 2) Fundamental radiative quantites, 3) Radiative transfer equation in stellar atmospheres, 4) Source function, 5) Schuster-Schwarzschild aproximaptive method, 6) Eddington approximations, 7) Chadrasekhar method, 8) Opacities of stellar matter, Saha equation, 9) Model atmospheres, 10) Line absorption, 11) Spectral line broadening processes in stellar atmospheres, 12) Spectroscopic diagnostics, dtermination of effective temperature, log g, 13) Hydrogen lines in stellar spectra, 14) Stellar chromospheres and coronae, 15) Stellar winds

STUDENT OBLIGATIONS DURING THE COURSE: seminar paper

METHODS TO EVALUATE STUDENT PERFORMANCE: seminar paper

EXAMINATION METHODS: written and oral

COURSE(s) NEEDED FOR THIS COURSE: none

COMPULSORY LITERATURE:

E. Bohm-Vitense, Introduction to Stellar Astrophysics, Vol. 2, Cambridge University Press, Cambridge, 1989

ADDITIONAL READING:

W. Novotny, Introduction to Stellar Atmospheres and Interiors, Oxford University Press, New York, 1973

COURSE TITLE: Electronics lab		
COURSE TEACHER/TEACHERS: Prof. dr.sc. Amir Hamzić		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 4		
SEMESTER: 8		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Laboratory exercises	3	*teacher and assistant*
ECTS credits: 5		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Assembling, measurements and analysis of basic electronic circuits and simple devices using discrete and integrated elements.

DESCRIPTION OF THE COURSE:
FET amplifiers,
BJT amplifiers,
feedback, differential amplifier
circuits with passive elements, operational amplifier
basic logic circuits, half and full adder, multiplying,
binar and decimal counters,
digital voltmeter, A/D i D/A converters,
time-base circuits,
voltage stabilization,
signal modulation and demodulation

STUDENT OBLIGATIONS DURING THE COURSE: analysis of measurement, discussion of results, partial exams (colloquy) each week, computer programming of specific physical measurements in real time (on-line experiment)

METHODS TO EVALUATE STUDENT PERFORMANCE: partial exams (colloquy), homework

EXAMINATION METHODS: written exam; the final score consists of the results of final written exam, weeks' partial exams, and evaluation of student's skills

COURSE(s) NEEDED FOR THIS COURSE: Microelectronics

COMPULSORY LITERATURE:
H.M.Jones, A Practical Introduction to Electronic Circuits, Cambridge Univer.

Press, 1987.
P. Biljanović, Elektronički sklopovi, Školska knjiga, Zagreb 1989.
Notices and instruction manuals (for internal use only).

ADDITIONAL READING:

COURSE TITLE: Energetics

PROPOSED BY: Đuro Miljanić, senior scientist, Ruđer Bošković Institute, Zagreb

PROGRAMME: *University study of research physics*

YEAR OF STUDY: 4

SEMESTER: 8

TYPES OF INSTRUCTION	CONTACT HRS PER WEEK	DELIVERED BY
Lectures	2	lecturer
Examples Classes	1	lecturer
Seminars		

ECTS CREDITS: 5

COURSE AIMS AND OBJECTIVES: To acquire knowledge on: a) main characteristics of different energy sources; b) physical and technological aspects of their use; c) social, environmental and economical issues connected with meeting present and future energy needs.

COURSE DESCRIPTION AND SYLLABUS: Work, energy, power. Primary energy sources: their main characteristics, reserves, production and consumption in Croatia and the world. Energy conversion: basics, processes, devices, engines, plants. Transmission, transport and storage of different forms of energy. Energy and society: impacts on human health and environment, economy, sustainable development.

TEACHING AND ASSESSMENT METHODS:

PREREQUISITES: Physics and mathematics courses – prerequisites for the third year of study.

READING LIST: 1. B. Udovičić: Energetika, Školska knjiga, Zagreb, 1993
    2. V. Knapp: Novi izvori energije I, Školska knjiga, Zagreb, 1993.
    3. P. Kulišić: Novi izvori energije II., Školska knjiga, Zagreb, 1991.

ADDITIONAL READING:

1. **Obnovljivi izvori energije (ed. B. Labudović), Energetika Marketing, Zagreb, 2002.**
2. **Energy Systems and Sustainability: Power for a Sustainable Future (ed. G. Boyle, B. Everett and J. Ramage), Oxford University Press, Oxford, 2003.**
3. **Renewable Energy: Power for a Sustainable Future (ed. G. Boyle), Oxford University Press, Oxford, 2004.**

COURSE TITLE:	**Medical Physics**

COURSE TEACHER/TEACHERS: **Prof.dr.sc. Mladen Vrtar**

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY:	**4.**

SEMESTER:	**8.**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**M.Vrtar (teacher)**
Exercises	**1**	**M. Vrtar (teacher)**

ECTS credits:: **5**

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS
The application of physical methods in modern medicine and the working area and responsibility of medical physicist in health care institutions. Additional help in choosing the direction of doctor or specialist study of medical physics.

DESCRIPTION OF THE COURSE:
Interaction of radiation and matter important in radiology and radiotherapy. Sources and production of radiation in medical practice. Exposition of ionising radiation, radiation quality and detectors. Absorbed dose in water. Dosimetric protocols in determination of absorbed dose. Radiotherapy physics in clinical practice. Use of radioisotopes in nuclear medicine. Influence of radiation to human tissue and radiation protection. Quality assurance in clinical use of radiation. Basic methods of tomographic reconstruction. Computerised tomography (CT). Positron emission tomography (PET). Single photon emission tomography (SPECT). Magnetic resonance (MR). Physical basis of ultrasound. Various records of ultrasonic echo. Application of thermography in medicine. Sources of bioelectric potentials, nerve cells, brain, sensor organs, muscles. Measurement of potentials in brain (EEG), heart (EKG), muscle (EMG), eye (ERG). Magnetic signals from heart (MKG) and brain (MEG).

STUDENT OBLIGATIONS DURING THE COURSE:
The students must be present on lectures and exercises. They explain one theme from medical physics in a semester and solve the numerical exercises from some chapters. The students are obliged to attend the organised visits at some medical institutions to see the practical demonstration of certain equipment and application of physics in medicine (the special attention should be directed to radiological diagnostic, radiotherapy and radiation protection).

METHODS TO EVALUATE STUDENT PERFORMANCE: **exams, obliged exercises**

EXAMINATION METHODS: **oral exam**

COURSE(s) NEEDED FOR THIS COURSE:

The obliged courses needed to enter the 8. semester

COMPULSORY LITERATURE:

Vrtar M. Medical physics (in Croatian). Internal script of Physics dept. Zagreb 2004)

    (available to photocopy)

ADDITIONAL READING:

1. Podgorsak E.B. Review of radiation oncology physics, IAEA, Vienna, Austria 2003. (dostupno i preko interneta)
2. Cherry S.R., Sorenson J.A., Phelps M.E. Physics in nuclear medicine, 3rd ed. Saunders, An Imprint of Elsevier Science, USA 2003.
3. Bushberg J.T., Seibert J.A., Leidholdt E.M., Boone J.M. The essential physics of medical
   imaging. Williams & Wilkins, Baltimore 1995.
4. PaićV. i Paić G.: Osnove radijacione dozimetrije i zaštite od zračenja, Udžbenik Sveučilišta u Zagrebu, Liber, Zagreb 1983.
5. Šantić A.: Biomedicinska elektronika,   Školska knjiga, Zagreb 1995.

COURSE TITLE: **Selected topics in optics**		
COURSE TEACHER/TEACHERS: dr. sc. Krešimir Furić, Institut "R. Bošković"		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 4		
SEMESTER: 8		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2+0	teacher
Exercises	-	-
Seminars	1+0	teacher
Lab		
ECTS credits: 5		
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:		
DESCRIPTION OF THE COURSE:Light scattering and interaction with matter, Fresnel equations. Matrix method in geometrical optics. Special optical elements: complex lenses, complex prisms. Classical optical devices: microscopes, telescopes, binocular, camera. Optical and other properties of thin films, special materials and their applications. Polarization of light, polarization by special devices. Lasers in the visible and near regions. Light transmitters in telecommunication devices. Interference of light, spectrometers and interferometers. Fourier-transform infrared spectrometer. Complex spectrometer with grids (Raman spectroscopy).		
STUDENT OBLIGATIONS DURING THE COURSE: Preparation of one seminar work. Due to small number of students enrolled, the course program is adaptable.		
METHODS TO EVALUATE STUDENT's PERFORMANCE:		
EXAMINATION METHODS: written and oral exam		
COURSE(s) NEEDED FOR THIS COURSE: General Physics III		
COMPULSORY LITERATURE: E. Hecht, Optics, Addison Wesley, Reading (Massachusetts) 1998		

ADDITIONAL READING:

M.Paić, Osnove fizike IV, Sveučilišna naklada liber, Zagreb 1983

F. A. Jenkins and H. E. White, Fundamentals of optics, McGraw-Hill, Tokyo 1976

COURSE TITLE: Atomic and Molecular Physics

COURSE TEACHER/TEACHERS: Prof. Damir Veža

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 4th

SEMESTER: 8th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		
Lab		

ECTS credits: 5

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Understanding. formulating and solving problems in the AMO Physics

DESCRIPTION OF THE COURSE:

1.Atomic energy levels 2.Molecular energy levels 3.Spectra of alkali atoms and molecules 4.Emission and absorption of radiation 5. Shift and broadening of spectral lines 6.Radiative transfer and population distributions 7.Ionized gases and plasma 8.Spectra of ionized gases and plasmas 9.Atomic collision processes in gases and plasmas 10.Elementary plasma diagnostics 11.Classical spectroscopy (methods and devices) 12.Laser spectroscopy (methods and devices) 13.Light sources and detectors
Exercises:
Complementary material to lectures. Solving problems in atomic and molecular physics.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lectures, homeworks

METHODS TO EVALUATE STUDENT PERFORMANCE: Homeworks and written exams

EXAMINATION METHODS: evaluation of homeworks and an exam at the end of the semester

COURSE(s) NEEDED FOR THIS COURSE: Quantum physics

COMPULSORY LITERATURE:

A.P.Thorne, U. Litzen, S, Johansson, *Spectrophysics*, Springer Verlag, Berlin 1999.

ADDITIONAL READING:

C. W. Bradley,O. A. Dale, *An introduction to modern stellar astrophysics*, Addison-Wesley, 1996.

F.F. Chen, *Introduction to Plasma Physics*, New York, 1974.

COURSE TITLE: Quantum statistical physics		

COURSE TEACHER/TEACHERS: Professor M. Šunjić		

STUDY PROGRAMME: University study of research physics		

YEAR OF STUDY: 4th		

SEMESTER: 8th		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	2	assistant
Seminars		

ECTS credits: 5		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Methods of the nonrelativistic field theory in the study of manybody systems, with application to some standard problems.

DESCRIPTION OF THE COURSE:

1) Quantum mechanical description of the many body system, basic problems. Approximation methods.

2) Propagators – Green's functions. Analytical properties, Kramers-Kronig relations

3) Perturbation expansion, Feynman diagrams and rules

4) Digramatic analysis of physical processes, fermion-fermion and fermion-boson interaction. Examples – 1st and 2nd order processes

5) Self energy, Dyson equation, spectral function, quasiparticles

6) Real and virtual transiitons. Renormalization of particle mass and energy

7) Linear response of the system, differential cross section and correlation functions, static and dynamical structure factors

8) Response functions, Lindhard function, application to the Coulomb gas

9) Dynamically screened Coulomb interaction, collective excitations, RPA

10) Dynamical oscillations (plasmons, zero sound) and static screening in a Coulomb gas

11) Equation of motion for Green's functions, Hartree and Hartree-Fock approximations

12) Density matrices, approximations, pair distribution function, Fermi hole

STUDENT OBLIGATIONS DURING THE COURSE: Homework; small projects submitted and orally presented.

METHODS TO EVALUATE STUDENT PERFORMANCE: Homework delivered regularly, successful project presentation.

EXAMINATION METHODS: Delivery and presentation of projects, and final oral exam.

COURSE(s) NEEDED FOR THIS COURSE: Advanced quantum physics

COMPULSORY LITERATURE: M. Šunjić: Kvantna fizika mnoštva čestica, (Školska knjiga, Zagreb, 2002)

ADDITIONAL READING:

T.D. Schultz: Quantum Field Theory and the Many-Body Problem, (Gordon and Breach, New York, 1963)

A.A. Abrikosov, L.P. Gorkov, I.E. Dzyaloshinskii: Methods of Quantum Field Theory in Statistical Physics, (Prentice-Hall, Englewood Cliffs, 1963)

A Mattuck: Guide to Feynman Diagrams in the Many-Body Problem, (New York, 1967)

A. Fetter-J. D. Walecka: Quantum Theory of Many-Particle Systems (McGraw Hill, New York, 1971)

COURSE TITLE: Physics of Disordered Systems
COURSE TEACHER/TEACHERS: Professor Dr.sc. Krešo Zadro
STUDY PROGRAMME: University study of research physics
YEAR OF STUDY: 4
SEMESTER: 8

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	teacher
Laboratory		

ECTS credits: 5
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:
DESCRIPTION OF THE COURSE: **Order – disorder: ordering rules, order parameters** **Glasses: insulating, metallic and spin glasses, neural networks.** **Fractals: fractal dimension, fractal patterns in nature, random walk and fractals.** **Percolation: percolation threshold, correlation length, phenomena on percolation networks.**
STUDENT OBLIGATIONS DURING THE COURSE: lectures attendance
METHODS TO EVALUATE STUDENT PERFORMANCE: student projects
EXAMINATION METHODS: oral examination
COURSE(s) NEEDED FOR THIS COURSE:
COMPULSORY LITERATURE: 1. N.E. Cusak, The Physics of Structurally Disordered Matter, Adam Higler, Bristol, 1988. 2. A. Bunde, S.Havlin , Eds., Fractala and Disordered Systems, Springer, Berlin, 1996., 3. D. Stauffer, A. Aharony, Introduction to Percolation Theory, Taylor& Francis, London, 1992.
ADDITIONAL READING:

COURSE TITLE: Seminar in Physics

COURSE TEACHER/TEACHERS: Prof. dr. sc. E. Babić and Prof.dr.sc. S. Barišić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5

SEMESTER: 9

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars	4	teacher

ECTS credits: 9

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Overwiev of the recent development in physics

DESCRIPTION OF THE COURSE: Individual work on selected topics in theoretical and/or experimental physics, studying appropriate research papers in physics journals and/or from Internet databases. Presentation (preferably arranged in MS Power Point) in the form of a seminar to the students that enrolled this course.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lectures, giving a seminar lecture

METHODS TO EVALUATE STUDENT PERFORMANCE: Listening to student seminar presentations and grading them.

EXAMINATION METHODS: Asking questions during student seminar presentations and discussing the presented material to test understanding

COURSE(s) NEEDED FOR THIS COURSE:

COMPULSORY LITERATURE:Selected articles from the journals Physics Today, Scientific American, American Journal of Physics

ADDITIONAL READING: Internet databases

COURSE TITLE: **Solid State Physics Lab**

COURSE TEACHER/TEACHERS: **Docent, Ivan Kokanović, Faculty of Science**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: V

SEMESTER: IX

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	teacher

ECTS credits: 14

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Teaching in the experimental techniques and methods in Solid State Physics using laboratory exercises for students.

DESCRIPTION OF THE COURSE: **Students carry out the measurements in the topical subjects in Experimental Solid State Physics at Department of Physics.**   **List of Experiments: Diffraction of electrons, Conductivity of Semiconductors, Magnetoresistance, Hall Effect, Seebeck Effect, Peltier effect.**
STUDENT OBLIGATIONS DURING THE COURSE: **Students have to carry out the measurements, to analyse the measurement data, to write the report for each experiment and to make the oral presentation (15 minutes for presentation data + 10 minutes for discussion).**
METHODS TO EVALUATE STUDENT PERFORMANCE: **Students have to carry out the measurements, to analyse the measurement data, to write the report for each experiment.**
EXAMINATION METHODS: **The oral presentation (15 minutes for presentation data + 10 minutes for discussion).**
COURSE(s) NEEDED FOR THIS COURSE: **No condition**

COMPULSORY LITERATURE: **The papers for the internal use.**

ADDITIONAL READING: C. Kittel, Introduction to Solid State Physics, John Wiley & Sons, 1971., New York.   V. Šips, Uvod u fiziku čvrstog stanja, Školska knjiga, Zagreb, 1991.

COURSE TITLE: Nuclear Physics Lab		

COURSE TEACHER/TEACHERS: Professor Ksenofont Ilakovac		

STUDY PROGRAMME: university study of research physics		

YEAR OF STUDY: 5		

SEMESTER: 9		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	teacher

ECTS credits: 14		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

Learning the functioning of detectors and electronics and acquiring the skills of measurement of nuclear radiation. Methods of analysis of spectra of nuclear radiation using computer programs and graphical presentation of the results. Learning the dangers of nuclear radiation and the methods of protection.

DESCRIPTION OF THE COURSE:

The work of the student in the Laboratory begins with an examination with the aim to check whether the student is prepared for the work, based on the course in the 9th semester, Instructions for the Work in the Laboratory and original articles which were milestones in the development of nuclear physics. The students work the following exercises:

1) Geiger-Mueller counter.
2) Radioactive decay of thoron, ionisation chamber.
3) Scintillation detector. Measurement of gamma-ray spectra.
4) Absorption of beta radiation.
5) Absorption of gamma radiation.
6) Radioactivity of kalium and in air.
7) Induced radioactivity.
8) Statistics.
9) Incoherent scattering of gamma radiation.
10) Szilard-Chalmers effect.

11) Germanium detector. Accurate measurement of gamma-ray spectra.

12) Radiative capture of neutron in hydrogen. Neutron mass.

STUDENT OBLIGATIONS DURING THE COURSE:

1) Prepare for the entry test and pass the colloquium.

2) Regular work in the Lab.

3) Work according to additional written and oral instructions for the work with radioactive substances.

4) Orderly and regularly write reports on measurements and analyses and discuss them.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Quality of the measurements and analyses of dana for ten exercises.

EXAMINATION METHODS:

Expremintal task, analysis of data and oral examination.

COURSE(s) NEEDED FOR THIS COURSE:

 Quantum theory. Nuclear Physics.

COMPULSORY LITERATURE:

1) Instructions for the Work in Nuclear Physics Laboratory.

2) I. Supek: Theoretical Physics and structure of Matter.

ADDITIONAL READING:

Original articles that were milestones in the development of nuclear physics **(Rutherford, Geiger and Marsden, Compton, Cockcroft and Walton, Chadwick, Anderson, Lawrence, Curie and Joliot, Fermi, Yukawa, Hahn and Strassmann).**

COURSE TITLE: **Particle Physics Lab**

COURSE TEACHER/TEACHERS: **Prof. Dr. Sc. Damir Bosnar**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **5.**

SEMESTER: **9.**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**0**	
Exercises		
Seminars		
Lab	4	teacher + assistant

ECTS credits: 14

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Skills in measurement methods and techniques in high energy physics.**

DESCRIPTION OF THE COURSE: **Radiation detection using scintillation detectors, semiconductor detectors, ionization detectors (MWPC and VDC). Timing and coincidence measurements. Fast electronics and data acquisition. Treatment of data and error analysis. Measurement of speed of cosmic mouns. Measurement of muon lifetime. Measurement of muon magnetic moment. Measurement of positronium lifetime.**

STUDENT OBLIGATIONS DURING THE COURSE: **Preparations for the laboratory exercises. Execution of the laboratory exercises. Data analysis and discussion.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Evaluation of each segment of given assignments.**

EXAMINATION METHODS: **Evaluation of student performance during laboratory exercises.**

COURSE(s) NEEDED FOR THIS COURSE: **Particle Physics. Electronics.**

COMPULSORY LITERATURE:
 	
   D. H. Perkins: Introduction to High Energy Physics, Cambridge University
 	
       Press, Cambridge 2000.
 	
 W. R. Leo: Techniques for Nuclear and Particle Experiments, Springer Verlag,
 	
    1994.

P. R. Bevington, D. K. Robinson: Data Reduction and Error Analysis for the Physical Sciences, McGraw-Hill, 1992
ADDITIONAL READING: **Selected scientific articles.**

COURSE TITLE: Atomic physics lab		

COURSE TEACHER/TEACHERS: Prof. Damir Veža

STUDY PROGRAMME: University study of reseyrch physics

YEAR OF STUDY: 5th

SEMESTER: 9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		
Exercises		
Seminars		
Lab	4	Teacher and assistant

ECTS credits: 14

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Acquiring experimental skills in AMO Physics and atomic spectroscopy

DESCRIPTION OF THE COURSE:

1. UV-Spectrograph with quartz prism: analysis of atomic spectra in UV.
2. Comparator and densitometer: principles of identifications of atomic lines.
3. Grating monochromator: analysis of atomic lines of complex atoms.
4. Ge-detector: analysis of characteristic X-ray spectra.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lab exercises

METHODS TO EVALUATE STUDENT PERFORMANCE: Regular oral exams and homeworks

EXAMINATION METHODS: Evaluation of homeworks, exam at the end of the semester

COURSE(s) NEEDED FOR THIS COURSE: Atomic and molecular physics

COMPULSORY LITERATURE:

 W. Demtoroeder, *Laser Spectroscopy*, Springer-Verlag, Berlin,1996.

ADDITIONAL READING:

A.P.Thorne, U. Litzen, S, Johansson, *Spectrophysics*, Springer Verlag, Berlin 1999.C. W. Bradley,O. A. Dale, *An introduction to modern stellar astrophysics*, Addison-Wesley, 1996.

COURSE TITLE: Gravity and cosmology		
COURSE TEACHER/TEACHERS: Professor Dr. Silvio Pallua		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: fifth		
SEMESTER: ninth		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		
ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The aim of the course is to get the understanding of basics of general theory of relativity illustrated on examples in atrophysics and cosmology.

DESCRIPTION OF THE COURSE:

-Basic principles of general theory of relativity.

-Tensors.

-Motion of particles in gravitational field.

-Newtonian limit.Gravitational redshift.

-Einstein equation.

-Schwarschild metric.

-Black holes.

-Robertson-Walker metric and application to cosmology.

STUDENT OBLIGATIONS DURING THE COURSE: following lectures and active presence on exercises with own presentations

METHODS TO EVALUATE STUDENT PERFORMANCE: Presentation of a written essay on a given topic,written examination,oral examination.

EXAMINATION METHODS:Evaluation includes results of written essay,written examination and oral examination

COURSE(s) NEEDED FOR THIS COURSE:Classical mechanics(second year),Classical electrodynamics(Third year)

COMPULSORY LITERATURE:-Ray d'Inverno,Introducing Einstein relativity,Oxford University Press 1992

-J B Hartle,An introduction to Einstein s General Relativity,Addison Wesley,2003

ADDITIONAL READING:

-R.Adsler,M.Bazin,M.Schiffer,An introduction in general relativity,Mc Graw Hill Kogakusha,Ltd Tokyo 1975

-L.D.Landau,E.M.Lifshitz,The classical theory of fields,Pergamon Press 1994

-S Weinber,1984,General relativity,University of Chicago Press

COURSE TITLE: Theory of Fields II

COURSE TEACHER/TEACHERS: Prof. Amon Ilakovac

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5th

SEMESTER: 9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	**Teacher**
Exercises	1	Assistant
Seminars	0	

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:
Students are familiarized with functionan methods of the field theory, notion of the renormalization group, basic techiques of renormalization of non-Abelian theory, anomalies (through examples) and operator product expansion (through examples).

DESCRIPTION OF THE COURSE:
1. Functional methods: A. Functional methods in Quantum mechanics, B. Quantization of a scalar field,
2. C. Conection between quantum field theory and statisticam mechanics, D. Quantization of electromagnetic field,
3. E. Quantization of spinor fields,
4. F. Functional methods and symmetries
5. Renormalization group: A. Wilson's approach to renormalization theory,
6. B. Callan-Symanzik equation (CSE); C. Evolution of coupling constants: QED as an example,
7. Non-Abelian gauge theories: A. Geometry of gauge invariance, B. Yang-Mills Lagrangian,
8. C. Invaririance of the Wilson loop to gauge transformations, D. Basic facts about Lie algebras,
9. Quantization of non-Abelian gauge theories: Interactions of non-Abelian gauge bosons,
   B. Fadeev-Popov Lagrangian,
10. C. Ghosts and unitarity, D. BRST symmetry,
11. E. Divergencies of non-Abelian gauge bosons on the one loop level, F. Asymptotic freedom,
12. Theory of anomalies on perturbative level :examples,
13. Operator products and effective vertices : examples

STUDENT OBLIGATIONS DURING THE COURSE: Solving homework problems.
METHODS TO EVALUATE STUDENT PERFORMANCE: Solutions of homewor problems
EXAMINATION METHODS: written and oral examination
COURSE(s) NEEDED FOR THIS COURSE: Reativistic Quantum Fields, Quantum Theory of fields I

COMPULSORY LITERATURE:
M.E. Peskina, D.E. Schroeder, An Introduction tu Quantum Field Theory, Addison Wesley, 1995
ADDITIONAL READING:
S. Weinberg, The Quantum Theory of Fields I, Cambridge, 1995
S. Weinberg, The Quantum Theory of Fields II, Acmbridge, 1996

COURSE TITLE:	**Topology in physics**

COURSE TEACHER/TEACHERS:	**Prof.dr.Marijan Mileković**

STUDY PROGRAMME:	**University study of research physics**

YEAR OF STUDY:	**5**

SEMESTER:	**9**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		
Laboratory		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The aim of the course is to provide students with topological tools which have applications in modern physics.

DESCRIPTION OF THE COURSE:

Metric and topological spaces.Manifolds.An introduction and basic concepts.

Fundamental group.Homotopy.Homotopy groups.

Homology.Homology groups.

Cohomology and de Rham cohomolgy.

Fibers and connections.Vector bundles and connections.Fiber bundles and connections.

Applications in physics.Topological stable defects.Dirac monopoles and string.t'Hoft-Polyakov monopoles.Nielsen-Olesen-Abrikosov vortex.Solitons and instantons.Topological setting of Yang-Mills gauge theories.

STUDENT OBLIGATIONS DURING THE COURSE: **Students should attend lectures and excersises regulary.There are 2 homeworks in semester.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Regular attendance of lectures and excersises.**

EXAMINATION METHODS: **Written and oral exams.Students which collect 50% points from homeworks have oral exam only.**

COURSE(s) NEEDED FOR THIS COURSE: **Course 'Differential geometry in physics' is reccommended.**

COMPULSORY LITERATURE:

C.Nash and S.Sen:'Topology and Geometry for Physicists' (Academic Press,1983).

A.S.Schwartz:'Topology for Physicists' (Springer Verlag,1996).

ADDITIONAL READING: **A.S.Schwartz:'Quantum Field Theory and Toplogy' (Springer Verlag,1993).**

T.Frankel:'The Geometry of Physics:an introduction' (Cambridge University Press,edition 2001).

COURSE TITLE:	Introduction in supersymmetries

COURSE TEACHER/TEACHERS:	Prof.dr.Marijan Mileković

STUDY PROGRAMME:	University study of research physics

YEAR OF STUDY:	5

SEMESTER:	9

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		teacher
Exercises		assistent
Seminars		
Laboratory		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: To provide students with basic concepts of supersymmetry and its application in particle physics.

DESCRIPTION OF THE COURSE:

Spinors and the Poincare' group.Two-component and four-component spinors.Irreducible representations of the Poincare' group.

Motivations for the supersymmetry.SUSY algebra and its representations.The example of SUSY quantum mechanics.

Superspace and superfields.N=1 superspace. Chiral superfields. Vector superfields.SUSY-invariant action.

SUSY gauge theories.N=1 SUSY gauge theory without/with matter.

The spontaneous breaking of the supersymmetry.The Goldstone theorem.Symmetry breaking mechanism (O'Raifeartaigh and Fayet-Iliopoulos mechanism) and mass formulae.The Witten index.

Supersymmetric models and Grand Unified Theories (SUSY GUT's).SUSY QCD.SUSY SU(5) model and (super)Higgs mechanism.

Perspectives.Experimental search for supersymmetric particles.The concept of local supersymmetry (N=1 supergravity).N=2 supersymmetry.Supersymmetry in higher dimensions.

STUDENT OBLIGATIONS DURING THE COURSE: Students should attend

lectures and excersises regulary.There are 2 homeworks in semester and 1 project in semester.

METHODS TO EVALUATE STUDENT PERFORMANCE: Regular attendance to lectures and excersises + project.

EXAMINATION METHODS: Written and oral exams.Students which collect 50% points from homeworks have the oral exam only.

COURSE(s) NEEDED FOR THIS COURSE: Field theory 1.

 (Field theory 2 is recommended.)

COMPULSORY LITERATURE: S.Weinberg:'Quantum Theory of Fields III:Supersymmetry' (Cambridge University Press,2000).

G.G.Ross:'Grand Unified Theories' (Benjamin/Cummings,1984).

ADDITIONAL READING: P.P.Srivastava:'Supersymmetry,superfields and supergravity:an introduction' (Adam Hilger,1986).

Internet archive: <http://xxx.lanl.gov>

COURSE TITLE:	Flavour Physics and CP Violation

COURSE TEACHER/TEACHERS:	Prof. Ivica Picek

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY:	5th

SEMESTER:	9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	teacher
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: introduction to the research by developing a skill of attacking (formulating and solving) the problem

DESCRIPTION OF THE COURSE:

1. **CP violation in the neutral-meson systems**
2. **CP violation via the electric dipole moments**
3. **CP violation beyond the Standard Model**
4. **System of neutral K mesons**
5. **Discrete symmetries and CP violation in the Standard Model**
6. **B-meson decays and CKM mixing angles**
7. **Massive neutrinos and PMNS mixing**
8. **CP i CPT violation in neutrino physics**

STUDENT OBLIGATIONS DURING THE COURSE: Participation in the activities of the course (solving the problems, ellaborating and exposing a given topic)

METHODS TO EVALUATE STUDENT PERFORMANCE: Participation in common projects

EXAMINATION METHODS: the activity in the course including the final exposition (seminar)

COURSE(s) NEEDED FOR THIS COURSE: Quantum physics, Elementary particle physics, Field theory

COMPULSORY LITERATURE:

G.C. Branco, L. Lavoura, J.P. Silva, CP VIOLATION,Clarendon Press, Oxford 1999

ADDITIONAL READING:

J.F. Donoghue, E. Golowich, B.R. Holstein, DYNAMICS OF THE STANDARD MODEL, University Press, 1992.

COURSE TITLE: Advanced topics in gravity		
COURSE TEACHER/TEACHERS: Prof.dr.sc.Silvio Pallua		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: fifth		
SEMESTER: ninth		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		
ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The aim of the course is to choose some advanced topics in gravity posssibly near to the student diploma thesis and develop students research skills.

DESCRIPTION OF THE COURSE:

Some of the topics:

-Gravitational waves.Projects LISA and LIGO.

-Sperically symmetric black holes.

-Rotating and charged black holes.

-Mechanics of black holes.

-Thermodynamics of black holes.

-Hawking radiation.

-Some aspects and problems of quantum gravity.

Quantum cosmology.Hartle Hawking vacuum.

-Brane cosmology.

STUDENT OBLIGATIONS DURING THE COURSE: Seminars when possible connected to the thesis

METHODS TO EVALUATE STUDENT PERFORMANCE: Performance on the seminar and connected work for the thesis if related to the course

EXAMINATION METHODS:Evaluation of the seminar plus a combination of written and oral examination

COURSE(s) NEEDED FOR THIS COURSE:Classical electrodynamics,Classical mechanics Statistical Physics,Quantum physics,Elementary particles physics.Field theory I.

One should in paralel follow the more elementary course: Gravity and Cosmology

COMPULSORY LITERATURA

-R.Wald(1984),General Relativity,University of Chicago Press

-V.P.Frolov,I.D.Novikov,Black hole physics,Basic concepts and new developments,kluwer Academic Publishers,1998

-P.K.Townsend,Black holes,gr-qc 9707012(lanl.arxiv.org-e Print)

ADDITIONAL READING:

-S.Hawking,Hawking on the Big Bang and Black holes,World Scientific 1993

-S.Cotsakis,E.Papantonopoulos,Cosmological crossroads,Springer 2001

-D.Langlois,Gravitation and cosmology in brane world,qr-qc/04010129(lanl.arxiv.org-e Print)

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COURSE TITLE:	Physics Beyond the Standard Model

COURSE TEACHER/TEACHERS:	Prof. Ivica Picek

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY:	5th

SEMESTER:	9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	teacher
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: introduction to the research by developing a skill of attacking (formulating and solving) the problem

DESCRIPTION OF THE COURSE:

1. **Precision test of electroweak radiation corrections**
2. **Global symmetries of the Stand Model**
3. **Chiral and custodial symmetries**
4. **Electroweak operators of higher dimensions**
5. **Weyl, Majorana and Dirac spinors**
6. **Massive neutrinos**
7. **Higgs sector**
8. **Supersymmetry**

STUDENT OBLIGATIONS DURING THE COURSE: Participation in the activities of the course
 (solving the problems, ellaborating and exposing a given topic)

METHODS TO EVALUATE STUDENT PERFORMANCE: Participation in common projects

EXAMINATION METHODS: the activity in the course including a final exposition (seminar)

COURSE(s) NEEDED FOR THIS COURSE: Quantum physics, Elementary particle physics, Field theory

COMPULSORY LITERATURE: `P. Ramond,JOURNEYS BEYOND THE STANDARD MODEL, Perseus Books, Cambridge, Massachusetts, 1999`

ADDITIONAL READING: **T. Morii, C.S. Lim, S.N. Mukherjee,** `THE PHYSICS OF THE STANDARD MODEL AND BEYOND, World Scientific, 2004.`

COURSE TITLE: **Nuclear Structure**

COURSE TEACHER/TEACHERS: **Prof. dr. sc. Dario Vretenar**

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: **5th**

SEMESTER: **9th**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **This intermediate level course will introduce the basic concepts and methods of theoretical nuclear structure. It follows the 4th year course in Nuclear Physics, and serves as an introduction to more specialized courses taught in the Ph.D. program. The emphasis is on physical concepts that underlie modern nuclear structure models. The course includes the necessary mathematical techniques, gives an overview of modern low-energy nuclear physics, and prepares the student for the master thesis.**

DESCRIPTION OF THE COURSE:

1. **Nuclear forces**
2. **The Shell Model**
3. **Rotation and single-particle motion**
4. **The Hartree-Fock method in nuclei**
5. **Pairing correlations in nuclei: the Hartree-Fock-Bogoliubov theory**
6. **Harmonic vibrations**
7. **Self-consistent mean-field approaches and configuration mixing**
8. **Restoration of broken symmetries**
9. **Algebraic nuclear structure models**

STUDENT OBLIGATIONS DURING THE COURSE: **homework assignments**

METHODS TO EVALUATE STUDENT PERFORMANCE: **homework problems will be graded, written and oral final examination.**

EXAMINATION METHODS: **Students will have a choice between: a) standard written and**

oral exam, or b) a project (investigating and reporting on a problem in nuclear structure) together with a final test at the end of the semester.

COURSE(s) NEEDED FOR THIS COURSE:**Nuclear Physics, Quantum Physics of Finite Systems**

COMPULSORY LITERATURE: **Peter Ring, Peter Schuck, The Nuclear Many-Body Problem, Springer Verlag , 2000**

ADDITIONAL READING: **Kris Heyde, The Nuclear Shell Model,Springer-Verlag , 1990**

Walter Greiner, **Joachim A. Maruhn**, **Nuclear Models, Springer-Verlag,1996**

COURSE TITLE: **Structure of the Nucleons**
COURSE TEACHER/TEACHERS: **Prof. Dr. Sc. Damir Bosnar**
STUDY PROGRAMME: **University study of research physics**
YEAR OF STUDY: **5.**
SEMESTER: **9.**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		

ECTS credits: 7
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Knowledge of the proton and neutron structure as the building blocks of atomic nucleus and acquiring basics for the investigations of nuclear structures and properties.**
DESCRIPTION OF THE COURSE: **Quark-gluon structure of the nucleons. Strong interactions, electro-weak interactions. Electromagnetic-structure of the nucleons: elastic electron scattering, inelastic electron scattering. Investigations of structure of nucleons using weak probes. Deep inelastic scattering. Properties of the nucleons from the QCD perspective and chiral symmetry. Many-body systems with strong interactions.**
STUDENT OBLIGATIONS DURING THE COURSE: **Student project and seminar connected with the selected experiment in the subatomic physics.**
METHODS TO EVALUATE STUDENT PERFORMANCE: **Participations at lectures and execution of given assignments.**
EXAMINATION METHODS: **Individual student project and seminar.**
COURSE(s) NEEDED FOR THIS COURSE: **Quantum Physics.**
COMPULSORY LITERATURE: **1) A.W. Thomas, W. Weise: The Structure of the Nucleon, Wiley-VCH, 2001.** **2) B.Povh, K. Rith, Ch. Scholz, F. Zetsche: Particles and Nuclei – An Introduction to Physical Concepts, Springer, 2005.**
ADDITIONAL READING: **Selected scientific articles.**

COURSE TITLE: **Nuclear Astrophysics**

COURSE TEACHER/TEACHERS: **Prof. dr. sc. Dario Vretenar**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **5th**

SEMESTER: **9th**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **This intermediate level course will introduce the basic concepts and methods of theoretical nuclear astrophysics. The emphasis is on those elements of astrophysics in which nuclear physics plays an important role: nuclear reactions in stars, nucleosynthesis, explosive processes, neutron stars, etc. The course introduces theoretical methods, presents an overview of a very active field of research in astrophyics, and prepares the student for the master thesis.**

DESCRIPTION OF THE COURSE: 1. **Element abundances and primordial nucleosynthesis** 2. **Cosmology: baryons, cosmic microwave background, dark matter** 3. **Nuclear reactions in stars (hydrogen burning, pp-chains, CNO-cycles, helium, carbon and oxygen burning)** 4. **Solar neutrinos** 5. **Core-collapse supernovae** 6. **Nova and supernova nucleosynthesis (s-process, r-process, rp-process)** 7. **Neutron stars** 8. Cosmic rays

STUDENT OBLIGATIONS DURING THE COURSE: **homework assignments**

METHODS TO EVALUATE STUDENT PERFORMANCE: **homework problems will be graded, written and oral final examination.**

EXAMINATION METHODS: **Students will have a choice between: a) standard written and oral exam, or b) a project (investigating and reporting on a problem in astrophysics) together with a final test at the end of the semester.**

COURSE(s) NEEDED FOR THIS COURSE:**Nuclear Physics, Particle Physics**
COMPULSORY LITERATURE: Rudolf Kippenhahn, A. Weigert, R. Kippenhah, Stellar Structure and Evolution, Springer-Verlag, 1994
ADDITIONAL READING: T. Padmanabhan, Theoretical Astrophysics: Volume 1: Astrophysical Processes, Cambridge University Press, 2000 Malcolm S. Longair, High Energy Astrophysics, Cambridge University Press, 1992

COURSE TITLE: Galaxies

COURSE TEACHER/TEACHERS: Prof. Krešimir Pavlovski

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5

SEMESTER: 9

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	assistant

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Introduction to understanding structure, evolution and formation of galaxies in the Universe. Introduction to an observational cosmology as quantitative science.

DESCRIPTION OF THE COURSE: 1) Summary on the strucutre and evolution of stars, and empriical stellar data, 2) Structure and rotation of Milky Way galaxy, 3) Stellar kinematics (epicyclic orbits, Boltzmann colission-less equation), 4) Globular clusters, 5) Morphological classification of galaxies, 6) Spiral galaxies, 7) Elliptical galaxies, 8) Local Group of galaxies, 9) Cluster of galaxies, and large-scale strucutre of the Universe, 10) Active galactic nuclei, quasars, the first galaxies, 11) Formation of galaxies, 12) Interaction of galaxies, mergers, 13) Chemical evolution of galaxies, 14) Cosmic Distance ladder, 15) Observational cosmology, expansion of the Universe

STUDENT OBLIGATIONS DURING THE COURSE: seminar paper

METHODS TO EVALUATE STUDENT PERFORMANCE: seminar paper

EXAMINATION METHODS: written and oral

COURSE(s) NEEDED FOR THIS COURSE: none

COMPULSORY LITERATURE: L. S. Sparke & J. S. Gallagher, Galaxies in the Universe, Cambridge University Press, Cambridge, 2000

ADDITIONAL READING: J. Binney & M. Merrifield, Galactic Astronomy, Princeton Series in Astrophysics, Princeton University Press, Princeton, 1998

COURSE TITLE:	Physics of Hadrons

COURSE TEACHER/TEACHERS: Prof. dr. sc. Dubravko Klabučar

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5.

SEMESTER: 9.

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher, assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Mastering the basic concepts and facts of hadronic phenomenology, of QCD and quark substructure of hadrons.

DESCRIPTION OF THE COURSE:

- ೞ Overview of hadronic phenomenology (spectroscopy and processes, electromagnetic structure of nucleons ...), the motivation for quark substructure of hadrons.

- ೞ Elements of QCD (perturbative and non-perturbative).

- ೞ Chiral symmetry and its breaking.

- ೞ Constituent quarks.

- ೞ Models of hadrons (baryons and mesons).

- ೞ Relativistic bound state equations.

- ೞ Some quark bound states and their processes.

STUDENT OBLIGATIONS DURING THE COURSE: Handing in at least a minimial number of homeworks (besides attendance).

METHODS TO EVALUATE STUDENT PERFORMANCE: Grading homeworks, quiz-tests, final examinations.

EXAMINATION METHODS: Written (which can be accomplished also by accumulating sufficient number of points on homeworks and quiz-tests) and oral.

COURSE(s) NEEDED FOR THIS COURSE: Quantum Mechanics, Relativistic Quantum Physics, mathematical courses.

COMPULSORY LITERATURE:

- U. Mosel: "Fields, Symmetries and Quarks" (Second, Revised and Enlarged Edition), Springer-Verlag Berlin, Heidelberg 1999.

- A. Hosaka, H. Toki, "Quarks, Baryons and Chiral Symmetry", World Scientific Publishing Company, Singapore 2001.

- B. Povh, K. Rith, C. Scholz, F. Zersche, "Particles and Nuclei: An Introduction to the Physical Concepts", Springer-Verlag Berlin, Heidelberg, 3rd edition 2002.

ADDITIONAL READING:

ᴔ M. D. Scadron: "Advanced Quantum Theory and its Applications Through Feynman Diagrams" (Second Edition, Texts and Monographs in Physics), Springer-Verlag Berlin, Heidelberg 1991.

ᴔ C. D. Roberts: "Nonperturbative QCD with modern tools", available in e-Print Archive as nucl-th/9807026 and published in Proceedings of the 11th Physics Summer School: Frontiers in Nuclear Physics, edited by S. Kuyucak (World Scientific, Singapore, 1999).

COURSE TITLE: **Experimental Techniques in Subatomic Physics**

COURSE TEACHER/TEACHERS: **Prof. Dr. Sc. Damir Bosnar**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **5.**

SEMESTER: **9.**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises	**1**	**assistant**
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Knowledge of principles of detectors operations and knowledge of methods and techniques used in measurements in nuclear and particle physics. Applications of these methods and techniques in other fields.**

DESCRIPTION OF THE COURSE: **Interaction of radiation with matter. Ionization detectors. Semiconductor detectors. CCD. Detectors with noble gases. Cherenkov detectors. Signals and electronics for signal processing. Data acquisition. Specific measurements: position of the particles, time measurements, measurements of energy and momentum, particle identification. Measurements with the specific detector systems. Biological effects of radiation and radiation protection. Applications of nuclear methods and techniques in other fields.**

STUDENT OBLIGATIONS DURING THE COURSE: **Student project and seminar connected with the selected experiment in the subatomic physics.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Participations at lectures and execution of given assignments.**

EXAMINATION METHODS:**Individual student project and seminar.**

COURSE(s) NEEDED FOR THIS COURSE:**Nuclear Physics. Particle Physics.**

COMPULSORY LITERATURE:
1) G.F. Knoll: Radiation Detection and Measurement, Wiley, 1999.
2) K. Kleinknecht: Detectors for Particle Radiation, Cambridge University Press, 1998.

ADDITIONAL READING: **Selected scientific articles.**

COURSE TITLE: **Reactor Physics**

COURSE TEACHER/TEACHERS: **Prof. Dr. Sc. Damir Bosnar**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **5.**

SEMESTER: **9.**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	**2**	**teacher**
Exercises		
Seminars	1	**assistant**

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Knowledge of principles of controlled nuclear fission chain reaction and reactor operation.**

DESCRIPTION OF THE COURSE: **Energy gain in the nuclear fission. Nuclear fission chain reaction. Neutron diffusion. Neutron moderation. Reactor criticality. Reactor kinetics. Nuclear fuel and burn-up. Radiation protection and shielding. Reactor safety.**

STUDENT OBLIGATIONS DURING THE COURSE: **Participations at the lectures and execution of given assignments.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Evaluation of assignments.**

EXAMINATION METHODS: **Written and oral exam.**

COURSE(s) NEEDED FOR THIS COURSE: **General Physics. Mathematical Methods in Physics.**

COMPULSORY LITERATURE: *W.M.Stacey: Nuclear Reactor Physics, Wiley-Interscience, 2001.*

ADDITIONAL READING: **J.L. Lamarsh, A.J. Baratta: Introduction to Nuclear Engineering,Prentice Hall, 2001.**

COURSE TITLE: Quantum fluids		
COURSE TEACHER/TEACHERS: Prof. dr. sc. Denis Sunko		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 5		
SEMESTER: 9		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		
ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: **Acquiring the descriptions of some macroscopic quantum states, which are generally accepted.**

DESCRIPTION OF THE COURSE:

1. **Reasons for the appearance of macroscopic quantum states.**
2. **The phenomenology of ^{4}He.**
3. **Variational description of ^{4}He. Phonons and rotons.**
4. **Superfluid ^{3}He. Leggett's description.**
5. **Bose-Einstein condensation of heavy-atom gases.**
6. **Plasmas.**
7. **Phenomenology of type I and II superconductivity.**
8. **London's description of the diamagnetic response of a superconductor.**
9. **Order parameter of a superconductor and the macroscopic description of Landau and Ginzburg.**
10. **Instability of the Fermi sea to perturbation by a weak attractive force.**
11. **BCS description at the level of the variational wave function.**

STUDENT OBLIGATIONS DURING THE COURSE: Homework assignments of limited extent, each concentrating on one actually observed phenomenon.

METHODS TO EVALUATE STUDENT PERFORMANCE: Assesment of homework during the course, examination at the end.

EXAMINATION METHODS:Written and oral part, written part should be passed to proceed to

oral. Homework may contribute to the final grade.

COURSE(s) NEEDED FOR THIS COURSE:Statistical physics, classical electrodynamics, quantum mechanics, solid state physics.

COMPULSORY LITERATURE:

J. F. Annett, Superconductivity, Superfluids and Condensates (Oxford Master Series in Physics), Oxford University Press 2004, ISBN 0198507569.

ADDITIONAL READING: Selected chapters from:

I.M. Khalatnikov and P.C. Hohenberg (translator), Introduction to the Theory of Superfluidity (Advanced Books Classics), Perseus Publishing 1989, ISBN 020109505X.

M. Tinkham, Introduction to Superconductivity vol. I, Dover 2004, ISBN 0486435032.

P.-G. de Gennes, Superconductivity of Metals and Alloys (Frontiers in Physics), Perseus Publishing 1995, ISBN 0201408422.

COURSE TITLE: Surface structures

COURSE TEACHER/TEACHERS: Prof. dr. sc. M. Šunjić

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5th

SEMESTER: 9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	assistant
Seminars		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Basic concepts in the physics of surfaces, structure and electronic properties,experimental (especially spectroscopic and STM) and theoretical methods, and some specific physical phenomena.

DESCRIPTION OF THE COURSE:

1) Basic concepts, modifications at the phase boundary
2) Symmetry of the surface, nets, ideal and real surfaces
3) Experimental methods – elastic processes, LEED
4) Experimental methods – inelastic transitions (EELS, photoemission, EXAFS)
5) Tunneling, STM, STS
6) Metal surfaces – local density of states
7) Metal surfaces – potentials
8) Semiconductor and insulator surfaces, surface states
9) Image potential states, quantum well states
10) Excitaitons at crystal surfaces, dielectric approach
11) Surface polaritons
12) Adsorbates: types and mechanisms of adsorption

STUDENT OBLIGATIONS DURING THE COURSE: Homework; small projects submitted and orally presented.

METHODS TO EVALUATE STUDENT PERFORMANCE: Homework delivered regularly, successful project presentation.

EXAMINATION METHODS: Delivery and presentation of projects, and final oral exam.

COURSE(s) NEEDED FOR THIS COURSE: Advanced quantum physics, Condensed matter physics I and II

COMPULSORY LITERATURE:

1. A. Zangwill, *Physics of Surfaces*, Cambridge University Press, 1988
2. M. Šunjić, *Surface Elementary Excitations*, in *Dynamics of Gas-Surfaace Interactions*, Springer Series in Chemical Physics, Vol. 21., G. Benedek, U. Valbusa, eds., 1982

ADDITIONAL READING:

3   N.W. Aschroft, N. D. Mermin, *Solid State Physics,* Holt, Rinehart and Winston,   1976.
3. C. Kittel, *Introduction to Solid State Physics*, Willey & Sons
4. C. Kittel, *Quantum Theory of Solids;* Willey & Sons, 1953
5. A. Prutton, ed. *Electronic Properties of Surfaces*, Adam Hilger, Bristol, 1984
6. E.L. Wolf, *Principles of Electron Tunneling Spectroscopy,* Oxford University Press, 1989
7. D.P. Woodruff, T. A. Delchar, *Modern techniques of surface science*, Cambridge University Press, 1985

COURSE TITLE: Low temperature physics and superconductivity		

COURSE TEACHER/TEACHERS: Prof. dr. Amir Hamzić		

STUDY PROGRAMME: University study of research physics		

YEAR OF STUDY: 5		

SEMESTER: 9		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	1	teacher
Seminars		

ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Knowledge of the techniques for the production of low temperatures, unique properties of helium (superfluidity) and basic characteristics and applications of superconductivity

DESCRIPTION OF THE COURSE:
Liquefying principles, helium and nitrogen liquefiers;
Work with cryogenic liquids (cryostats, thermal losses);
Low temperature thermometry,
Properties of He^4 and He^3 (superfluidity);
Temperatures below 1 K (He^3 cryostat, He^3- He^4 dilution cryostat);
Superconductivity (basic properties – ideal conductivity and Meissner effect);
Characteristics of low- and high-temperature superconductors;
London theory, thermodynamical properties;
Main results of Ginzburg-Landau i Bardeen-Cooper-Schrieffer models;
Large- and small-scale application of classic and high-temperature superconductivity (research, industry, medicine, power, transport).

STUDENT OBLIGATIONS DURING THE COURSE: (written and exposed) reports on given subjects, active participation in the low-temperature laboratory

METHODS TO EVALUATE STUDENT PERFORMANCE: submitted reports

EXAMINATION METHODS: oral exam

COURSE(s) NEEDED FOR THIS COURSE: solid state physics, statistical physics

COMPULSORY LITERATURE:
D. Tilley, J. Tilley, Superfluidity and Superconductivity, IOP Publishing Ltd., 1990.
M. Cyrot, D. Pavuna: Introduction To Superconductivity and High Tc Materials,
World Scientific Publishing Co., Singapore, 1992.

ADDITIONAL READING:

COURSE TITLE:	**MODERN METHODS OF ELECTRON MICROSCOPY**

COURSE TEACHER/TEACHERS: **Professor Anđelka Tonejc**

STUDY PROGRAMME: **University study of research physics**

YEAR OF STUDY: **5th year course**

SEMESTER: **9 th**

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures		teacher
Exercises		teacher and assistent
Seminars		teacher

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: The course gives an overwiev of the modern methods of the electron microscopy used in order to examine and determine the fine structure of materials. The course would be wellcome to the students that will work in an electron microscopy laboratory after graduation.

DESCRIPTION OF THE COURSE:
 Fundamentals of electron microscopy.
Application of electron microscopy and electron diffraction in materials science, chemistry and geology.
The modern methods of examination of materials in an electron microscope:
Scanning electron microscope (SEM), SEM for enviromental examination (ESEM),
of materials by energy dispersive X-ray analyses (X-ray mapping), Transmission electron microscopy and selected area electron diffraction (TEM and SAED), High resolution electron microscopy (HRTEM), Convergent beam electron diffraction (CBED).
The interpretation of the TEM images and diffraction of the polycrystalline, monocrystalline and amorphous samples.
The diffraction contrast . The characterisation the defects in the material. The determination of Burgers vector of the dislocation and type of dislocation. Characterisation of stacking faults, tweens and antiphase boundaries using bright and dark field images.
The phase contrast. The high resolution imaging. Observation of different type of defects in high resolution mode (HRTEM) and Z- contrast imaging with the resolution beyond 0.1 nm.
The crystallographic image processing of high resolution images in order to determine the lattice deformation, dislocations, the lattice parameter , stacking faults, grain and phase boundaries. The structural resolution from 0.2 to 0.1 nm.
CBED is used for space group determination, the lattice parameter of examined crystal, thickness of the crystall examined in EM.
The latest discoveries in electro microscopy will be given: observation of oxigen positions and bonds in cuprite; atomic –scale imaging of individual dopant atoms and clusters in bulk silicon.

Examination of nanocrystalline materials.
The structure factor determination from HRTEM images and electron diffraction (ED). The application of Rietveld method to the images of nanocrystalline materials. The grain size, microstrain and unit cell parameters of nanocrystalline samples. The comparison of ED, X-ray and neutron diffraction .
Exercises: Practical work in EM laboratory; the evaluation of TEM, HRTEM and ED images. The practical presentation of the methods working in the JEOL 200 kV EM. The HRTEM image processing analyses of some images and ED.

STUDENT OBLIGATIONS DURING THE COURSE: Course attendance is controlled. The students receive the topics for written seminars and oral presentation. The results of the seminars will be included into the final note. The students will be given practical work in EM laboratory: the preparation of the samples for EM observation and practical review of the methods of high resolution microscopy will be given.

METHODS TO EVALUATE STUDENT PERFORMANCE: The presence to the lectures will be controlled. The students should be present at seminars, work in computer laboratory in order to learn how to evaluate microstructural parameters from ED scans and HRTEM digitised images.

EXAMINATION METHODS: Oral presentation of seminars in power-point presentation.

COURSE(s) NEEDED FOR THIS COURSE: The 3rd and 4th year courses. Solid State Physics.

COMPULSORY LITERATURE:
1. **M. Ruhle and M. Wilkens, Electron Microscopy , in R.W. Cahn and P. Haasen, eds. Physical Metallurgy; fourth, revised edition, Elsevier Science BV, 1996.**

2. **D.B. Williams and C.B. Carter, Transmission Electron Microscopy, A Textbook for Materials Science, Plenum Press, New York 1996.**

3. **J.J. Goldstein, D.E. Newbury, P. Echlin, D.C. Joy , C. Fiori, E. Lihshin, Electron Microscopy and X- ray Microanalysis, Plenum Press, New York / London, 1984.**

ADDITIONAL READING:
1. **ELECTRON CRYSTALLOGRAPHY, Novel Approaches for Structure Determination of Nanosized Materials, the 36th International Crystallographic Course, Erice-Sicily, 9 to 20 June 2004. eds. T.E. Weirich, J. Labar and X.D. Zou,** *Nato ASI Series C,* **Kluwer Academic Publishers, Dordrecht, (2004), in press.**

2. **J. C. H. Spence: High-Resolution Electro Microscopy, third edition,**
   Oxford University Press, 2003.

COURSE TITLE: Nanomaterial Physics

COURSE TEACHER/TEACHERS: professor dr. sc. Antun Tonejc

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5

SEMESTER: 9

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	teacher
Laboratory		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: To provide a students with basic concepts of physics of nanomaterials, using experimental facts and theoretical models.

DESCRIPTION OF THE COURSE:
1. Crystal structure of monocrystalls, polycrystalls, quasicrystalls, nanocrystalls and nanoglasses.
2. Point defects and dislocations
3. Diffusion in crystalline and i nanocrystalline materials
4. Physical methods for nanomaterials characterisation
5. Phase diagrams
6. Structure of metals, solid solutions, intermetallic compounds and glassy materials
7. Diffusive and nondiffusive phase transformations
8. Metastable state of materials
9. Metastable micro- and nanostructures
10. Mechanical properties of micro- and nanocrystalls
12. Magnetic properties of micro- and nanocrystalls
13. Nanotubes
13. Nanocrystalls as new materials for applications

STUDENT OBLIGATIONS DURING THE COURSE: **Students have to attend lectures and give one seminar of a selected topic (40 minutes long seminar). Students have to work out homeworks and colloquia.**

METHODS TO EVALUATE STUDENT PERFORMANCE: **Regulary attendence of**

lectures and exercises. Reasonable good presentation of the seminar.

EXAMINATION METHODS: no exam

COURSE(s) NEEDED FOR THIS COURSE: Solid State physics

COMPULSORY LITERATURE:
R. W. Cahn, P. Haasen, Physical Metallurgy, Vol. I-III, North-Holland, Amsterdam 1996.

J**. I. Gersten, F. W. Smith, The Physics and Chemistry of Materials, Yohn Wiley&Sons, New York, 2001**

ADDITIONAL READING:
 W. D. Callister, Materials Science and Engineering, Yohn Wiley&Sons, New York, 2003

A. R. West, Basic Solid State Chemistry, Yohn Wiley&Sons, New York, 1999

COURSE TITLE: PHYSICS OF SEMICONDUCTORS

COURSE TEACHER/TEACHERS: Professor Miroslav Požek

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: fifth

SEMESTER: ninth

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises	0	
Seminars	1	teacher

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Fundamentals of semiconductors physics and insight into current research on semiconductor physics in Croatia

DESCRIPTION OF THE COURSE:

Lectures: Elementary definition of semiconductors, historical overview, chemical approach. Zone theory of semiconductors. Intrinsic an extrinsic semiconductors. Origin and classification of defects. Controlled introduction of defects. Concentration of carriers in thermal equilibrium. Types of semiconductors and compensation. Scattering and transport properties. Electrical conductivity, thermoelectromotive force and Hall effect. Recombination. Optical properties. Absorption of radiationa and photoconductivity. Experimental determination of semiconducting parameters. Electrical and optical methods. Elemental semiconductors and semiconducting compounds. Crystal, amorphous and glassy semiconductors. Superlattices.

Seminar: Student visits one of the research groups and makes a seminar about actual research. The seminar is to be presented to other students.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance of lectures and seminars.

METHODS TO EVALUATE STUDENT PERFORMANCE: seminar

EXAMINATION METHODS: Oral exam.

COURSE(s) NEEDED FOR THIS COURSE:Quantum physics, statistical physics

COMPULSORY LITERATURE: B. Sapoval and C. Hermann, Physics of Semiconductors, Springer Verlag, New York, 1995.

ADDITIONAL READING: R.A. Smith, Semiconductors, 2nd Edition, Cambridge University Press, London, 1978.

COURSE TITLE: Magnetism and Magnetic Materials		
COURSE TEACHER/TEACHERS: Prof. dr.sc.Krešo Zadro,		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 5		
SEMESTER: 9		

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	teacher
Laboratory		

ECTS credits: 7
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:
DESCRIPTION OF THE COURSE: **Basic magnetostatics. Magnetization and magnetic materials. Methods of magnetic measurements. Origins of magnetic properties of materials. Diamagnetism. Paramagnetism. Ferromagnetism. Magnetic domains. Antiferromagnetism. Ferrimagnetism. Magnetic anisotropy. Nanomagnets. Applications of magnetic materials.**
STUDENT OBLIGATIONS DURING THE COURSE: lectures attendance
METHODS TO EVALUATE STUDENT PERFORMANCE: student projects
EXAMINATION METHODS: oral examination
COURSE(s) NEEDED FOR THIS COURSE: Solid State Physics
COMPULSORY LITERATURE: 1. **J. Crangle, Solid State Magnetism, Van Nostrand Reinhold, New York, 1991.**   2. **N. Spaladin, Magnetic Materials, Cambridge University Press, 2003.**
ADDITIONAL READING:

COURSE TITLE: Introduction in bioinformatic of the centromere of human genome		
PROGRAM AUTHOR: Professor dr. sc. Vladimir Paar		
NAZIV DIPLOMSKOG STUDIJA: University study of research physics		
YEAR OF STUDY: 5		
SEMESTER: 9		
TEACHING METHODS	**CONTACT HRS PER WEEK**	**DELIVERED BY** (*teacher or assistant*)
Lectures	2	**teacher**
Exercises		
Seminars	1	**assistant**
ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

Computer identification of repeats and higher order repeats and its structure for centromeric region of human genome in GenBank data; a preliminary insight into relevant actual theoretical literature.

DESCRIPTION OF THE COURSE:
Introduction to GenBank database, usage and analysis.
Automatic annotation of repetitive DNA using BLAST program.
Partial identification of HORs using RepeatMasker.
Complete identification of HORs using KeyStringAlgorithm and ColorHOR.
Analysis of repetitive and HOR structure and significant substructures using KSA algorithm.
Frequency based algorithm analysis.

STUDENT OBLIGATIONS DURING THE COURSE:

Lectures and seminars attendance, monitoring student's achievement via projects.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Lectures and seminars attendance, seminars and projects, are required for signature.

EXAMINATION METHODS:
Written and oral examinations plus project evaluation.

COURSE(s) NEEDED FOR THIS COURSE:

Classical mechanics. Quantum physics.

COMPULSORY LITERATURE:

ADDITIONAL READING:

S.A. Krawetz, D.D. Womble, Introduction to Bioinformatics ((Humana Press, Totowa, 2003)

http://repeatmasker.genome.washington.edu

G. Benson, Tandem Repeats Finder: a program to analyze DNA sequencesNucleic Acids Res.27, 573 (1999).

M. Rosandić, V. Paar, I. Basar, Key-string segmentation algorithm, J. Theor. Biol. 221, 29 (2003).

V. Paar, N. Pavin, M. Rosandić, M. Glunčić, I. Basar, R. Pezer, S. Durajlija Žinić, ColorHOR – novel graphical algorithm for fast scan of alpha satellite higher order repeats and HOR annotation for GenBank sequence of human genome, Bioinformatics, doi:10.1093/bioinformatics/bti072 (2005).

COURSE TITLE: Data Analysis and corelations in biology		

COURSE TITLE: Data Analysis and corelations in biology

PROGRAM AUTHOR: Professor Vladimir Paar, PMF

NAZIV DIPLOMSKOG STUDIJA: University study of research physics

YEAR OF STUDY: 5

SEMESTER: 9

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY *(teacher or assistant)*
Lectures	2	**teacher**
Exercises		
Seminars	1	**assistant**

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

Accomplishing skills and methods necessary for analysis nonlinear dynamics, fractal geometry and information theory, a preliminary insight into relevant actual theoretical literature.

DESCRIPTION OF THE COURSE:
Data analysis novel methods in theoretical physics and information theory
Data analysis on the specific examples in biology
Nonlinear time sequences
Fractal geometry methods in biology and other natural sciences
Analysis of data with space-time dynamics
Analysis of noise in biology
Deterministic chaos identification in biological and other natural objects

STUDENT OBLIGATIONS DURING THE COURSE:

Lectures and seminars attendance, monitoring student's achievement via preliminary exams, home works, seminars, projects.

METHODS TO EVALUATE STUDENT PERFORMANCE:

Lectures and seminars attendance is required for signature.

Preliminary exams are imperative condition for examination and have effect on grades.

EXAMINATION METHODS:

Written and oral examinations plus monitoring student's achievement via preliminary exams.

COURSE(s) NEEDED FOR THIS COURSE:

Classical mechanics. Quantum physics.

COMPULSORY LITERATURE:

ADDITIONAL READING:

H.O. Peitgen, H. Juergens, D. Saupe, Chaos and fractals (Springer, New York, 1993)

A. Bunde, S. Havlin (eds.) Fractals in Science (Springer, Berlin, 1995)

J.H. Brown, G.B. West, Scaling in biology (Oxford University Press, Oxford, 2000)

COURSE TITLE: Cell biophysics		
COURSE TEACHER/TEACHERS: Igor Weber, Marina Ilakovac Kveder		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 5th		
SEMESTER: IX		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	Lecturers
Exercises	-	
Seminars	-	
ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: To introduce a multidisciplinary approach to cell biology. Emphasis will be on physical principles and methods applied to cell research. Students will be introduced to a multidisciplinary research of biological systems and prepared for their future work in the laboratory.

DESCRIPTION OF THE COURSE:

1. Supramolecular structure of eukaryotic cells

2. Structure and function of the cytoskeleton

3. Viscoelastic properties of the cells

4. Biological molecular motors, cell motility

5. Biomembranes: why they appear and how to define their shapes

6. Phase transitions in biomembranes

7. Heterogeneity and asymmetry in the organization of basic building blocks

8. Liposomes

9. Transport through the membrane

10. Transport mechanisms in the cytoplasm

11. Molecular dynamics of biomembranes

12. Signaling pathways and information transfer in cells

STUDENT OBLIGATIONS DURING THE COURSE: To concieve and present a virtual research project.

METHODS TO EVALUATE STUDENT PERFORMANCE: Examination and colloquia.

EXAMINATION METHODS: Oral examination

COURSE(s) NEEDED FOR THIS COURSE: General biophysics (VII and VIII term)

COMPULSORY LITERATURE:

1. T. F. Weiss, Cellular Biophysics, 1996 MIT, ISBN 0-262-23184-0

2. B. Alberts i suradnici, Molecular Biology of the Cell, 4th edition, New York: Garland Publishing, 2002

ADDITIONAL READING:
1. Biochimica et Biophysica Acta - Biomembranes; Reviews of biomembrane. Elsevier

2. J. Howard, Mechanics of Motor Proteins and the Cytoskeleton, Sunderland MA: Sinauer Associates, 2001

3. D. Bray, Cell Movements, 2nd edition, New York: Garland Publishing, 2001

COURSE TITLE: Selected Topics of Theoretical Atomic physics

COURSE TEACHER/TEACHERS: Professor Amon Ilakovac

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5th

SEMESTER: 9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	Teacher
Exercises	1	Assistant
Seminars	0	

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:
Familiarization with the theory and methods of calculation of structore of many-electron atoms

DESCRIPTION OF THE COURSE:
13. One electron atoms: Relativistically induced interactions : LS coupling with external electromagnetic field, relativistic correction to kinetic energy, Hydrogen atom : ls and jj wave functions,
2. Static fields: A. Magnetic fields, B. Electic fields,
3. N-electron atoms : A. Slater's determinant; B. Hamiltonian : integrals in the two-particle-interaction approximation
૪ Variation methods; Hartree-Fock formulation : A. Hamiltonian, B. Self-consistent fields, filling the atomic shells,
૪ C. Hartee-Fock equations for general spin orbitals,
6. D. Integrodifferential form of the Hartee-Fock equations, E. Numerical procedures;
7. F. Application of Hartee-Fock equations on real physical problems,
8. Application of Hartee-Fock equations to physical problems,
૪ Multiplet wave functions: A. Terms and multiplet wave functions in LS representation, B. Procedure for finding terms for general valence configuration,
૪ C. Construction of multiplet wave functions,
૪ Matrix elements: A. Matrix elements for two electrons, B. Matrix elements for more than two elecrons,
૪ C. Eletrostatic matrix elements for many equivalent electrons. D. LS interaction of many electrons.
૪ E. Interaction of any-electron atom with static magnetic field. Hyperfine magnetic interaction for n-electron system.

STUDENT OBLIGATIONS DURING THE COURSE:
solving homeworks

METHODS TO EVALUATE STUDENT PERFORMANCE:
Correct solutions of homeworks

EXAMINATION METHODS:
oral and written examinations

COURSE(s) NEEDED FOR THIS COURSE: Quantum Mechanics, Classical Electrodynamics

COMPULSORY LITERATURE:
M. Weisbluth, atoms and moleculs, Stanford, Academic Press, New York 1978

ADDITIONAL READING:

COURSE TITLE: Experimental Methods of Atomic Physics		
COURSE TEACHER/TEACHERS: Dr. sc. Goran Pichler, research professor		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 5th		
SEMESTER: 9th		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	Dr. sc. Goran Pichler
Exercises		
Seminars	1	Dr. sc. Goran Pichler
ECTS credits: 7		
DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:		
DESCRIPTION OF THE COURSE: Energy structure of complex atoms and molecules. Methods of classical and laser spectroscopy. Femtosecond and attosecond lasers. Methods of atomic and molecular beams. Optical pumping and radio-frequency spectroscopy, interferometric optical methods and holographic interferometry. Coherent control with femtosecond lasers, applications. Cooling and trapping of ultra cold atoms and molecules, applications.		
STUDENT OBLIGATIONS DURING THE COURSE: Seminar with power point presentation, project task.		
METHODS TO EVALUATE STUDENT PERFORMANCE: Seminar with power point presentation		
EXAMINATION METHODS: Written preparation and then oral examination of the course chapters		
COURSE(s) NEEDED FOR THIS COURSE: Quantum Mechanics		
COMPULSORY LITERATURE: Demtroeder, Laser Spectroscopy, 3rd edition, Springer, Berlin, 2003. Young, Optics and Lasers, Springer, 5th edition, Berlin,2000. Budker, Kumball, DeMillel, Atomic Physics, Oxford University Press, 2004		
ADDITIONAL READING: Metcalf, van der Straten, Laser Cooling and Trapping, Springer, Berlin 1999. Diels, Rudolph, Ultrashort Pulse Phenomena, 2nd edition, Elsevier, 2005.		

COURSE TITLE: Selected topics of molecular physics		
COURSE TEACHER/TEACHERS: Dr. sc. Davor Kirin, Institut «Rudjer Bošković»		
STUDY PROGRAMME: University study of research physics		
YEAR OF STUDY: 5		
SEMESTER: 9		
TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	Teacher
Exercises	1	Assistant
Seminars		
ECTS credits: 7		

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS:

Introduction to the basic principles of molecular physics and molecular spectroscopy. Strong interconnection between experimental excersises and theoretical background, in order to get basic notions of molecular physics and spectroscopy. Develop the ability to understand molecular spectra and to relate them to physical and chemical properties of molecules.

DESCRIPTION OF THE COURSE:

Introduction to fundamental ideas related to molecular structure and molecular spectroscopy methods. Theoretical models for description of molecular rotational, vibrational and electronic energy levels of diatomic and polyatomic molecules. Extraction of relevant information from molecular spectra, i.e. Raman, infrared and electronic spectra. Examples of use of molecular spectroscopy in fundamental and applied reserch, as well as in industrial processes, quality control, environmental studies etc.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to practical laboratory work.
Use of Raman, infrared and related spectroscopic methods.

METHODS TO EVALUATE STUDENT PERFORMANCE: Evaluation of written essay (homework) on laboratory work, seminars.

EXAMINATION METHODS: Oral exam, seminars

COURSE(s) NEEDED FOR THIS COURSE: Quantum mechanics, classical electrodynamics

COMPULSORY LITERATURE: 1. C.N. Banwell, E.M. McCash: «Fundamentals of Molecular Spectroscopy», McGraw Hill 1994, ISBN: 0-07-707976-0.

2. Jack D. Graybeal: «Molecular Spectroscopy», McGraw Hill 1988, ISBN: 0-07-024391-3

3. P.W. Atkins**,** Molecular Quantum Mechanics, 2nd edition, Oxford University Press, Oxford (1982),

1. **ADDITIONAL READING:** Philip R. Bunker: «Molecular Symmetry and Spectroscopy», NRC Research Press, 1998, ISBN: 0660175193.
2. Gerald Burns: «Introduction to Group Theory with Applications (Materials Science and Technology)», Academic Press 1977, ISBN: 0121457508.

3. Godišnje obnovljena lista siteova na webu sa sadržajima vezanim uz molekulsku fiziku.

COURSE TITLE: Selected topics of Atomic spectroscopy

COURSE TEACHER/TEACHERS: Prof. Damir Veža

STUDY PROGRAMME: University study of research physics

YEAR OF STUDY: 5th

SEMESTER: 9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	teacher
Exercises		
Seminars	1	assistant
Lab		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Formulating and solving specific problems in AMO Physics

DESCRIPTION OF THE COURSE:

Lectures
A) Laboratory and astrophysical plasma diagnostics. Role of fundamental data in atomic physics.
B) Selected examples of advanced methods in classical spectroscopy: Fourier-transform spectroscopy, time resolved emission spectroscopy.
C) Selected examples of advanced methods in cw-laser spectroscopy: laser absorption atomic spectroscopy, wavelength modulation spectroscopy, opto-galvanic spectroscopy, «Doppler-free» spectroscopic methods.
Seminar:
Complementary material to lectures. Discussing practical problems in atomic and molecular physics.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lectures, homeworks

METHODS TO EVALUATE STUDENT PERFORMANCE: Homeworks and written exams

EXAMINATION METHODS: evaluation of homeworks and an exam at the end of the semester

COURSE(s) NEEDED FOR THIS COURSE: Quantum physics

COMPULSORY LITERATURE:
 W. Demtoroeder, Laser Spectroscopy, Springer-Verlag, Berlin,1996.

ADDITIONAL READING:

A.P.Thorne, U. Litzen, S, Johansson, *Spectrophysics***, Springer Verlag, Berlin 1999.C. W. Bradley,O. A. Dale,** *An introduction to modern stellar astrophysics***, Addison-Wesley, 1996.**

COURSE TITLE: Laser Physics

COURSE TEACHER/TEACHERS: Prof. A. Dulcic

STUDY PROGRAMME: Master of Physics

YEAR OF STUDY: 5th

SEMESTER: 9th

TEACHING METHODS	CONTACT HRS PER WEEK	DELIVERED BY (*teacher or assistant*)
Lectures	2	**teacher**
Exercises	1	**assistant**
Seminars		
Lab		

ECTS credits: 7

DEVELOPMENT OF GENERAL AND SPECIFIC COMPETENCIES – KNOWLEDGE AND SKILLS: Understanding elementary processes governing action of lasers

DESCRIPTION OF THE COURSE:

Classical radiation theory, population inversion and stimulated radiation. Radiation modes and frequncy coupling. Raman effect. Types of lasers. Laser applications: ultrastrong pulses, ultrashort pulses, nonlinear effects, holography.

STUDENT OBLIGATIONS DURING THE COURSE: Attendance to lectures

METHODS TO EVALUATE STUDENT PERFORMANCE: Regular oral exams and homeworks

EXAMINATION METHODS: Evaluation of homeworks, exam at the end of the semester

COURSE(s) NEEDED FOR THIS COURSE: Quantum physics

COMPULSORY LITERATURE:

 W E. M.Sargent,M.O.Sculli,W.E.Lamb, *Laser Physics,* **Addison Wesley, London 1974.**

ADDITIONAL READING:

J. Hecht, *Optics***, Addison Wesley, Reading (Massachusetts) 1998**