Undergraduate academic research program:

BACHELOR OF GEOPHYSICS

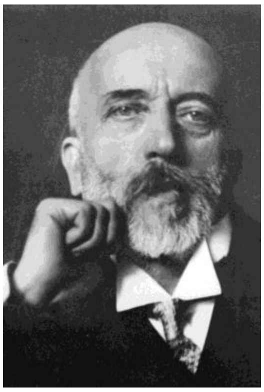
UNIVERSITY OF ZAGREB
FACULTY OF SCIENCE
DEPARTMENT OF GEOPHYSICS

Founded in 1861

Zagreb, January 2015

STUDY OF GEOPHYSICS

Geophysics at the University of Zagreb has a long tradition - it is being taught since 1898, at first at the Faculty of Philosophy of the University. The first lectures were on meteorology and climatology, and in 1910 *Andrija Mohorovičić* introduced lectures on seismology too. When in 1946 Faculty of Science separated from the Faculty of Philosophy, it also incorporated the Geophysical Institute (today within the Department of Geophysics of the Faculty). It is the only institution in Croatia providing academic education in fundamental geophysical disciplines – meteorology, oceanography, seismology, geomagnetism and aeronomy. Besides this, during the last almost 100 years, the affiliates of the Institute held basic geophysical courses at various other faculties in Croatia. Today such courses are offered to other departments of the Faculty, as well as to the Universities of Osijek and Split.



The curriculum is built on the fundamental physical and mathematical education that students acquire during their first two years of study at the Department of Physics of the Faculty of Science. In the course of time, the contents of subjects have constantly been upgraded following advancements and scientific development of particular geophysical disciplines.

The study of geophysics at the Faculty of Science takes three years, with the total of 180 ECTS credits. It ends with the exams in all courses included in the program and collecting 180 ECTS credits. The program itself is unique in that it insists on a relatively broad general geophysical education before specialization by individual professions. Thus, graduates of geophysics learn about the physical basis of geophysical disciplines that are nurtured in the Geophysical Institute, and skills needed for professional and technical work: conducting measurements, maintenance and calibration of instruments, data collection and their basic interpretation, routine analysis of geophysical series, data archiving and field work (e.g. macroseismic research).

The study of geophysics at the European and world-wide universities is organized in very different ways, and to find two universities where the study is organized in the same manner seems like an impossible task. This is the consequence of the specifics of geophysics, which is strongly linked to physics as well as to other geosciences, and of the fact that geophysics developed in different countries under strong influence of local circumstances and tradition. For instance, some countries with low seismicity do not offer seismological courses at the (pre)graduate level at all, or exists only at the doctoral level (Belgium, for example). Similar situation is also with oceanography which is the most developed in countries with a strong naval tradition. On the other hand, there are geophysical disciplines (like volcanology) that

are nonexistent in Croatia, but are very much developed elsewhere. Tradition also conditioned the organizational framework providing geophysical education – at some universities it is provided within the structural units dealing with physics (e.g. Helsinki, Bologna), elsewhere it may be under departments of geosciences and/or geology (Trieste, Edinburgh, Athens). Of all the European universities, the most similar program to the one proposed here is that at the Charles University in Prague (A. Mohorovičić studied there!), where meteorology (dynamic and synoptic meteorology and climatology), seismology, gravity and figure of the Earth, geomagnetism and aeronomy are taught at the Faculty of Physics and Mathematics. Our program is also similar to the one offered at the University of Oslo, where bachelors of meteorology and oceanography, as well as the masters of these and related disciplines are educated.

Interest in the undergraduate and graduate studies of geophysics exists in Croatia for a very long time. Graduated students generally easily find employment in professional organizations (Meteorological and Hydrological Service or the Croatian Seismological Survey), scientific institutes, academic institutions, companies dealing with exploration geophysics, banks, etc.

The learning outcomes for undergraduate university degree in geophysics

After graduation, the student will be able to:

KNOWLEDGE AND UNDERSTANDING

- demonstrate knowledge and understanding of the natural sciences (physics, mathematics) which are the basis of geophysics
- demonstrate knowledge and understanding of the fundamentals of the main geophysical disciplines (meteorology, seismology and physical oceanography)
- demonstrate knowledge of terminology and nomenclature and use of bibliography in the field of geosciences
- demonstrate understanding of the temporal and spatial dimensions of physical processes on Earth
- demonstrate knowledge and understanding of the complex nature of interaction within the geosphere

APPLICATION OF KNOWLEDGE AND UNDERSTANDING

- develop a way of thinking that enables the setup of basic models or the recognition and use of existing models in search for solutions to specific geophysical problems
- apply standard methods of mathematical physics, in particular mathematical analysis and linear algebra and corresponding numerical methods in solving geophysical problems
- independently carry out relevant numerical calculations on a personal computer including the development of simple programs
- the ability to use quantitative methods and their application to geophysical problems
- basic ability to combine theory and practice
- basic knowledge on the application of information technologies in geophysics

MAKING JUDGMENTS

- develop the ability to choose and use appropriate analytical methods
- develop the ability to perform appropriate experiments, analysis and interpretation of data, and to draw conclusions

COMMUNICATION SKILLS

- ability to work individually and as part of a team
- ability to present own results as well as results obtained by other people
- ability to use English as a professional language in communication, reading literature and writing professional papers
- basic knowledge of management in professional work and understanding of ones limitations

ABILITY OF LEARNING

- independently use the professional literature and other relevant sources of information, which implies a good knowledge of English for specific purposes
- the ability to receive and integrate the information from different sources (eg. text, numerical, verbal, graphical)
- recognition of the need for lifelong learning

Description of the undergraduate study program of geophysics

I. YEAR	Winter Semester		Summer Semester	
Compulsory courses	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
General Physics 1	4+2+1	10		
Mathematical Analysis 1	3+3+0	8		
Linear Algebra 1	2+2+0	7		
Computing and practicum	1+3+0	5		
Physical and Health Education 1*	0+2+0			
General Physics 2			4+2+1	10
Mathematical Analysis 2			3+3+0	8
Linear Algebra 2			2+2+0	7
Statistics and basic measurements			2+3+0	5
Physical and Health Education 2*			0+2+0	
TOTAL:	**21**	**30**	**22**	**30**

L = number of teaching hours per week, **E** = number of training hours (practicum) per week, **S** = number of Seminar hours per week

**** In accordance with the Statute of the University of Zagreb, teaching Physical and Health Education is mandatory for students I and II, the undergraduate and integrated undergraduate and graduate studies, but does not enter the schedule nor earn ECTS credits.***

II. YEAR	Winter Semester		Summer Semester	
Compulsory courses	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
General Physics 3	4+2+1	10		
Initial Physical Laboratory 1	0+4+0	3		
Mathematical Methods of Physics 1	3+3+0	8		
Classical Mechanics 1	3+3+0	7		
Symbolic Programming	1+2+0	2		
Physical and Health Education 3*	0+2+0			
General Physics 4			4+2+1	10
Introduction to Quantum Physics			2+2+0	2
Mathematical Methods in Physics 2			3+3+0	8
Classical Mechanics 2			3+2+0	7
Initial Physical Laboratory 2			0+4+0	3
Physical and Health Education 4*	0+2+0		0+2+0	
TOTAL:	**26**	**30**	**26**	**30**

L = number of teaching hours per week, **E** = number of training hours (practicum) per week, **S** = number of Seminar hours per week

**** In accordance with the Statute of the University of Zagreb, teaching Physical and Health Education is mandatory for students I and II, the undergraduate and integrated undergraduate and graduate studies, but does not enter the schedule nor earn ECTS credits.***

III. YEAR	Winter Semester		Summer Semester	
Compulsory courses	**L+E+S**	**ECTS**	**L+E+S**	**ECTS**
Theory of Elasticity with Application in Geophysics	2+1+0	4	2+1+0	5
Physical Oceanography I	2+1+0	5		
Seismology I	2+2+0	5		
Introduction to Geophysical Fluid Dynamics	2+1+0	4		

Introduction to Spectral Analysis	2+1+0	3		
Advances Laboratory Exercises in Physics I	0+4+0	3		
Computing and numerical mathematics	2+1+0	3		
Statistical methods in geophysics	2+1+0	3		
Physical Oceanography I			2+1+0	5
Seismology I			2+2+0	5
Advances Laboratory Exercises in Physics II			0+4+0	3
Seismometry			2+1+0	2
Dynamic meteorology I			4+2+0	8
Meteorological measurements			2+1+0	2
TOTAL:	**26**	**30**	**26**	**30**

L = number of teaching hours per week, **E** = number of training hours (practicum) per week, **S** = number of Seminar hours per week

Course descriptions

COURSE: **General Physics 1**	
YEAR OF STUDY: **I.**	
SEMESTER: **1.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**4**
Exercises	**2**
Seminars	**1**
ECTS CREDITS: **10**	
COURSE OBJECTIVES: **Acquisition of theoretical and experimental knowledge of the basics of mechanics and physics of fluids, gaining operational knowledge of the methods for solving numerical problems in mechanics and physics of fluids, and achieving skills of reducing the real mechanical problems on the physical model and setting up the appropriate equations.**	
COURSE CONTENT: **Lectures:** **The physical quantities, dimensions and units. Mathematical tools. Coordinate systems. Description of motion: velocity and acceleration. Examples of simple movements. Relative speed. Newton's laws. The forces: gravitational, electrical, magnetic, elastic, frictional force. Diagram of forces and motion equations. Examples: hanged body, pulling the body, bevel. Examples: body motion in a fluid and charge in a homogeneous magnetic field. Relativity of motion. Inertial systems. Non-inertial systems. The apparent force. Work, kinetic and potential energy. Power. The laws of conservation of energy, momentum and angular momentum. Collisions. Statics and dynamics of rigid bodies. The harmonic oscillator: definition and basic examples. The force decreases with the square of the distance. Mechanics (statics and dynamics) fluid.** **Exercises:** **Repeat mathematics necessary for the course. Coordinate systems. Description of motion: velocity and acceleration. Examples of simple movements. Relative speed. Newton's laws. Force: the force diagrams and equations of motion. The motion of bodies under the influence of forces: they hanged the body, pulling the body, bevel. Examples: body motion in a fluid and charge in a homogeneous magnetic field. Relativity of motion. Inertial systems. No inertial systems. The apparent force. Work, kinetic and potential energy. Power. The laws of conservation of energy, momentum and angular momentum. Collisions.**	

Statics and dynamics of rigid bodies. The harmonic oscillator: definition and basic examples. The force decreases with the square of the distance. Mechanics (statics and dynamics) fluid.
LEARNING OUTCOMES: **Upon completion of the course General Physics 1 student will be able to:** **1. develop a simple physical model applicable to solving a given problem in the field of mechanics and fluid mechanics;** **2. set up mathematical formulation of a given physical model of mechanics;** **3. solve numerical tasks for systems known in the field of mechanics and fluid mechanics;** **4. demonstrate knowledge of basic concepts of kinematics, and in particular the concepts of speed and acceleration;** **5. demonstrate knowledge of Newton's laws, the Galilean transformation, and the law of conservation of energy and momentum;** **6. demonstrate basic knowledge of kinematics and dynamics of rigid bodies, including the conditions of balance and rotation around fixed axis;** **7. qualitatively and quantitatively describe the motion of the harmonic oscillator;** **8. qualitatively and quantitatively describe the motion of bodies in the field of inverse square force;** 9. **demonstrate knowledge of basic concepts of fluid mechanics, which includes the most important phenomena and statics (hydrostatic pressure, buoyancy) and fluid dynamics (continuity equation, Bernoulli equation)**
TEACHING METHODS: **Lectures, exercises, independent work.**
METHODS OF MONITORING AND VERIFICATION: **Monitoring the regularity of attendance, preliminary exams, tests, written and oral exams.**
TERMS FOR RECEIVING THE SIGNATURE: **Students are required to regularly attend lectures, seminars and exercises and actively participate in solving problems during exercises. Furthermore, students are required to pass two preliminary exams and four tests during the semester, and on them to achieve at least 33% of the total number of points.**
EXAMINATION METHODS: **The final exam consists of a written and oral examination, final score is the average value of grades obtained on each of them. Rating written examination form as follows: 0-50% points – not enough to pass the exam, 51-64% of points – score 2, 65-77% of points – score 3, 78-89% of points – score 4, 90-100 % score 5. Additional points can be achieved by successful solving homework assignments and competitions. Pass mark in the written test is possible to achieve by successful resolving the preliminary exams (with the same, given the above, criterion).**
COMPULSORY LITERATURE: **Charles Kittel, Walter D. Knight, Malvin A. Ruderman: Mechanics: Berkeley Course, Vol. 1,**

Mcgraw-Hill Book Company, 1967. **Script of courses are available in the e-learning system Merlin.**
ADDITIONAL LITERATURE: **Richard Feynman: Lectures in Physics I, Addison-Wesley Publishing Company, 1964.** **Hugh D. Young, Roger Freedman: Sears and Zemansky's University Physics, Pearson Addison-Wesley, 2008.**

<table>
<tr><td colspan="2">COURSE: Mathematical Analysis 1</td></tr>
<tr><td colspan="2">YEAR OF STUDY: I.</td></tr>
<tr><td colspan="2">SEMESTER: 1.</td></tr>
<tr><td>TEACHING METHODS</td><td>CONTACT HRS PER WEEK</td></tr>
<tr><td>Lectures</td><td>3</td></tr>
<tr><td>Exercises</td><td>3</td></tr>
<tr><td>Seminars</td><td>0</td></tr>
<tr><td colspan="2">ECTS CREDITS: 8</td></tr>
<tr><td colspan="2">COURSE OBJECTIVES:
Introduction to basic mathematical concepts, mastering the techniques of differential calculus and understanding of the associated theory.</td></tr>
<tr><td colspan="2">COURSE CONTENT:
Set, functions, bijection, inverse function. Natural numbers and the axiom of mathematical induction. Real numbers, supremum. Elementary functions. A number of series and limes. Limit of function in point, a continuous function on the segment. Derivative. Differentiation rules. Derivatives. Taylor's theorem. Extremes. Testing function.</td></tr>
<tr><td colspan="2">LEARNING OUTCOMES:
Upon completion of the course Mathematical Analysis 1 student will be able to:
• define and correctly interpret the basic concepts of mathematical analysis (sequences, limits, derivatives, Taylor series and their properties);
• specify the elementary functions and their properties and use them in practical accounts;
• derive the elementary functions;
• use derivatives and their properties when tested flow and graphing functions;
• use the Taylor series approximation of the function.</td></tr>
<tr><td colspan="2">TEACHING METHODS:
Lectures, Exercises.</td></tr>
<tr><td colspan="2">METHODS OF MONITORING AND VERIFICATION:
Preliminary exams, homework, oral exam.</td></tr>
<tr><td colspan="2">TERMS FOR RECEIVING THE SIGNATURE:
The students are required to attend classes regularly and solve the homework.</td></tr>
</table>

EXAMINATION METHODS: **Knowledge is checked and evaluated continuously during the semester through homework and tests, and the final score is determined by final oral examination.**
COMPULSORY LITERATURE: **B.Guljaš, Mathematical Analysis I & II, script, http://web.math.pmf.unizg.hr/~guljas/skripte/MATANALuR.pdf** **S. Kurepa, Mathematical Analysis 1 i 2, Tehnička knjiga, Zagreb** **B.P. Demidovič, Zadaci i riješeni primjeri iz više matematike, Tehnička knjiga, Zagreb**

COURSE: **Linear Algebra 1**	
YEAR OF STUDY: **I.**	
SEMESTER: **1.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **7**	

COURSE OBJECTIVES:

Introduction to basic concepts of linear algebra, mastering the techniques of matrix algebra and understanding of corresponding theoretical basis.

COURSE CONTENT:

Real and complex numbers. Systems of linear equations. The triangular systems. Elementary transformations in equations. Gaussian elimination. Homogeneous systems. The vector space R^n. Linear shell vector. Elementary transformations on vectors. The bases in R^n. Bases and elementary transformations. Linear independence in R^n. Vector space dimension. Kronecker-Capelli theorem. Theorem of Rank and Defect. Rank transposed matrix. Norms and scalar products on R^n and C^n. Triangle inequality. Orthonormal bases. Gram-Schmidt orthogonalization. Theorem about projection. The theorem on the best approximation. Least squares method. Determinants. Determinants and elementary transformations. Orientation to the R^N. Cramer's rule. The determinant of the matrix transpose. Laplace development. Gram determinant. Vector product in R^3. Lines and planes in R^n. Equations of lines and planes. Analytical geometry in R^2 and R^3.

LEARNING OUTCOMES:

Upon completion of the course the student will be able to:
- solve the system of linear equations with Gauss method - to determine the matrix of linear mappings from R^n to R^m
- reduced matrix of elementary transformations on a stepped form
- find the base subspace in R^n default probability generating system and find the base subspace in R^n given system of equations
- interpret determinant as the volume of Convexity in R^n
- prove Binet-Cauchy theorem
- explain the connection between scalar product of vectors and orthogonal projection of the vector direction
- ortonorm by Gram-Schmidt procedure a number of independent vectors and solve the minimization problem || Ax - b || by least squares method
- describe sets of O (2), SO (2), U (2), SU (2) an orthonormal basis in R^2 and C^2

- apply vector product in solving some geometric questions in R^3.
TEACHING METHODS: **Lectures, Exercises.**
METHODS OF MONITORING AND VERIFICATION: **Two preliminary examinations, practical work.**
TERMS FOR RECEIVING THE SIGNATURE: **Class attendance, attending preliminary exams.**
EXAMINATION METHODS: **Oral examination (if applicable).**
COMPULSORY LITERATURE: **N. Elezović, Element, Zagreb** **D. Bakić, Linearna algebra, Školska knjiga, Zagreb, 2008.**
ADDITIONAL LITERATURE: **K. Horvatić, Linearna algebra, PMF-Matematički odjel i LPC, Zagreb**

COURSE: **Computing and practicum**	
YEAR OF STUDY: **I.**	
SEMESTER: **1.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**1**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **5**	

COURSE OBJECTIVES:

Enable students to be ready on senior years to independently conduct numerical calculations on a personal computer including the development of simple programs. For this purpose, as part of this course, students are introduced to the normal computer work environment (Linux, latex, html), as well as the basic elements of programming languages C and Python. It is essential to develop independence in learning and the search for information (especially on the Internet) necessary for solving tasks so that the senior years of study and future career can be easily adapted to the specific conditions of research. Also, as programming is demanding discipline and the differences in the foreknowledge of students are huge, the goal is to enable a large number of hours of practice in the computer lab to students who need it (e.g. Those who first encounter with programming) and individual support within Demonstration.

COURSE CONTENT:

Input and output, basic operators and loops. Data types, operators. Flow control, functions. Specific work with numbers on a computer. Fields structure. Pointers (pointers). Sequences of characters / strings. Text files. Binaries. The allocation of memory. Sorting fields. Comparison languages C and Python: input / output, operators, branching / looping, functions. Comparison languages C and Python: fields, strings, files. Comparison languages C and Python on: sorting, functional programming. Examples of use.

LEARNING OUTCOMES:

Upon completion of the course the student will be able to:

1. **Work independently on a computer in a Linux environment which includes saving files in directories, work with email, use the terminal, use a web browser;**
2. **Independently apply basic elements of html, latex, programming languages ci python;**
3. **Develop your own ways of learning and thinking that enable the adoption of rules of programming and its application in the new context;**
4. **Independently develop simple computer programs that involve simple calculations and graphic presentation, file, sort the contents of the boxes, dynamic memory allocation;**

5. **Vary unformatted (binary) and formatted (text) data set in memory or file, and apply the appropriate functions to read and write;**
6. **Use some simple algorithms: brute force (counting, finding the minimum), binary search (bisection), run length encoding compression data, generate random numbers having given distribution using random numbers having uniform distribution;**
7. **Use standard methods of storing numbers in the text file;**
8. **Use interoperability program (one result is the starting point for others);**
9. **Independently use scientific literature and other relevant sources of information, especially the Internet.**

LEARNING MODE:

Attending lectures, practicum and demonstrations not mandatory.

Communication related to the course (notices, send solved tasks, etc.) is performed using the system Merlin.

Although attendance to Practicum is not mandatory, arrival at a particular time is the only way to collect points. List of terms for each student will be given on Merlin. In the case of excused absence replacement dates will be organized.

TEACHING METHODS:

Lectures, demonstrations, individual assignments.

METHODS OF MONITORING AND VERIFICATION:

Homework, independent work, preliminary exams.

TERMS FOR RECEIVING THE SIGNATURE:

Achieve passage on both preliminary exams. The passage at the preliminary exams is achieved if addressing a whole task or if the collected half points from the entire preliminary exam. Students who are found to have copied the preliminary exam cannot get a signature on ISVU.

EXAMINATION METHODS:

The requirement for sufficient assessment: The sum of points achieved on preliminary exams, individual assignments and tasks bonus greater than 40% of the maximum number of preliminary exams + individual assignments.

The total score is formed, as a rule, on the basis of points: practicum (60%) and the score of the written exam that consists of 2 tests (20% + 20%).

Practicum points students acquire during practicum: oral examination previously solved homework and tests via computer. In doing so, some points can be a bonus in terms of the type that are not counted in the maximum number of points.

Written exam consists of 2 tests. For each of the 2 tests, there are four possible terms for routing:

1) pre-term (end of October) - before the material is processed in lectures

2) full dates (first colloquium: mid-December, the second: the end of January) - after the

material has been dealt

3) first additional term (next week exam period) - after the end of classes

4) other additional term (fourth week exam period).

It is allowed to repeatedly come out on individual colloquium in which case it takes a final ranking last release in which he achieved the passage.

Preliminary exams are solved on paper. Time allowed 45 minutes for each of the colloquium.

Students who achieve more than 70% of colloquia in pre-term (this refers to the average of both tests) can get the final grade only on the basis of tests and thus relieve the writing task.

The final grade is determined by the following thresholds: (points, score): 40% 2; 55% 3; 70% 4; 85% 5th

COMPULSORY LITERATURE:

Brian W. Kernighan, Dennis M. Ritchie, The C Programming Language, 2. edition, Prentice Hall, Inc., 1988 or later.

ADDITIONAL LITERATURE:

Byron Gottfried, Schaum's Outline of Programming with C, 2. edition, McGraw-Hill, 1996

Oxford University Computing IT (OUITS) tutorial on web page: http://www-teaching.physics.ox.ac.uk/computing/ProgrammingResources/programming.html

David Griffiths, Dawn Griffiths, Head First C, 1. edition, O'Reilly Media Inc., 2012

COURSE: **General Physics 2**	
YEAR OF STUDY: **I.**	
SEMESTER: **2.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**4**
Exercises	**2**
Seminars	**1**
ECTS CREDITS: **10**	

COURSE OBJECTIVES:

Acquisition of theoretical and experimental knowledge of basic electromagnetism, the acquisition of operational knowledge in methods of solving numerical problems in basic electromagnetism, and achieving the skills of reducing the real problems in electromagnetism on a physical model and setting up the appropriate equations.

COURSE CONTENT:

Lectures:

Speed of light. Lorentz transformations. Relativistic addition of velocities. Relativistic dynamics. The relativistic transformation of energy, momentum and force. Electrostatics: electric charge and field. Coulomb's law. Gauss's law and its application. Electric potential. Field as a potential gradient. The energy of the electric field. Gauss's law in differential form. Poisson's and Laplace equation. The rotation of a vector field. Conductors and insulators. Faraday cage. Capacitors. Dielectrics. The electric current. Ohm's law. Electromotive force. Kirchhoff rules. Electric and magnetic field charge in motion. The relativistic transformation of electric and magnetic fields. Magnetostatics: Biot-Savart and Ampere's law. The magnetic dipole moment. Magnetism in materials. The vector potential. Faraday's law of electromagnetic induction. Lenz's rule. Eddy currents. The coil as part of the circuit. Mid-induction and self-induction. Alternating currents and their circles. The method of rotating vectors. The method of complex numbers. Maxwell's equations. Electromagnetic waves in a vacuum.

Exercises:
Lorentz transformations. Relativistic addition of velocities. Relativistic dynamics. Relativistic transformation of energy, momentum and force. Electrostatics: electric charge and field. Gauss's law. Application of Gauss's law. Electric potential. Field as a potential gradient. The energy of the electric field. Gauss's law in differential form. Poisson's and Laplace equation. The rotation of a vector field. Capacitors. Dielectrics. The electric current. Ohm's law. Electromotive force. Kirchhoff rules. Electric and magnetic field charge in motion. The relativistic transformation of electric and magnetic fields. Magnetostatics: Biot-Savart and Ampere's law. The magnetic dipole moment. Magnetism in materials. The

vector potential. Faraday's law of electromagnetic induction. Lenz's rule. The coil as part of the circuit. Mid-induction and self-induction. Alternating currents and their circles. The method of rotating vectors. The method of complex numbers. Maxwell's equations. Electromagnetic waves in a vacuum.

LEARNING OUTCOMES:

Upon completion of the course General Physics 2 student will be able to:

1. **develop a simple physical model that is applicable to solving a given problem in the field of electromagnetism;**
2. **set up mathematical formulation of a given physical model in the field of electromagnetism, and solve numerical tasks for systems known in the field of electromagnetism;**
3. **demonstrate knowledge of the basic tenets of relativistic physics, especially Lorentz transformations;**
4. **demonstrate knowledge of the basic tenets of electrostatics and Coulomb law and Gauss's law and its application;**
5. **operatively deal with mathematical operators gradient, divergence and rotation;**
6. **demonstrate knowledge of Kirchhoff's rules of circuits and their application;**
7. **qualitatively and quantitatively describe the electric and magnetic field charge in motion and their relationship;**
8. **demonstrate the basic knowledge of Magnetostatics, Biot-Savart and Amper's law, and electromagnetic induction;**
9. **to use methods of rotating vectors and complex numbers in solving problems related to alternating current circuits;**
10. **demonstrate knowledge of Maxwell's equations and electromagnetic waves in a vacuum.**

TEACHING METHODS:

Lectures, demonstrations, individual assignments.

METHODS OF MONITORING AND VERIFICATION:

Regular attendance of lectures, colloquia, written and oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Students are required to regularly attend lectures, seminars and exercises and actively participate in solving problems during exercises. Furthermore, students are required to pass two preliminary exams and four tests during the semester, and on them to achieve at least 33% of the total number of points.

EXAMINATION METHODS:

The final exam consists of a written and oral examination, final score is the average value of grades obtained on each of them. Rating written examination form as follows: 0-50% points – not enough to pass the exam, 51-64% of points – score 2, 65-77% of points – score 3, 78-89% of points – score 4, 90-100 % score 5. Additional points can be achieved by successful solving homework assignments and competitions. Pass mark in the written test is possible to achieve by successful resolving the preliminary exams (with the same, given

the above, criterion).
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1 (completed)**
COMPULSORY LITERATURE: **Edward M. Purcell: „Electricity and Magnetism“ Berkeley Course Vol. 2, McGraw-Hill Book Company, 1967.** **Script of courses are available in the e-learning system Merlin.**
ADDITIONAL LITERATURE: **Richard Feynman: Lectures in Physics II, Addison-Wesley Publishing Company, 1964.** **Hugh D. Young, Roger Freedman: Sears and Zemansky's University Physics, Pearson Addison-Wesley, 2008.**

COURSE: **Mathematical Analysis 2**	
YEAR OF STUDY: **I.**	
SEMESTER: **2.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**3**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **8**	

COURSE OBJECTIVES:

Mastering the techniques of integration and understanding of the associated theory.

COURSE CONTENT:

Riemann integral. Indefinite integral and primitive function. Integrability of monotone and continuous functions. Newton-Leibniz formula. Methods of integration. Series of real numbers. Series of functions. Functions of several variables. Taylor series Double and triple integrals, integral curve.

LEARNING OUTCOMES:

Upon completion of the course Mathematical Analysis 2 student will be able to:

- **Define and correctly interpret the basic concepts of mathematical analysis (integrals and their properties, series, Taylor series);**
- **Apply the rules of integral calculus to solve the known types of integrals;**
- **Use Taylor series approximation of the functions of several variables;**
- **Solve the known types of double and triple integrals and apply them in calculating the surface area and volume;**
- **Solve the known types of line integrals and apply them in calculating the arc length.**

TEACHING METHODS:

Lectures, Exercises.

METHODS OF MONITORING AND VERIFICATION:

Preliminary exams, homework assignments, oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

The students are required to attend classes regularly and solve homework.

EXAMINATION METHODS:

Knowledge is checked and evaluated continuously during the semester through homework and tests, and the final score is determined by final oral examination.
COURSE(S) NEEDED FOR THIS COURSE: **Mathematical Analysis 1 (completed)**
COMPULSORY LITERATURE: **B.Guljaš, Mathematical Analysis I & II, script, http://web.math.pmf.unizg.hr/~guljas/skripte/MATANALuR.pdf** **S. Kurepa, Mathematical Analysis 1 and 2, Tehnička knjiga, Zagreb** **B.P. Demidovič, Zadaci i riješeni primjeri iz više matematike, Tehnička knjiga, Zagreb**

COURSE: **Linear algebra 2**	
YEAR OF STUDY: **I.**	
SEMESTER: **2.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **7**	

COURSE OBJECTIVES:

Introduction to basic concepts of linear algebra, mastering the techniques of matrix algebra and understanding of corresponding theoretical basis.

COURSE CONTENT:

The linear mappings from R^n to R^m and matrices. Image and core linear mappings. The composition of linear maps and matrix multiplication. Regular operators. Inverting matrices Gauss-Jordan transformations. Matrix of linear operators and base changes. Vector space operators with R^n in R^m. Algebra operators on R^n. Binet-Cauchy theorem. The determinant of a linear operator. Characteristic polynomial, eigenvalues and eigenvectors of a linear operator. The spectrum of A and solution of linear system of differential equations y'=Ay. Nilpotent and semisimple operators. Jordan decomposition (without proof). Selfadjoint adjoint operator. Quaternions. Unitary operators. Rotation and reflection in R^3 and R^n. Theorem on diagonalization of normal operators. Selfadjoint operators and quadratic forms.

LEARNING OUTCOMES:

Upon completion of the course the student will be able to:

- **Prove Theorem of Rank and Defect linear operator**
- **Determine the regular operators, rank, defect and determinants**
- **Calculate the inverse of a regular matrix by the Gauss-Jordan method**
- **Explain the properties of the coordinates of the current base vector space**
- **Calculate the matrix operator when changing the base area**
- **Explain the algebraic structure of the algebra of operators and prove that the eigenvalues of operators zeros characteristic polynomial**
- **Calculate at least one solution of the system of differential equations y '(t) = AY (t) for a given eigenvalue operator A**
- **To prove a theorem on diagonalization of selfadjoint operator and explain the basic properties of unitary operators**
- **Calculate the axis and angle of rotation A of the group SO (3)**

TEACHING METHODS: **Lectures, Exercises.**
METHODS OF MONITORING AND VERIFICATION: **Preliminary exams, oral exam.**
TERMS FOR RECEIVING THE SIGNATURE: **Class attendance, preliminary exams.**
EXAMINATION METHODS: **During the semester are held two tests and at the end of the semester will be held oral examination (if necessary).**
COURSE(S) NEEDED FOR THIS COURSE: **Linear algebra 1 (completed)**
COMPULSORY LITERATURE: **Neven Elezović, Element, Zagreb** **D. Bakić, Linearna algebra, Školska knjiga, Zagreb, 2008.**
ADDITIONAL LITERATURE: **K. Horvatić, Linearna algebra, PMF-Matematički odjel i LPC, Zagreb**

COURSE: **Statistics and basic measurements**	
YEAR OF STUDY: **I.**	
SEMESTER: **2.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **5**	

COURSE OBJECTIVES:

The acquisition of theoretical knowledge in the field of probability and statistics, the acquisition of operational knowledge in the method of processing the measured data in physics and acquiring skills in the collection and processing of data during the experimental work in the laboratory.

COURSE CONTENT:

Lectures:
Basic methods and principles of data processing independent measurements. Graphic data; method of least squares; linearization problems. Fundamentals of combinatorics (permutations, variations and combinations). Historical overview of the concept of probability; some paradoxes and problems of pre-axiomatic theory of probability. Axiomatic theory of probability, Kolmogorov axioms. Conditional probability, independent events; Bayes' theorem. Definition of random variables; discrete and continuous random variable. Simple examples of random variables. The expectation and variance of the random variable; moments. Bernoulli and binomial distribution; central limit theorem. Poisson distribution; Gaussian distribution. Multidimensional random variables; law of large numbers. Fundamentals of statistics; statistical 'paradigm' with examples. The term appraiser; method of maximum likelihood. Impartiality appraiser; Gamma function.
Exercises:
Repeat basic formulas and principles of data processing independent measurements; examples. Elaborated examples of graphics data, the least squares method and linearization problems. First colloquium. Fundamentals of combinatorics (permutations, variations and combinations) and calculation of probabilities. Calculation of probability (using combinatorics). Conditional probability, independent events. Bayes' theorem; geometric probability. Examples of random variables. Second colloquium. Expectation and variance of different random variables. Moments of random variables. Bernoulli and binomial distribution. Poisson distribution; Gaussian distribution. Other random (low profile and continual) random variables. 3rd Colloquium.
During the semester, each student in three weeks perform three laboratory exercises in order to familiarize with the experimental work and data processing:

Exercise 1: Timing - Maxwell Drive / Mathematical pendulum
Exercise 2: Measurement of current and voltage - resistor / coil
Exercise 3: Basic oscilloscope

LEARNING OUTCOMES:

Upon completion of the course Statistics and basic measuring student will be able to:

- **Clearly distinguish the axiomatic approach to the concept of probability in relation to the heuristic approach and the need for axiomatic approach**
- **Demonstrate knowledge of the limit theorem and the law of large numbers**
- **Qualitatively and quantitatively establish the connection between the axiomatic theory of probability and stochastic processes in real life**
- **Demonstrate knowledge of statistical concepts (expectation, variance, moments, unreliability)**
- **Qualitatively and quantitatively and critically comment on the numerical values obtained features in a lab experiment**
- **Demonstrate knowledge of average value, variance, unreliability and determine the linear adjustment of a set of measured values using the least squares**
- **Qualitatively describe the statistical paradigm, which in physics is used to display the results**

TEACHING METHODS:

Lectures, Exercises, laboratory.

METHODS OF MONITORING AND VERIFICATION:

Experimental work, preliminary exams, oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Passed first colloquium and three laboratory Exercises.

EXAMINATION METHODS:

During the semester, students can take three tests of which the passage of the first colloquium is required. Preliminary exams typically contain three tasks, and the total number of points per exam is 60. It is considered that the student has passed a colloquium if received at least 24 points. Overall rating of the colloquium is formed by adding all points: less than 40% - insufficient for passage, less than 56% - 2 (sufficient), less than 72% - 3 (good), less than 88% - 4 (very good) and 88% or more - 5 (excellent).Students who have passed the first colloquium can access the laboratory exercises. Students who have passed all three preliminary exams are exempt from the written part of the final exam.

The oral part of the final exam is accessible only to students who have successfully passed all three laboratory Exercises (and thus the first colloquium) and students who have passed the written (or passed all three tests).

Written part of the final exam has five tasks with the total score 100. Rating written examination form as follows: less than 40% - insufficient for passage, less than 56% - 2 (sufficient), less than 72% - 3 (good), less than 88% - 4 (very good) and 88% or more - 5 (excellent).

The total final grade is formed by evaluation of written (or ratings from the three tests), assessment of laboratory exercises and evaluation of an oral part, with approximately the same weight proportion of each.
COMPULSORY LITERATURE: **A. M. Mood, F. A. Graybill, D. C. Boes, Introduction to the theory of statistics, McGraw Hill 1974** **Lectures are available on the website of the course.**
ADDITIONAL LITERATURE: **Ž. Pauše, Uvod u matematičku statistiku, Školska knjiga, Zagreb, 1993.** **J. L. Devore, Probability and statistics for engineering and the sciences, Cengage Learning; 8th edition (2011)**

COURSE: **General Physics 3**	
YEAR OF STUDY: **II.**	
SEMESTER: **3.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**4**
Exercises	**2**
Seminars	**1**
ECTS CREDITS: **10**	

COURSE OBJECTIVES:

Acquisition of theoretical and experimental knowledge of basic vibrations and waves, the acquisition of operational knowledge in methods of solving numerical problems in physics of vibrations and waves, and the achievement of the skills of reducing the real problems of the physics of vibrations and waves on the physical model and setting up the appropriate equations.

COURSE CONTENT:

Lectures:

A simple harmonic oscillator. Examples. Feel free oscillation of a body in complex systems. Free vibrations in a system with two or more bodies. Longitudinal and transverse oscillation. Approximation of the continuum. The linearity of differential equations and the principle of superposition. Amplitude modulation. Hit. Forced oscillations of mechanical systems. Damped harmonic oscillator. Impedance harmonic oscillator. Absorption and dispersion amplitude. Description oscillation method of complex numbers. Forced Oscillations of systems with two or more particles. The connection of an external force and the system. Mechanical filters. Forced Oscillations continuum. Waves in one dimension: the emergence and spread. The wave function as a solution of the wave equation. Dispersion relations. Phase velocity. Val in the continuum. Impedance waveform funds. Power transmission via wave. Reflection and transmission of waves. Standing waves. The superposition of waves and group velocity. Frequency spectrum. Wave package. Oscillations and waves in three dimensions. Polarization flicker. Plane waves. Interference. Acoustics. Sound like a plane wave in the gas. The noise level. Doppler effect. Oscillations and waves in the electrical system. The impedance of the electrical system. Transmission lines. Electromagnetic waves. Electromagnetic Spectrum. The intensity and pressure of electromagnetic radiation. The relativistic Doppler effect. The light in the dielectric. Approximation of the laws of geometrical optics. Origin of image in geometric optics. Around and optical devices. Interference of light. Diffraction of light.

Exercises:

A simple harmonic oscillator. Free oscillation of a body in complex systems. Free vibrations in a system with two or more bodies. Amplitude modulation. Hit. Forced oscillations of

mechanical systems. Damped harmonic oscillator. Description oscillation method of complex numbers. Waves in one dimension. Wave function and wave equation. Dispersion relations. Phase velocity. Reflection and transmission of waves. Standing waves. The superposition of waves and group velocity. Frequency spectrum. Wave package. Oscillations and waves in three dimensions. Polarization flicker. Plane waves. Interference. Doppler effect. Oscillations and waves in the electrical system. The impedance of the electrical system. Electromagnetic waves. The intensity and pressure of electromagnetic radiation. The relativistic Doppler effect. Geometrical optics. Interference and diffraction of light.

LEARNING OUTCOMES:

Upon completion of the course General Physics 3, students will be able to:
Develop a simple physical model applicable to a given problem solving in physics of waves and vibrations;
Set mathematical formulation of a given physical models in physics of waves and vibrations;
Solve numerical tasks for known systems in physics of waves and vibrations;
Qualitatively and quantitatively describe suppression and compulsion in the system which behave like the harmonic oscillator;
Demonstrate knowledge of basic concepts of emergence and spread of waves, including dispersive relation;
Demonstrate knowledge of the occurrence of reflection, transmission and interference of waves;
Demonstrate knowledge and operational use of the concepts of geometrical and physical optics.

TEACHING METHODS:

Lectures, exercises, seminars and workshops, individual assignments.

METHODS OF MONITORING AND VERIFICATION:

Regular attendance of lectures, seminars, colloquia, written and oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Students are required to regularly attend lectures, seminars and exercises and to actively participate in solving problems during exercises. Furthermore, students are required to pass two preliminary tests and four tests during the semester, and on them to achieve at least 33% of the total number of points.

EXAMINATION METHODS:

The final exam consists of a written and oral examination, final score is the average value of grades obtained on each of them. Rating written examination form as follows: 0-50% points – not enough to pass the exam, 51-64% of points - 2 (sufficient), 65-77% of points - 3 (good), 78-89% of points - 4 (very good), 90-100 % - 5 (excellent). Additional points can be achieved by successful solving homework assignments and reward tasks. Pass mark in the written test is also possible if colloquium is successfully resolved (with the same, given the above, criterion).

COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1, 2, Mathematical Analysis 1, 2**
COMPULSORY LITERATURE: **F.S. Crawford: „Waves“, Berkeley Physics Course, vol. III, McGraw-Hill, New York, 1965.** **Script of courses are available in the Merlin e-learning system.**
ADDITIONAL LITERATURE: **Richard Feynman: Lectures in Physics II, Addison-Wesley Publishing Company, 1964.** **Hugh D. Young, Roger Freedman: Sears and Zemansky's University Physics, Pearson Addison-Wesley, 2008.**

COURSE: **Initial Physical Laboratory 1**	
YEAR OF STUDY: **II.**	
SEMESTER: **3.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**0**
Exercises	**4**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

Through laboratory practice students will be introduced to the basics of experimental work that is essential for the integrity of research in physics in general. Their knowledge on theoretical subjects in the field of mechanics, electricity and magnetism shall be determined and related to their own work in laboratory. They will be introduced and practiced to independently operate the basic devices for measuring mechanical and electrical physical sizes and in making the apparatus with the aim of simple experimental research. Students will, through specific situations, gain the measured data processing skills (manual and computer), and based on these results they will adopt special and general conclusions. These rounded up process for the given physical problems will developed their ability to integrate their way of solving problems in future research.

COURSE CONTENT:

Students independently perform the following Exercises rotating every two weeks:

Mathematical pendulum: the photocell accurately measure the period of oscillation of mathematical pendulum depending on the length and on the corner deflection and at high angles establishes a departure from the formula that describes the oscillation of small deviations derived from the first set of measurements;

Energy conservation: from the measured time plunging wheel that is unwound from or with different heights are obtained parameters of motion and analyzes the different forms of energy;

Module torsion: measuring the force required to determine the properties of the torsion bars, and measuring the torsional oscillation periods is calibrated by a resonant system and then examine him rods of different materials, diameter and length to find the principles that determine torsion;

Free and damped oscillation: explores the oscillation of the wheel with spring for different deviations with negligible attenuation and describes the oscillation after the introduction of suffocation by induced eddy currents;

Electromagnetic induction: investigating the dependence of the induced voltage to the

amplitude and frequency of the external magnetic field and the size and number of winding coils in the extent to which the induced voltage is measured;

The magnetic dipole moment in the field: the magnetic field is produced by the measured current through the electromagnet coils and the magnetic moment on the current loop in the field is measured and principles that describe the interaction are obtained;

Transformer: dependence of voltage and current in the primary and secondary transformer and checking rules are measured, and for stronger currents the deviation from the ideal transformer is studied;

Measuring bridge for inductance and capacity: With the Wheatstone bridge for measuring the complex impedance the self-inductance and the capacity of the unknown coil and capacitor is determined.

For each exercise, it is possible to work in laboratory for at least 5 full hours, which is preceded by the preparation at home.

LEARNING OUTCOMES:

Upon completion of the course, students will be able to:
• independently use measuring devices and apparatus in the field of mechanics and electromagnetism to carry out simple experiments according to the tasks and instructions;
• analyze the measured data using statistical methods handheld calculator and computer and numerically and graphically display the results;
• present the results of their work in the form of full reports;
• connect theoretical knowledge with performing Exercises and functioning of the components of the apparatus;
• generalize the results of measurements which are critically examined and interpreted in the light of the well-known theory.

LEARNING MODE:

Students must be prepared to work before arriving at a given exercise. They must first demonstrate their preparedness, and then individually prepare the apparatus and make measurements, followed by the analysis of the results and by oral explaining and answering. Completed written report must be submitted prior to departure from the laboratory.

TEACHING METHODS:

Laboratory.

METHODS OF MONITORING AND VERIFICATION:

Experiment - a written report, practical work, preliminary exams, oral exams.

EXAMINATION METHODS:

Input colloquium of five short questions about the corresponding exercises must be positively evaluated. Testing during operation in the workshop on the physical background exercises, functioning instruments and apparatus, results, analysis, and other necessary knowledge related to exercise, must also result in a positive mark. Report from the

assumed form must contain answers to all the tasks and include a description of the results, analysis, graphics, and earn a passing grade. Final grade is calculated from these three components respectively included with the weight of 20%, 40%, 40%, and the final score is the average of all exercises. The drop is allowed at most one exercise, but then the same must be re-done with a passing grade. Since it is fully inspected in all the essential elements when working with any exercise, there is no final exam.
COURSE(S) NEEDED FOR THIS COURSE: **General physics 1, 2, Statistics and basic measurements**
COMPULSORY LITERATURE: **Preparations for the Exercises, for internal use** **Lectures and textbooks for General Physics 1 and, 2**
ADDITIONAL LITERATURE: **Textbooks for General Physics - optional.**

COURSE: **Mathematical methods of physics 1**	
YEAR OF STUDY: **II.**	
SEMESTER: **3.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**3**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **8**	

COURSE CONTENT:

Lectures:
Introduction: sets, functions of a real variable. The basic operation in the field of complex numbers, functions of a complex variable, complex plane, Riemann surfaces. Sequences and series of complex numbers. Continuity and derivability of complex functions. The integration of complex functions (Cauchy-Goursatov theorem, Cauchy integral formula). Laurent's development, singularities and residues. Gamma function. Asymptotic expansions. Linear ordinary differential equations of the first order (resolution methods, uniqueness of solution). Linear ordinary differential equations of higher order (characteristic equation, Wronskian). Frobenius method. Hypergeometric differential equation. Systems of linear ordinary differential equations.
Exercises:
Complex numbers, complex plane. Functions of a complex variable, equations and inequalities with complex numbers. Riemann surfaces. Sequences and series of complex numbers, the Cauchy-Riemann conditions. Taylor and Laurent development: an introductory tasks, classification of singularities, Picard's theorem. Cauchy's integral formula, Residue theorem, the integration of complex functions - introductory tasks. Integrating complex functions - integration of rational functions and integration by the arc. Integrating complex functions - integrating ambiguous function, rectangular integration, special cases, the gamma function. Differential equations - introductory tasks, differential equations of the first order: separation of variables, homogeneous equations. Differential equations of the first order: exact equations, Euler multiplier. Linear differential equations of the first order: physical examples. Linear differential equations of second order: the method of variation of constants. Systems of ordinary differential equations. Frobenius method - introductory tasks. Frobenius method - advanced tasks.

LEARNING OUTCOMES:

Upon successful completion of the course Mathematical methods of physics 1 student will be able to:
1. **Develop complex functions in the corresponding Laurent's development**
2. **Solve complex integrals by different methods (different choices of the integration curve)**

3. **Solve real integrals that can be displayed by means of complex integrals**
4. **Sum up the ranks through a complex integration**
5. **Use gamma function in practical accounts**
6. **Solve linear ordinary differential equations of the first order**
7. **Solve linear ordinary differential equations of the second order (the method of variation of constants, Frobenius method)**
8. **Solve linear ordinary differential equations of higher order with constant coefficients**
9. **Solve simple systems of linear ordinary differential equations**

TEACHING METHODS:

Lectures, Exercises.

METHODS OF MONITORING AND VERIFICATION:

Regular attendance, written and oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Students are required to regularly attend lectures and exercises, and actively participate in solving problems during exercises.

EXAMINATION METHODS:

Students can pass written exam through tests (2 during the semester) or via the "standard" written examination which takes place at regular periods. Marks at each examination shall be determined on a scale from 0 to 100 points, in increments of 5 points: 40-55 points -2, 60-70 points -3 , 75-85 points - 4 (very good) and 90-100 points - 5 (excellent). To pass at each examination it is necessary to solve at least one task in its entirety, as well as to cross the threshold of scoring 40 points.

In the event of passing on both tests written exam is passed with a mean grade of colloquium. In the case where one or both of the colloquium are not passed, the student must go to the "standard" written exam, where any extra points are transmitted, 5 points for each entirely solved task of the colloquium (up to a maximum of 20 extra points). Additional points accomplished at colloquia add up to credits on the "standard" written exam only if the exam is passed independently of them.

Overall the examination mark shall be determined after passing the oral examination, and in relation to the written exam the highest grade may differ for two marks.

COURSE(S) NEEDED FOR THIS COURSE:

Mathematical Analysis 1, 2

COMPULSORY LITERATURE:

Butkov: Mathematical Physics (Addison-Wesley, 1968.)

I. Smolić: scripts for Mathematical Methods of Physics 1 and 2 (available in pdf format on the website of lecturers)

S. Benić, I. Smolić: script with solved tasks from Mathematical methods of Physics 1 and 2 (available in pdf format on the website of lecturers)

ADDITIONAL LITERATURE:

G.B. Arfken, H. J. Weber: Mathematical Methods for Physicists (Academic Press, 1995.), Lang: Complex Analysis (Springer, 2003.), Tenenbaum, Pollard: Ordinary Differential Equations (Dover, 1985.)

COURSE: **Classical Mechanics 1**	
YEAR OF STUDY: **II.**	
SEMESTER: **3.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**3**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **7**	

COURSE OBJECTIVES:

Introducing the fundamental laws and methods of classical mechanics. The further development of acquired mathematical skills on concrete physical problems. Preparation for the remaining courses of theoretical physics during the study.

COURSE CONTENT:

Lectures:
Introduction and historical development of classical mechanics. Space and time in classical mechanics. Galilean transformations. Newton's formulation of classical mechanics. The laws of conservation of momentum, angular momentum and energy. Conservative systems. Central Powers. The problem of two bodies and the concept of reduced weight. Movement in the field of central forces. Kepler problem. Scattering in a central potential. Rutherford formula. Mechanical similarity and virial theorem. Variational procedure. Lagrange formulation of classical mechanics. Example: a particle in the field of central forces. Systems with limitations. D'Alambertov principle. Static balance. Example: Archimedes' lever. Equivalence of Lagrangian and Newtonian mechanics. Kinematics of rigid body. Fixed and movable system, the concept of angular velocity. Euler angles. The kinetic energy of a rigid body and tensor of inertia. The system of the main axis. Types of tops. Dynamics of rigid bodies. Euler-Lagrange equations for rigid body. Examples: rolling on a horizontal surface, free symmetric top. Symmetrical top in the field of gravity. Description of rigid body in the system related to solid. The vector change in the moving system. A copy of the Euler equations. Examples: free symmetric top and free asymmetric top.
Exercises:
Algebra of vectors. Vector functions. Line integrals. The conservative field. Surface integrals and Green's theorem. Differential equations. Solving Newton's equations for conservative systems in one dimension. Solving Newton's equation for a particle that moves in the medium. Paths in the field of central forces. Kepler problem. The problem of scattering. Variational principle and the Euler-Lagrange equations in systems without restrictions. Euler-Lagrange equations in systems with constraints. D'Alambertov principle. Orthogonal transformation. The notion of a tensor. Tensor of inertia of the rigid body. The

transformation of the system of the main axis of the axis of a rigid body. Solving equations of motion of a rigid body in a fixed system and system related to the body.

LEARNING OUTCOMES:

Upon successful completion of the course Classical Mechanics 1 Students will be able to:

1. **Demonstrate knowledge of the basic settings of classical mechanics including Newton determinism, Galileo invariance and the laws of conservation of momentum, angular momentum and energy.**
2. **Qualitatively describe the motion of a general one-dimensional mechanical system and perform analytical solution of Newton's equations for several well-known examples of one-dimensional mechanical systems.**
3. **Outline possible particles paths in the field of any central forces and perform analytical expression for the trajectory particles in the field of several well-known examples of central forces, including Kepler problem.**
4. **Describe the scattering experiment, especially Ruthefordov experiment, carried out an expression for the differential and total cross sections and interpret them in the context of the experiment.**
5. **Formulate variational principle, perform Euler-Lagrange equations and apply them in the description of physical systems with or without limitations.**
6. **Formulate D'Alambertov principle and apply it to several well-known examples of physical systems, and in particular the problem of static equilibrium.**
7. **Demonstrate basic knowledge of the kinematics of rigid bodies, including the concept of angular velocity and kinetic energy of a rigid body, as well as the role of Euler angles in the description of rigid body.**
8. **Calculate the inertia tensor for a selected few regular solids and determine their main axes.**
9. **Perform Euler-Lagrange equations for the motion of a rigid body and apply them to the example of a symmetric top's (description of rigid body in a fixed system).**
10. **Perform Euler equations and apply them to examples of symmetrical and asymmetrical free tops (description of rigid body in the system related to the body).**

TEACHING METHODS:

Lectures, Exercises, e-learning.

METHODS OF MONITORING AND VERIFICATION:

Regular class attendance, homework, midterms, written and oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Students are required to regularly attend lectures and exercises, actively participate in solving problems in exercises and solve homework. Furthermore, students are required to pass two exams during the semester, i.e. at each colloquium achieved 7.5 out of a possible 15 points.

EXAMINATION METHODS:

Students are required to pass two exams during the semester, i.e. at each colloquium achieved 7.5 out of a possible 15 points. On the final exam a student can earn a maximum

of 70 points, while the passage could be achieved with 25 points. It is then added to points with colloquia, and the total score of the written exam is formed as follows: 40-54 points - 2 (sufficient), 55-69 points - 3 (good), 70-84 points - 4 (very good), 85-100 points - 5 (excellent). Overall the examination shall be determined after passing the oral examination, and in relation to the written exam the highest grade can be distinguished by one grade.

COURSE(S) NEEDED FOR THIS COURSE:

General Physics 1, 2, Mathematical Analysis 1, 2, Linear Algebra 1, 2

COMPULSORY LITERATURE:

H. Goldstein, C.P. Poole, J.L. Safko : Classical Mechanics 3rd Edition, Addison-Wesley Publishing Company, 2001

L.D. Landau, E.M. Lifschitz: Mechanics, Buttenworth-Heinemann, 2001

Spiegel M.R.: Theoretical Mechanics, Schaum's Outline Series, McGraw-Hill, 1967

G.L. Kotkin, V.G. Serbo: Collection of Problems in Classical Mechanics

ADDITIONAL LITERATURE:

V.I. Arnold, Mathematical Methods of Classical Mechanics, Springer-Verlag, 1991

COURSE: **Symbolic Programming**	
YEAR OF STUDY: **II.**	
SEMESTER: **3.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**1**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **2**	

COURSE OBJECTIVES:

The student should be familiar with the work in the context of a system for computer algebra (e.g. Sage, IPython + modules, mathematics, Maple or similar). Student should know in this system numerically and graphically represent mathematical objects encountered on courses of mathematical analysis and algebra and mathematical methods of physics. The corresponding mathematical problems should be solved by single-line computer code, or if needed by something more complex programming. Using all the above skills should be able to computer-simulate physical systems. The main objective of the course is to equip students with the necessary skills to solve problems with a computer in the further course of study.

COURSE CONTENT:

Introduction to the course and systems for computer algebra. Interface. Worksheet and cells. Elementary computing. Help system. Error messages. Programming. Lists and other containers. Flow control execution. Functions. Drawing graphs. Math. The symbolic expressions. Equations. Mathematical analysis. Linear algebra. Differential equations. Statistics. Customize function data. Examples from Physics: Mechanics.

LEARNING OUTCOMES:

After successfully passing the course the student will be able to:

1. **Quantitative perform standard calculations on computer from mathematical analysis and algebra (symbolic and numerical solution of ordinary differential equations and, symbolic and numerical integration and differentiation, manipulate matrices and vectors) within the system for computer algebra.**
2. **Statistical process the data and adjust the parameters of the model to them.**
3. **Graphically display functions or numeric fields.**
4. **Develop simple computer programs.**
5. **Numerically simulate and graphically visualize simple physical systems.**

TEACHING METHODS:

Lectures, Exercises, e-learning.

METHODS OF MONITORING AND VERIFICATION:

Regular school attendance, homework, project, on-line assessment.

TERMS FOR RECEIVING THE SIGNATURE:

Solving homework, accessing on-line assessment, preparation of final project on the computer.

EXAMINATION METHODS:

During the semester students do homework and access the on-line knowledge tests (60 points), and in the end made the final project (40 points). Grading scale is 40-54 points – 2 (sufficient), 55-69 - 3 (good), 70-84 – 4 (very good) and 85-100 - 5 (excellent).

COURSE(S) NEEDED FOR THIS COURSE:

Computing and practicum

ADDITIONAL LITERATURE:

K. Kumerički, Sage računalno okruženje za fizičare, http://www.phy.pmf.unizg.hr/~kkumer/sage/

COURSE: **General Physics 4**	
YEAR OF STUDY: **II.**	
SEMESTER: **4.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**4**
Exercises	**2**
Seminars	**1**
ECTS CREDITS: **10**	
COURSE OBJECTIVES: **Acquisition of theoretical and experimental knowledge of basic statistical physics and thermodynamics, the acquisition of operational knowledge in methods of solving numerical problems in basic statistical physics and thermodynamics, and achieve the skills of reducing the real problems of the basics of statistical physics and thermodynamics of the physical model and setting up the appropriate equations.**	
COURSE CONTENT: **Lectures:** **The macroscopic, microscopic and available thermodynamic conditions. The basic postulate of statistical physics. Steady state and fluctuations. Temperature. Entropy. The canonical distribution. The partition function. Zero law of thermodynamics. Extensive and intensive thermodynamic quantities. Temperature scale. Mean kinetic energy and pressure of an ideal classical gas. Thermometers. Paramagnetism. Negative temperature. Oscillations particulate solids: Einstein and Debyeov model. Heat capacity. Ideal classic gas: partition function. Photoelectric effect. Canonical distribution in the classical approximation of statistical physics. Equipartition of energy and its applications. Boltzmann distribution. The distribution of molecules by velocities. Thermal radiation. Planck's law of radiation of black bodies. The first, second and third laws of thermodynamics. Almost equilibrium and irreversible processes. Thermodynamic equilibrium. Thermodynamic functions of state. The enthalpy and free energy. Maxwell's thermodynamic relations. Systems of variable number of conditions. Thermodynamics of ideal gases. Isothermal, isochoric, isobaric and adiabatic processes. Maximum technically useful work. The entropy of an ideal gas. The mixture of ideal gases. Mean free path. Real gases and van der Waals equation. Phase transitions. Muted flow of real gases. Heat Engines: Carnot cycle. The steam engine, Stirling machine, petrol and diesel engines. Transport phenomena: heat transfer, diffusion, viscosity.** **Exercises:** **The macroscopic, microscopic and available thermodynamic conditions. Temperature. Entropy. The canonical distribution. The partition function. Mean kinetic energy and**	

pressure of an ideal classical gas. Paramagnetism. Negative temperature. Oscillations particulate solids. Heat capacity. Ideal classic gas: partition function. Photoelectric effect. Canonical distribution in the classical approximation of statistical physics. Equiparition. Boltzmann distribution. The distribution of molecules by velocities. Thermal radiation. Planck's law of radiation of black bodies. The first, second and third laws of thermodynamics. Almost equilibrium and irreversible processes. Thermodynamic equilibrium. Thermodynamic functions of state. The enthalpy and free energy. Maxwell's thermodynamic relations. Systems of variable number of conditions. Thermodynamics of ideal gases. Isothermal, isochoric, isobaric and adiabatic processes. The entropy of an ideal gas. The mixture of ideal gases. Mean free path. Real gases and van der Waals equation. Phase transitions. Muted flow of real gases. Heat Engines: Carnot cycle. The steam engine, Stirling machine, petrol and diesel engines. Transport phenomena: heat transfer, diffusion, viscosity.
LEARNING OUTCOMES: **Upon completion of the course General Physics 4 student will be able to:** 1. **Develop a simple physical model applicable to solving a given problem in statistical physics and thermodynamics;** 2. **Set mathematical formulation to given physical models in statistical physics and thermodynamics;** 3. **Solve numerical tasks for systems known in statistical physics and thermodynamics;** 4. **Handle operatively with statistical distributions relevant to thermodynamics;** 5. **Demonstrate knowledge of the properties of the paramagnetic, classical ideal gas, and ground vibration particle solids;** 6. **Demonstrate knowledge of the equilibrium and irreversible processes;** 7. **Demonstrate knowledge of internal combustion engines;** 8. **Demonstrate knowledge of the basics of real gases and phase transitions.**
TEACHING METHODS: **Lectures, exercises, seminars and workshops, independent work.**
METHODS OF MONITORING AND VERIFICATION: **Regular class attendance, seminars, colloquia, written and oral exams.**
TERMS FOR RECEIVING THE SIGNATURE: **Students are required to regularly attend lectures, seminars and exercises and actively participate in solving problems during exercises. Furthermore, students are required to pass two preliminary tests and four tests during the semester, and on them to achieve at least 33% of the total number of points.**
EXAMINATION METHODS: **The final exam consists of a written and oral examination. Final score is the average value of grades obtained on each of them. Rating written examination form as follows: 0-50% points – not enough to pass the exam, 51-64% of points - 2 (sufficient), 65-77% of points - 3 (good), 78-89% of points - 4 (very good), 90-100 % - 5 (excellent). Additional points can be achieved by successful solving homework assignments and competitions. Pass mark in the**

written test is possible with successfully solved Colloquium (with the same, given the above, criterion).
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1, 2, Mathematical Analysis 1, 2** **General Physics 3 (completed)**
COMPULSORY LITERATURE: **F. Reif: „Statistical Physics“, Berkeley Physics Course, vol. V, McGraw-Hill Book Company, New York, 1967.** **Script of courses are available in the Merlin e-learning system.**
ADDITIONAL LITERATURE: **Richard Feynman: Lectures in Physics II, Addison-Wesley Publishing Company, 1964.** **Hugh D. Young, Roger Freedman: Sears and Zemansky's University Physics, Pearson Addison-Wesley, 2008.**

COURSE: **Introduction to Quantum Physics**	
YEAR OF STUDY: **II.**	
SEMESTER: **4.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **2**	
COURSE OBJECTIVES: **To introduce students to the basic concepts of quantum physics, the further development of acquired mathematical skills in selected examples of finally-dimensional quantum mechanical systems and to prepare students for Quantum Physics course.**	
COURSE CONTENT: **Lectures** **The structure of matter, the basic scale, fundamental interactions, classical and quantum physics. Start of quantum physics, black body radiation - thermodynamic analysis, ultraviolet catastrophe and the quantization of energy, the photoelectric effect - Milikanov experiment and Einstein's hypothesis. Waves and particles, de Broglie hypothesis, diffraction and interference of cold neutrons, interference of particles in two gaps, and interpretation of experiments Heisenberg inequalities, the energy in classical and quantum physics. Bohr model, finally-dimensional Hilbert space, linear, Selfadjoint and unitary operators, projectors and Dirac notation. Diagonalization of Hermitian operators, properties of eigenvalues and eigenvectors, diagonalization illustrative example 2 x 2 matrix, a complete set of compatible operators and switches. The functions of the operator. Polarization of electromagnetic waves, polarizers and analyzers, linear polarization of light, circular polarization of light, a unitary transformation between the two bases of polarization, polarization and photon probability amplitude, projectors polarization along the vertical axis. Angular momentum and magnetic moment in classical physics, Stern-Gerlach experiment, the spin projection along an arbitrary axis, the rotation of the spin, the Pauli matrices and commutation relations, the dynamics of the spin system. The principle of superposition and space conditions, the probability amplitude and Bourne rule, physical properties and operators, the expected value operator, the collapse of the wave function. Heisenberg uncertainty relation, dispersion observables. The equation of evolution of the system state at the time, preserving the state standards, evolution operator, stationary states, the case of Hamiltonian that does not depend explicitly on time. Heisenberg time inequality, Schrödinger and Heisenberg pictures. Molecules of ethylene - symmetric and antisymmetric states, benzene molecule - cyclic boundary conditions, to diagonal multi-dimensional system, degeneration condition. A**	

particle of spin ½ in periodic magnetic field, Rabbi oscillations, nuclear magnetic resonance. The molecule of ammonia and skipping between configuration, resonance, atom with two states, interaction with electromagnetic field, spontaneous emission, stimulated emission. Tensor product of two vector spaces, dimensions of Product Area, Base Construction of the new space. The system of two spin ½. Operator density - definition and properties, the expected value operator, operator of density for a system of two states, reduced density operator. The time-dependent density operator, Einstein-Podolsky-Rosen paradox, Bell's inequalities, the three-particle twisted state. **Exercises** **Photoelectric effect, the wave properties of particles, the state of electrons in a hydrogen atom. Track operators and trace properties, switches and properties commutation relations. The functions of the operator, the operator of rotation. Pauli matrices, team general unitary matrices. Dispersion operators, Feynman-Hellmann theorem. Diagonalization of two-dimensional systems, the evolution of the system in time. Representation of operators in a given situation base, 3D systems and the wave function collapse. Neutrino oscillations in 2D schematic model, the symmetry of the system and structures inherent in the situation on the example of a tri-atomic molecules. Analysis molecules butane-1, 3-diene. Pauli matrices, properties and commutation relations. Systems of two particles of spin ½. Spin in a magnetic field, the systems of multiple particles in a magnetic field. Tensor coupling vector spaces, construction of spin operators in the Commodity space. Operators of raising and lowering the spin, system of three particles.**
LEARNING OUTCOMES: **Upon completion of the course Introduction to quantum physics student will be able to:** **1. list the problems of classical physics that led to the development of quantum physics - black body radiation, photoelectric effect, interference and Bohr model;** **2. explain the basic concepts of quantum mechanics - the superposition principle, the collapse of the wave function, Heisenberg inequality; and apply them to examples of polarization of light and systems spina1/2;** **3. apply the methods of linear algebra in the quantitative description of finite-dimensional quantum systems;** **4. qualitatively and quantitatively describe the stationary state of a few selected finite-dimensional quantum systems (molecules of ethylene and benzene);** **5. explain how to describe the time evolution of the quantum system and qualitatively and quantitatively describe the dynamics of spin 1/2 particles in an oscillating magnetic field (e.g. nuclear magnetic resonance);** **6. explain the tensor product of two vector spaces, calculate the dimension of the new space and construct the base, and apply this formalism to the system of two particles of spin 1/2;** **7. state the definition and properties of the operator density, calculate its eigenvalues, construct a density operator for the system of two states, and explain the concept of reduced density operators;** **8. qualitatively describe the time evolution operator density;** 9. **describe the Einstein-Podolsky-Rosen paradox, identify and explain Bell's inequalities, qualitatively and quantitatively describe three-particle interlaced state.**

TEACHING METHODS: **Lectures, exercises, independent work, and e-learning.**
METHODS OF MONITORING AND VERIFICATION: **Regular class attendance, independent work, written and oral exams.**
TERMS FOR RECEIVING THE SIGNATURE: **Students are required to regularly attend lectures and exercises (at least 70%), and actively participate in solving problems during exercises.**
EXAMINATION METHODS: **The exam consists of a written and an oral part. Written exam carries 100 credits of which 40 related to theoretical questions, and 60 on the numerical task. Rating scale at the final examination is 40-54 - 2 (sufficient), 55-69 - 3 (good), 70-84 - 4 (very good), 85-100 - 5 (excellent).**
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1, 2, Mathematical Analysis 1, 2** **General Physics 3, Classical Mechanics 1 (courses completed)**
COMPULSORY LITERATURE: **Michel Le Bellac, Quantum Physics, Cambridge University Press**

COURSE: **Mathematical Methods of Physics 2**	
YEAR OF STUDY: **II.**	
SEMESTER: **4.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**3**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **8**	

COURSE CONTENT:

Lectures:
Introduction to unitary spaces (definitions of basic concepts, properties of scalar product and the norm). The space of square-integrable functions. Orthonormal sets of vectors, vector projection on the subspace, partial Fourier series, Gibbs phenomenon. Completeness of unitary space. The classical Fourier series and its convergence. Fourier transform and it's inverse. Plancherel's theorem, uncertainty principle. Convolution. Delta function. Green's functions and ordinary differential equations. Classification of linear partial differential equations, physical examples. D'Alembert formula for (1 + 1) - dimensional wave equation. Poisson equation (the mean value theorem, the application of Green's functions). Separation of the Helmholtz equation in spherical and cylindrical coordinate system. Legendre polynomials and functions of Sphere. Bessel and Neumann functions. Variational calculus.

Exercises:
Fourier series - basic examples, orthogonality in a set of square-integrable functions. Fourier transform. Delta functions: representation, properties, multi-dimensional delta function, Jacobijan, the density distribution of matter across the delta function. Green's function for ordinary differential equations. Partial differential equations of the first order - method of characteristics. Linear partial differential equations of the second order - one-dimensional systems - introductory tasks. Linear partial differential equations of the second order - one-dimensional systems - advanced tasks, two-dimensional systems: Cartesian coordinates. Linear partial differential equations of the second order - two-dimensional systems - Cartesian and polar coordinates. Continuous systems: key function. Legendre polynomials - introductory tasks. Legendre polynomials - advanced tasks. Sphere functions. Bessel functions - introductory tasks. Bessel functions - Advanced tasks. Variational calculus without restrictions. Variational calculus with constraints.

LEARNING OUTCOMES:

Upon successful completion of the course Mathematical Methods of Physics 2, students will be able to:

1. **develop a periodic function in Fourier series**
2. **calculate the Fourier transform of the function**
3. **use the delta function in practical accounts**
4. **solve linear partial differential equations by means of separation, the method of characteristics and joint transform**
5. **solve linear ordinary and partial differential equations using Green's function.**
6. **perform separation of partial differential equations in curved coordinate systems (e.g. spherical or cylindrical)**
7. **apply special functions (Legendre polynomials, Sphere functions, Bessel and Neumann functions) in practical accounts**

TEACHING METHODS:

Lectures, Exercises.

METHODS OF MONITORING AND VERIFICATION:

Regular class attendance, colloquia, written and oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Students are required to regularly attend lectures and exercises, and actively participate in solving problems during exercises.

EXAMINATION METHODS:

Students can pass written exam through tests (2 during the semester) or via the "standard" written examination which takes place at regular periods. Marks at each examination shall be determined on a scale from 0 to 100 points, in increments of 5 points: 40-55 points -2, 60-70 points - 3 (good), 75-85 points – 4 and 90-100 points - 5 (excellent). To pass at each examination it is necessary to entirely solve at least one task, as well as to cross the threshold of scoring 40 points.

In the event of passing on both tests written exam is passed with a mean grade of colloquium. In the case where one or both of the colloquiums are not passed, the student must go to the "standard" written exam, where any extra points are transmitted, 5 points for each entirely solved task of the colloquium (up to a maximum of 20 extra points). Additional points accomplished at colloquia add up to credits on the "standard" written exam only if the exam is passed independently of them.

Overall the examination mark shall be determined after passing the oral examination, and in relation to the written exam the highest grade may differ for two marks.

COURSE(S) NEEDED FOR THIS COURSE:

Mathematical Analysis 1, 2, Mathematical Methods of Physics 1

COMPULSORY LITERATURE:

Butkov: Mathematical Physics (Addison-Wesley, 1968.)

I. Smolić: scripts for Mathematical methods of Physics 1 and 2 (available in pdf format on the website of lecturers)

S. Benić, I. Smolić: script with solved tasks from Mathematical methods of Physics 1 and 2 (available in pdf format on the website of lecturers)
ADDITIONAL LITERATURE: **G.B. Arfken, H. J. Weber: Mathematical Methods for Physicists (Academic Press, 1995.), Jefferey: Applied Partial Differential Equations (Academic Press, 1995.)**

COURSE: **Classical Mechanics 2**	
YEAR OF STUDY: **II.**	
SEMESTER: **4.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**3**
Exercises	**3**
Seminars	**0**
ECTS CREDITS: **7**	
COURSE OBJECTIVES: **The conceptual and systematic understanding of classical mechanics, as well as preparing students for follow-up of theoretical courses in their curriculum.**	
COURSE CONTENT: **Lectures:** **The equation of motion of particles in no inertial system and interpretation of individual members. The influence of the Coriolis force on the motion of bodies near the Earth's surface. Linearization of the equations of motion and stability testing of the system with n degrees of freedom. Determination of normal coordinate system. Lissajeusove path. Vibrations of molecules. Forced Oscillations, Green's function, resonance phenomena. Damped oscillation and dissipative function. Parametric resonance. Hamilton's formulation of classical mechanics. The phase space. Canonical transformation. Hamilton-Jacobi formulation of classical mechanics. Separation of variables in the Hamilton-Jacobijevoj equations. Geometric interpretation of Hamilton-Jacobi functions and connections with geometrical optics. The transition to quantum mechanics. Variable angle and action. Periodic and quasi-periodic orbits, the degeneration of the system. An example of a two-dimensional harmonic oscillator and Kepler's problem. Liouville theorem. Poincare theorem return. Poincare invariants. Poisson brackets. Invariance Poisson bracket on the canonical transformation. Infinitesimal canonical transformation. Noether theorems. Link between the Poisson bracket and quantum mechanics. Canonical perturbation and applications on systems with one or more degrees of freedom. Adiabatic invariant. Integrable and nonintegrable systems. Chaos in Hamiltonian systems.** **Exercises:** **Solving equations of motion for a particle moving near the surface of the Earth to the effects of the Coriolis force. Determination of stationary points of more variables and testing their stability. Linearization function near the minimum. Solving the system of connected harmonic oscillators. Normal coordinates. Solving equations of motion for the forced harmonic oscillator with suffocation. Solving Mathieu equation development in Fourier series. Hamilton's equations in Cartesian, cylindrical and spherical system. The**	

phase portrait of the one-dimensional conservative systems. Solving the Hamilton-Jacobi equations by separation of variables. Variable angle and action. Algebra Poisson bracket. Canonical perturbation and adiabatic invariant.

LEARNING OUTCOMES:

Upon completion of the course students will be able to:

1. **derive the equation of motion of particles in no inertial system, qualitatively describe the influence of individual members of the equation on the motion of the particles, to describe the influence of the Coriolis force on the motion of bodies near the Earth's surface.**
2. **determine the point of equilibrium systems with any number of degrees of freedom, to examine their stability and linearized equations of motion near the stable equilibrium points.**
3. **determine the normal coordinates of system of n connected harmonic oscillators, sketch paths untied two oscillators in a plane and apply the formalism of determining the normal coordinates on the flickering of two-atomic and three-atomic molecules.**
4. **perform response harmonic oscillator with a forced oscillation with and without attenuation, explain the phenomenon of resonance.**
5. **write Hill's equation and perform Floquet theorem. Perform exact and perturbative solution of Mathieu equation and sketch Inceov diagram. Apply Mathieu equation solution on examples of destabilization and stabilization of mathematical pendulum.**
6. **demonstrate knowledge of Hamilton's formulation of classical mechanics and the concept of phase space, sketch the phase portrait of a one-dimensional conservative systems.**
7. **demonstrate knowledge of the Hamilton-Jacobi formulation of classical mechanics, separated Hamilton-Jacobi equation in Cartesian, cylindrical and spherical coordinate system, explain the concept of global integrals of motion, explain the relationship between the Hamilton-Jacobi and Schrödinger equation by using the analog connections between the geometrical and physical optics.**
8. **explain the concept of variable angle and action, execute a function, probability generating function for the transformation of the variable angle and action, explain the connection between the degeneration of the system and the number of global integrals of motion.**
9. **demonstrate knowledge of algebra Poisson bracket, perform and explain Noether theorems, explain the connection formalism between the Poisson bracket and quantum mechanics.**
10. **apply canonical perturbation to the system with time dependent parameter that is changing slowly, show that at the same time the variable of action is not changing.**

TEACHING METHODS:

Lectures, Exercises, e-learning.

METHODS OF MONITORING AND VERIFICATION:

Regular class attendance, homework, midterms, written and oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

Students are required to regularly attend lectures and exercises, actively participate in solving problems in exercises and solve homework. Furthermore, students are required to pass two exams during the semester, i.e. at each colloquium achieved 7.5 out of a possible 15 points.

EXAMINATION METHODS:

Completed course in Classical Mechanics 1 is a prerequisite for taking the exam in the following courses in Classical Mechanics 2

Students are required to pass two exams during the semester, i.e. at each colloquium achieved 7.5 out of a possible 15 points. On the final exam a student can earn a maximum of 70 points, while the passage could be achieved with 25 points. It is then added to colloquia points, and the total score of the written exam is formed as follows: 40-54 points - 2 (sufficient), 55-69 points - 3 (good), 70-84 points - 4 (very good), and 85-100 -5. Overall the examination shall be determined after passing the oral examination, and in relation to the written exam the highest grade can be distinguished by one grade.

COURSE(S) NEEDED FOR THIS COURSE:

General Physics 1, 2, Mathematical Analysis 1, 2, Linear Algebra 1, 2

Classical Mechanics 1 (completed)

COMPULSORY LITERATURE:

H. Goldstein, C.P. Poole, J.L. Safko : Classical Mechanics 3rd Edition, Addison-Wesley Publishing Company, 2001

L.D. Landau, E.M. Lifschitz: Mechanics, Buttenworth-Heinemann, 2001

Spiegel M.R.: Theoretical Mechanics, Schaum's Outline Series, McGraw-Hill, 1967

G.L. Kotkin, V.G. Serbo: Collection of Problems in Classical Mechanics

ADDITIONAL LITERATURE:

V.I. Arnold, Mathematical Methods of Classical Mechanics, Springer-Verlag, 1991

COURSE: **Initial Physical Laboratory 2**	
YEAR OF STUDY: **II.**	
SEMESTER: **4.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**0**
Exercises	**4**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

Through laboratory practice students will be introduced to the basics of experimental work that is essential for the integrity of research in physics in general. Their knowledge on theoretical subjects in the field of mechanics, electricity and magnetism shall be determined and related to their own work in laboratory. They will be introduced and practiced to independently operate the basic devices for measuring mechanical and electrical physical sizes and in making the apparatus with the aim of simple experimental research. Students will, through specific situations, gain the measured data processing skills (manual and computer), and based on these results they will adopt special and general conclusions. These rounded up process for the given physical problems will developed their ability to integrate their way of solving problems in future research.

COURSE CONTENT:

Students independently perform the following Exercises rotating every two weeks:

Surface tension: precisely measured breakout force of the ring at the surface and explores the surface tension as a function of temperature and tension is measured also by the capillary effect of the surface;

The viscosity of the liquid: the viscosity coefficient dependence on temperature is explored and measured by balls falling in two viscous media;

Liquid Density: the density of water is measured through buoyancy over a wide temperature range, water anomalies and its coefficients of thermal expansion are explored;

The gas laws: study the isothermal, isochoric and isobaric change to a given quantity of air;

Lenses and optical instruments: obtaining images from different systems of lenses their focal length are determined. Various optical instruments are constructed, like telescopes, slide projector, a microscope;

Speed of light: the speed of light is determined by measuring the phase shift modulated light for various routes which she passed, and by deflection of the various components of

white light the dependence of refractive index glass prisms on the wavelength is determined;

Diffraction and interference of light: interfering images obtained with Fresnel mirrors or bi-prism and the analysis of the interference pictures determines the wavelength of laser light, a diffraction pattern obtained using cracks describes the theoretical model.

For each exercise, it is possible to work in laboratory for at least 5 full hours, which is preceded by the preparation at home.

LEARNING OUTCOMES:

Upon completion of the course, students will be able to:
• independently use measuring devices and apparatus in the field of mechanics and electromagnetism to carry out simple experiments according to the tasks and instructions;
• analyze the measured data using statistical methods handheld calculator and computer and numerically and graphically display the results;
• present the results of their work in the form of full reports;
• connect theoretical knowledge with performing Exercises and functioning of the components of the apparatus;
• generalize the results of measurements which are critically examined and interpreted in the light of the well-known theory.

TEACHING METHODS:

Laboratory

METHODS OF MONITORING AND VERIFICATION:

Students must be prepared to work before arriving at a given exercise. They must first demonstrate their preparedness, and then individually prepare the apparatus and make measurements, followed by the analysis of the results and by oral explaining and answering. Completed written report must be submitted prior to departure from the laboratory.

EXAMINATION METHODS:

Input colloquium of five short questions about the corresponding exercises must be positively evaluated. Testing during operation in the workshop on the physical background exercises, functioning instruments and apparatus, results, analysis, and other necessary knowledge related to exercise, must also result in a positive mark. Report from the assumed form must contain answers to all the tasks and include a description of the results, analysis, graphics, and earn a passing grade. Final grade is calculated from these three components respectively included with the weight of 20%, 40%, 40%, and the final score is the average of all exercises. The drop is allowed at most one exercise, but then the same must be re-done with a passing grade. Since it is fully inspected in all the essential elements when working with any exercise, there is no final exam.

COURSE(S) NEEDED FOR THIS COURSE:

Initial Physical Laboratory 1

General Physics 3 (completed)
COMPULSORY LITERATURE: **Preparations for the Exercises, for internal use** **Lectures and textbooks used at the General Physics 1, 2 and 3**
ADDITIONAL LITERATURE: **Textbooks of General Physics by choice.**

COURSE: **The Theory of Elasticity with Applications in Geophysics**	
YEAR OF STUDY: **III.**	
SEMESTER: **5. and 6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **4 + 5**	

COURSE OBJECTIVES:

Describe and analyze the stress and deformation tensors, and the coordinate transformation of the tensors. Analyses the elastic body equilibrium. Application of the analyses to the Earth's crust. Apply the stress-strain relations to real bodies, especially in cases when it is characterized by moduli of elasticity.

Synthesis of equations of motion and Hooke's law in the Lame's equations. Generalization of Lame's equations in the Navier-Stokes equation. Proof and discussion of the Lame's theorem. Kirchhoff's solution to the wave equation demonstrates retarded potentials and action at a distance. Generalized solution is analyzed in four cases, in one of which a Huygens' principle is recognized. Application of Kirchhoff's solution to single force, single-dipole and double-dipole point source models.

COURSE CONTENT:

Analysis of stress. Analysis of strain. Strain of the Earth's crust. The stress-strain relations. Constants and modules of elasticity.

Lame's equations. Motion and potential. Kirchhoff's solution of the wave equation. Application of the Kirchhoff's solution to different point source models.

LEARNING OUTCOMES:

After the final exam for the course Theory of elasticity with applications in geophysics student will be able to:

- **distinguished members of the relative displacement of the translational and rotational deformity,**
- **propose and split the potential of displacement in the translational and rotational,**
- **determine the direction and magnitude of the principal axes of stress and strain,**
- **calculate the amount of major deformation of the Earth's crust and decide which geographic direction they provide in relation to the measured values,**
- **calculate surface and volume dilatation on the basis of the known displacement,**
- **express Lame's constants and Poisson's ratio using the strain and stress of a core sample of the well, and evaluate material samples,**

- synthesize nucleation phases of the earthquakes (starting from stress-strain relations in real media),
- understand the meaning of Hooke's law and motion in the continuum,
- explain generalization Lame's equations to the Navier-Stokes equation,
- prove Lame's theorem and discuss the decomposition into the scalar and vector wave equation,
- explain the retarded potentials; derive Kirchhoff's solution in the absence of singularities, generalizing including sources,
- analyze the Kirchhoff's solution of the wave equation to find the far field solution and Huygens' principle,
- apply Kirchhoff solution to find the characteristics of radiation pattern of displacement point sources model for one force, single and double-dipole,
- describe the interpretation the spatial distribution of compression and dilatation of the first arrival of the longitudinal waves of earthquakes in terms of determining the focus mechanism.

LEARNING MODE:

- Attending of lectures, study notes and study literature,
- Derivation of the equations,
- Analysis of application examples that follow from the derived equations,
- Synthesis of resulting equations in geophysical phenomena.

TEACHING METHODS:

- Lectures, discussion,
- Derivation of the equations,
- Analysis of the equations and their analytical solutions,
- Independent solving problems in connection with equations.

METHODS OF MONITORING AND VERIFICATION:

Homework, preliminary exam, written and oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Solved homework, Seminar papers.

EXAMINATION METHODS:

Written and oral exam

COURSE(S) NEEDED FOR THIS COURSE:

General Physics 1-4, Classical Mechanics 1, 2

COMPULSORY LITERATURE:

Aki, K., P.G. Richards: Quantitative Seismology, 2nd Ed., University Science Books, Sansalito, California 2002.
Bath, M.: Mathematical Aspects of Seismology, Elsevier, Amsterdam, 1968.

COURSE: **Physical oceanography I**

YEAR OF STUDY: **III.**

SEMESTER: **5.**

TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**

ECTS CREDITS: **5**

COURSE OBJECTIVES:

The course prepares students to analyze data documenting properties of the sea, to describe spatial and temporal distribution of the properties in the world seas and oceans, and to perform elementary modeling of the properties.

COURSE CONTENT:

Subject of the course and methodology. Measurement of salinity, temperature and pressure, determination of density, analysis of water masses. Measurement of currents (indirect methods, direct methods – according to Lagrange and to Euler), of high-frequency (wave gauge) and of low-frequency (tide gauge) sea level variability. Equations of motion and continuity, equation of state and its approximations, equations of heat and salt exchange. Properties of the seas and oceans: salinity, temperature, pressure, density, water masses. Basic modeling of the spatial distribution of salinity and temperature and of the annual temperature cycle.

Exercises include analysis of vertical profiles of salinity and temperature and of horizontal distribution of these properties using subjective and objective methods. Vertical distribution of the pressure is considered as well, utilizing measured profiles of salinity and temperature.

LEARNING OUTCOMES:

Students will be able to

1. **analyze salinity and temperature data,**
2. **describe properties of the world seas and oceans,**
3. **identify factors controlling spatial distribution and temporal variability of the properties,**
4. **solve equations of the conservation of salt and heat that capture properties of the sea.**

LEARNING MODE:

1. Following the lectures as well as studying the lecture notes and literature,

2. analyzing the data (vertical and horizontal distribution).
METODE POUČANJA: **1. Presentation and discussion,** **2. Posing the problems relying on data collected primarily in the Adriatic.**
METHODS OF MONITORING AND VERIFICATION: **Attending the lectures, homeworks, written and oral examination.**
TERMS FOR RECEIVING THE SIGNATURE: **Regular attendance to the lectures, successful completion of the exercises.**
EXAMINATION METHODS: **Written and oral exam**.
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1-3, Mathematical Analysis 1, 2, Computer Science and Laboratory General Physics 4 (completed)**
COMPULSORY LITERATURE: **Knauss J. A.: Introduction to Physical Oceanography, Second Edition, Prentice Hall, New Jersey, 1996.** **Open University Course Team: Seawater – Its Composition, Properties and Behaviour, Second Edition, Butterworth-Heinemann, Oxford, 1995.** **Open University Course Team: Ocean Circulation, Second Edition, Butterworth-Heinemann, Oxford, 2001.** **Stewart R. H.: Introduction to Physical Oceanography, Department of Oceanography Texas A&M University, 2003 (http://oceanworld.tamu.edu/home/course_book.htm).** **Talley L. D., G. L. Pickard, W. J. Emery and J. H. Swift: Descriptive Physical Oceanography – An Introduction, Sixth Edition, Elsevier, Amsterdam, 2011.**

COURSE: **Seismology I**	
YEAR OF STUDY: **III.**	
SEMESTER: **5.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **5**	
COURSE OBJECTIVES: **Analyses of Earth structure, seismicity, Earth models and plate tectonics. Exploration of Earth structure using wave propagation. Interpreting and collecting macroseismic data.**	
COURSE CONTENT: **Origins, classification and distribution of the earthquakes, seismicity and structure of Earth, plate tectonics, macroseismology: macroseismic scale, interpretation of isoseismal maps. Body waves, travel time tables, Mohorovičić discontinuity, Wiechert-Herglotz method.**	
LEARNING OUTCOMES: **After completing the course, students are able to:** **- Analyse, interpret and collect macroseismic data,** **- Describe effects of earthquakes according to macroseismic scales,** **- Define basic terms of macroseismology, plate tectonics and structure of the Earth,** **- Compute macroseismic parameters of earthquakes.**	
LEARNING MODE: **Listening of the lectures, active cooperation at exercises and case study and programming.**	
TEACHING METHODS: **Lectures, exercises and case study.**	
METHODS OF MONITORING AND VERIFICATION: **Presence at lectures, exercises and colloquium. Written and oral exam.**	
TERMS FOR RECEIVING THE SIGNATURE: **The presence at lectures and preliminary exam.**	
EXAMINATION METHODS:	

Oral exam.
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1-3, Mathematical Analysis 1, 2, Linear Algebra 1, 2** **General Physics 4 (completed)**
COMPULSORY LITERATURE: **Aki, K., P. G. Richards: Quantitative Seismology, 2nd edition, University Science Books, Sausalito, California, 2002.** **Stein, S. and M. Wysession: An introduction to Seismology, Earthquakes and Earth structure, Blackwell Publ., 2003.** **Lay, T., T. C. Wallace: Modern Global Seismology, Academic Press, San Diego, 1995.** **Udias, A.: Principles of Seismology, Cambridge University Press, United Kingdom, 1999.** **Ben-Menahem, A., S. J. Singh: Seismic waves and sources, Springer Verlag, New York – Heidelberg – Berlin, 1981.**

COURSE: **Introduction to Geophysical Fluid Dynamics**	
YEAR OF STUDY: **III.**	
SEMESTER: **5.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **4**	

COURSE OBJECTIVES:

To enable students to describe and define the fundamental physical principles and processes in the atmosphere and the sea, analysis of their structure and analysis of fluids in rest and in motion.

COURSE CONTENT:

Atmosphere-ocean system: Solar radiation. Temperature distribution. Greenhouse effect. Convection. Variability of radiative forcing and consequent horizontal gradients. Atmosphere-sea interaction. Characteristics of fluid in rest – Equation of state. Thermodynamic variables. Water vapour in atmosphere. Phase transitions. Fluid parcels in equilibrium (pressure gradient force, gravity), hydrostatic equation. Vertical structure of atmosphere and sea. Static stability, Brunt-Väisälä.frequency, potential temperature, potential density. Vertical profiles and their graphical presentation. Fluid in motion – Fluid parcel. Continuity equation. Equation of conservation of scalar quantity (humidity, salinity). Heat equation. Equation of motion, Coriolis force, viscosity effects (molecular, turbulent). Scales of motion. Boundary conditions (solid boundary, material boundary, internal boundary).

LEARNING OUTCOMES:

Students will have the knowledge and skills to

1. **describe and analyze the characteristics and structure of the atmosphere and ocean,**
2. **understand and explain the basic properties of the dry and moist air and interpret associated processes,**
3. **interpret, calculate and analyse atmospheric static stability,**
4. **understand basic principles of geophysical fluid dynamics,**
5. **derive and solve equations that govern a fluid and discuss their solutions,**
6. **derive and explain the consequences of the Earth's rotation.**

LEARNING MODE:

1. **listening sessions, study the notes and literature, seminars,**

2. systematic perception and deduction, **3. case study, derivation of equations and problem solving.**
TEACHING METHODS: **1. presentation, discussion,** **2. task of equation derivation and solving numerical problems.**
METHODS OF MONITORING AND VERIFICATION: **Homework, seminar, colloquium, written and oral exam.**
TERMS FOR RECEIVING THE SIGNATURE: **Regular attendance to the lectures (at least 70%), homework, colloquium.**
EXAMINATION METHODS: **Written and oral exam.**
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1-3, Mathematical Analysis 1, 2, Linear Algebra 1, 2** **General Physics 4 (completed)**
COMPULSORY LITERATURE: **Gill, A., 1982: Atmosphere-Ocean Dynamics. Academic Press, Orlando. 662 str.** **Cushman-Roisin, B., 1994: Introduction to Geophysical Fluid Dynamics, Prentice Hall, London, 320 str.** **Kundu, P. K., 1990: Fluid mechanics. Academic Press, San Diego, 638 str.**

COURSE: **Introduction to Spectral Analysis**	
YEAR OF STUDY: **III.**	
SEMESTER: **5.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

Enable students for application of basic tools in spectral analyses, especially dealing with geophysical time-series.

COURSE CONTENT:

Types of data. Fourier series and its complex form. Fourier integral. Inverse Fourier transformation. Power density spectrum, Autocorrelation function and its link to the power spectrum. Properties of physical systems with respect to the frequency. Dirac delta function, properties and applications. Dirac's comb and its Fourier pair. Digital filtering, convolution integral, ideal low-pass filter. Filtering discrete data. Trend. Sampling and aliasing. Sampling theorem. Data samples of finite length.

LEARNING OUTCOMES:

After completing the course on Introduction to Spectral Analyses students are able to:

– identify time-series appropriate to be analysed by harmonic or by spectral analyses,
– analyse data by Fourier series expansion,
– compute amplitude and phase spectra for periodic and transient data,
– define amplitude- and phase-spectra, and the power density spectra,
– compare physical systems according to their frequency response,
– define Dirac's delta-function and its basic properties,
– perform time-domain filtering with ideal filters,
– argue for the choice of the sampling interval for analysed time-series.

LEARNING MODE:

– Attending lectures, study of literature and lecture notes,
– Derivation of the equations and case study.

TEACHING METHODS:

- Lectures, discussions,
- Derivation of the equations,

- Solving problems.
METHODS OF MONITORING AND VERIFICATION: **Regularly attending lectures, problem solved. Colloquium and oral exam.**
TERMS FOR RECEIVING THE SIGNATURE: **Solved task and a short report, attendance of lectures.**
EXAMINATION METHODS: **Oral exam.**
COURSE(S) NEEDED FOR THIS COURSE: **Mathematical Analysis 1, 2, Mathematical methods of physics 1,** **Mathematical methods of physics 2 (completed)**
COMPULSORY LITERATURE: **Bath, M. Spectral analysis in geophysics, Elsevier, Amsterdam, 1974.** **Bracewell, R. N: The Fourier transform and its applications, McGraw-Hill, New York, 1983.** **Papoulis, A: The Fourier integral and its applications, McGraw-Hill, New York, 1962.**

COURSE: **Advanced physical practicum I**	
YEAR OF STUDY: **III.**	
SEMESTER: **5.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**0**
Exercises	**4**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

By performing advanced lab exercises, students will learn about the more complex aspects of experimental work, which is an indispensable part of research in physics. The knowledge gained from lectures in general physics students will deepen by experimental work on individual problems, contributing to deeper understanding of individual topics and acquiring experimental experience. They will be introduced and practiced in the separate use of advanced devices for measurement of physical quantities and in assembling the apparatus with the aim of experimental research. At the advanced physical practicum students have great autonomy in solving tasks, and each exercise is done in two consecutive terms, which allows them to form a working hypothesis after the first experimental results, that after further measurements can be confirmed or rejected. In this way, students will develop a comprehensive ability to solve problems in future research.

COURSE CONTENT:

Students independently perform five of the following 10 exercises:
Joule-Thomson effect: Students experimentally determined Joule-Thomson coefficient of N_2 and CO_2 emissions, and compare the results with literature values and theoretical models.
Barometric formula: Students use the apparatus to simulate the thermodynamic phenomena using glass balls comparing the number of balls height with barometric formula predicted results.
Electrical oscillating circuit: Students study the dependence of impedance and phase shift for serial and parallel RLC circuit. Also, study the damped oscillations in RLC circuit.
Measurement of low resistance: Students learn to measure electrical resistance method with four relays, and by van der Pauw method.
Modulus of elasticity: Students measure the deformation dependence of the force with metal bars.
Free and forced oscillation: Using torsional pendulum with damping and excitation, students study the behavior of free oscillators, damped and driven oscillators and damped oscillators.
Coupled pendulums: Students study phenomena in coupled oscillation of the pendulum:

the oscillation of the phase oscillation in antiphase, and the regime of shock.
Stefan-Boltzmann law of radiation: Students use Moll thermopile and incandescent lamps to experimentally determine energy exitance dependence on body temperature, and compare observations with the Stefan-Boltzmann law.
Specific electron charge: Students use a vacuum tube in which electrons accelerate by an electron gun, and swing using magnetic fields. By measuring the diameter of the electron and the applied voltage and the magnetic field, specific electron charge is determined.
Magnetic susceptibility of liquids: Students measure the magnetic susceptibility solution with different concentrations of paramagnetic salts.
Student makes each exercise in two consecutive terms.

LEARNING OUTCOMES:

Upon completion of the course, students will be able to:
• independently use measuring devices and apparatus in the field of mechanics, electromagnetism, optics and thermodynamics, to perform complex experiments;
• analyze the measured data using statistical methods and graph the results;
• present the results of their work in the form of a written report, which is structured as a scientific work, as well as a short oral report, which is structured as a lecture at a scientific conference;
• connect theoretical knowledge with performing exercises and functioning of the components of the apparatus;
• generalize the results of measurements and critically examine and interpret in the light of the well-known theory.

LEARNING MODE:

Introduction to the physical basics before each Exercise. Regular preparation of reports. Preparation and presentation of seminars. Mandatory attendance to seminars.

TEACHING METHODS:

Laboratory

METHODS OF MONITORING AND VERIFICATION:

Students must be prepared in advance before arriving at a given exercise. Students independently compile apparatus and carry out measurements. On the second term students repeat measurements or carry out additional measurements and orally answer questions. Written report is submitted at next lab. At the end of the last practicum students orally present their results.

TERMS FOR RECEIVING THE SIGNATURE:

All the exercises and seminars completed.

EXAMINATION METHODS:

During the course students orally recite on every exercise and submit a written report after each exercise that are also evaluated. At the end of the practicum assistants conclude the final assessment of the oral tests and written reports. Students orally present results on the last practicum before the practicum coordinator, who further examined then and

concludes the final grade. By weight of certain factors the final grade is distributed on an oral answer 30%, written reports 40%, and the final presentation 30%.
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1-4, Initial Physical Laboratory 1, 2**
COMPULSORY LITERATURE: **Preparations for the Exercises, for internal use** **Textbooks for General Physics 1, 2, 3 and 4**

COURSE: **Computing and Numerical Mathematics**	
YEAR OF STUDY: **III.**	
SEMESTER: **5.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

Student will be able to use Linux, Matlab and Fortran at basic level and to apply basic methods of numerical mathematics by using computer.

COURSE CONTENT:

Short review of GNU/LINUX operating system, Matlab and Fortran, errors in numerical computing (error types and floating point arithmetic), evaluation of polynomials and their derivatives, summation of series, recursions, nonlinear equations (methods of bracketing, secant and Newton), approximations of functions (polynomial interpolation, Chebishev and Fourier approximation), least squares method, orthogonal bases, global and local smoothing, numerical differentiation, numerical integration (Newton-Cotes and Gauss formulae), basics of numerical linear algebra (systems of linear equations, matrix condition number, basics of perturbation theory).

LEARNING OUTCOMES:

Students will be able to:
- **state basic features of the GNU/Linux operating system, of Matlab computing system and Fortran programing language**
- **use Linux, Matlab and Fortran at primary level**
- **explain and compare the round-off error and truncation error**
- **evaluate polynomial and sum of function series and identify problems that can affect the calculation**
- **apply least square method to approximation of functions**
- **calculate numerically derivative and integral and provide the error estimate**

LEARNING MODE:

- **attending lectures, study of literature and lecture notes**
- **analyzing of examples, solving of assigned problems by using computer**
- **doing homework**

TEACHING METHODS:

- **presentation, discussion**
- **problem solving by using computer**

METHODS OF MONITORING AND VERIFICATION:

Preliminary, written and oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Attending the lectures, homeworks (correctly solved at least 50%), colloquium, written and oral exam.

EXAMINATION METHODS:

Written and oral exam.

COURSE(S) NEEDED FOR THIS COURSE:

Mathematical Analysis 1, 2, Linear Algebra 1, 2, Mathematical Methods of Physics 1

Mathematical methods of physics 2 (completed)

COMPULSORY LITERATURE:

Z. Drmač, M. Marušić, M. Rogina, S. Singer, S. Singer: Numerička analiza, script on the Internet, 2003/2004.

ADDITIONAL LITERATURE:

J. H. Mathews, K. D. Fink: Numerical Methods using Matlab, Prentice Hall, New Jersey, 2004.

W. H. Press , S. A. Teukolsky , W. T. Vetterling , B. P. Flannery: Numerical Recipes in Fortran 90, electronic edition (http://www.nrbook.com/nr3/).

M. Metcalf, J. Reid: FORTRAN 90/95 Explained, Oxford Univ. Press, 1999.

T. M. R. Ellis, I. R. Philips, T. M. Lahey: Fortran 90 Programming, Addison-Wesley, 1996.

Z. Pasarić: Kratki uvod u Matlab, script on the Internet, 2004. (http://skola.gfz.hr/kratki_uvod_u_matlab.pdf).

COURSE: **Statistical Methods in Geophysics**	
YEAR OF STUDY: **III.**	
SEMESTER: **5.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

To enable student to apply basic statistical methods in geophysical context and to critically examine the obtained results.

COURSE CONTENT:

Elements of probability, conditional probability, Bayes theorem, Bayes factor, persistence as conditional probability. Random variables and vectors, mathematical expectation, joint, marginal and conditional distributions, independence. Descriptive statistics. Empirical distributions and parameter fitting. Some theoretical distributions with application in geophysics. Hypothesis testing. Simple and multiple linear regression with geometrical interpretation. Bivariate normal distribution. Basics of time-series analysis. Tests for data homogeneity.

LEARNING OUTCOMES:

Students will be able to:

- **define and discuss basic probability terms**
- **distinguish types of random variables and describe their properties**
- **apply mathematical expectation in practice**
- **relate the independence of random variables with the intuitive idea of independence**
- **relate properties of random variables with statistical attributes of empirical data sets**
- **explain and apply methods for parameter estimation**
- **define and recognize applicability of theoretical probability distributions**
- **critically apply statistical tests**
- **explain and apply the method of linear regression using the geometrical representation.**

LEARNING MODE:

- **attending lectures, study of literature and lecture notes**
- **analyzing examples, solving of assigned problems**

- **doing homework based on small sets of real data**
TEACHING METHODS: - **presentation, discussion** - **problems to be solved by student himself**
METHODS OF MONITORING AND VERIFICATION: **Preliminary, written and oral exam.**
TERMS FOR RECEIVING THE SIGNATURE: **Regular class attendance. Homework.**
EXAMINATION METHODS: **Written and oral exam.**
COURSE(S) NEEDED FOR THIS COURSE: **Mathematical Analysis 1, 2, Linear Algebra 1, 2, Statistics and basic measurements**
COMPULSORY LITERATURE: **Wilks, D.S.: Statistical Methods in the Atmospheric Sciences, Academic Press, New Yorak, 2011.**
ADDITIONAL LITERATURE: **Penzar B., B. Makjanić: Osnovna statistička obrada podataka u klimatologiji, Sveučilište u Zagrebu, 1978.**

COURSE: **Physical Oceanography II**	
YEAR OF STUDY: **III.**	
SEMESTER: **6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **5**	

COURSE OBJECTIVES:

The course prepares students to analyze data documenting sea motion, to describe spatial and temporal distribution of currents and wave dynamics in the world seas and oceans, and to perform elementary modeling of the motion.

COURSE CONTENT:

Quasi-steady currents: geostrophic/hydrostatic model, currents in the seas and oceans, wind-driven currents (Ekman model), thermohaline currents (simple diffusion model). Free waves: model of waves in deep and shallow water and its use in the interpretation of swell and tsunami, gravity-inertia and Rossby waves. Forced waves: tides, response of the sea to the air pressure and wind forcing (storm surges), thermohaline forcing and its influence on annual variability of temperature, salinity and sea level.

Exercises include a basic analysis of current and sea level time series. Besides, the series are subjected to filtering and spectral analysis.

LEARNING OUTCOMES:

Students will be able to
1. **analyze current and sea-level data,**
2. **describe currents and wave dynamics of the world seas and oceans,**
3. **identify factors controlling spatial distribution and temporal variability of the motion,**
4. **solve equations of motion and continuity that capture the sea motion.**

LEARNING MODE:

1. **following the lectures as well as studying the lecture notes and literature,**
2. **analyzing the data (time series of currents and sea level).**

TEACHING METHODS:

1. Presentation and discussion,
2. Posing the problems relying on data collected primarily in the Adriatic.

METHODS OF MONITORING AND VERIFICATION: **Attending the lectures, homeworks, written and oral examination.**
TERMS FOR RECEIVING THE SIGNATURE: **Regular attendance to the lectures, successful completion of the exercises.**
EXAMINATION METHODS: **Written and oral examination.**
COURSE(S) NEEDED FOR THIS COURSE: **Physical Oceanography I (completed)**
COMPULSORY LITERATURE: **Bowden K. F.: Physical Oceanography of Coastal Waters, Ellis Horwood, Chichester, 1983.** **Cushman-Roisin B. and J.-M. Beckers: Introduction to Geophysical Fluid Dynamics, Second Edition, Elsevier, Amsterdam, 2011.** **Knauss J. A.: Introduction to Physical Oceanography, Second Edition, Prentice Hall, New Jersey, 1996.** **Open University Course Team: Ocean Circulation, Second Edition, Butterworth-Heinemann, Oxford, 2001.** **Open University Course Team: Waves, Tides and Shallow-Water Processes, Second Edition, Butterworth-Heinemann, Oxford, 2002.** **Pond S. and G. L. Pickard: Introductory Dynamical Oceanography, Third Edition, Butterworth-Heinemann, Oxford, 1997.** **Stewart R. H.: Introduction to Physical Oceanography, Department of Oceanography Texas A&M University, 2003 (http://oceanworld.tamu.edu/home/course_book.htm).**

COURSE: **Seismology II**	
YEAR OF STUDY: **III.**	
SEMESTER: **6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **5**	

COURSE OBJECTIVES:

Introduction to the physics of generation and propagation of body and surface elastic waves, and study of their basic properties in simple Earth models.

COURSE CONTENT:

1. Basic theory of elasticity (repetitorium), 2-3. Navier and wave equations and their solutions: Helmholtz theorem, elastic potentials, 4. Fourier principle of superposition. Snell's law, ray parameter. P, SV, SH-waves. 5-6. Reflection on the free surface: conversion of phases, coefficients of reflection and conversion. 7. Inhomogeneous waves. 8-9. Rayleigh waves in half-space, eigenfunctions. 10-12. Love waves in a layer over halfspace, period equation, dispersion, modes. 12-13. Phase and group velocity.

LEARNING OUTCOMES:

After completing the course students can:
- **Define elastic wave types and their properties.**
- **Apply the Helmholtz theorem in solving the Navier equation.**
- **Distinguish between three types of motion (P, SV, SH), and define them.**
- **Distinguish between homogeneous and inhomogeneous waves, and define them.**
- **Define boundary conditions end derive reflection and conversion coefficients for P-SV waves at the free surface.**
- **Define boundary conditions end derive reflection and refraction coefficients for SH waves at the boundary between two media.**
- **Define boundary conditions and derive period equations for surface waves in the simplest Earth models; discuss the period equation for Love waves and argue for existence of modes and dispersion.**
- **Analyse and compute eigenfunctions for Rayleigh waves in the homogeneous halfspace.**
- **Describe oscillation of particles on the free surface during the passage of Rayleigh waves.**
- **Define the phase and group velocity, and compute one from the other.**

LEARNING MODE:

– Studying textbook and other literature (including lecture notes), attending lectures, **– Derivation of the equations and study of examples.**
TEACHING METHODS: **– lectures, discussions** **– derivations of the equations** **– solving problems**
METHODS OF MONITORING AND VERIFICATION: **Attending lectures, solved homeworks; Attending the Geophysical seminar (at least 75%). Written colloquium and oral exam.**
TERMS FOR RECEIVING THE SIGNATURE: **Solved homeworks, and written report.**
EXAMINATION METHODS: **Oral exam.**
COURSE(S) NEEDED FOR THIS COURSE: **Introduction to spectral analysis (completed)**
COMPULSORY LITERATURE: **Aki, K., P. G. Richards: Quantitative Seismology, 2nd edition, University Science Books, Sausalito, California, 2002.** **Stein, S. and M. Wysession: An introduction to Seismology, Earthquakes and Earth structure, Blackwell Publ., 2003.** **Lay, T., T. C. Wallace: Modern Global Seismology, Academic Press, San Diego, 1995.** **Udias, A.: Principles of Seismology, Cambridge University Press, United Kingdom, 1999.** **Ben-Menahem, A., S. J. Singh: Seismic waves and sources, Springer Verlag, New York – Heidelberg – Berlin, 1981.**

COURSE: **Advanced Physical Practicum II**	
YEAR OF STUDY: **III.**	
SEMESTER: **6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**0**
Exercises	**4**
Seminars	**0**
ECTS CREDITS: **3**	

COURSE OBJECTIVES:

By performing advanced lab exercises, students will learn about the more complex aspects of experimental work, which is an indispensable part of research in physics. The knowledge gained from lectures in general physics students will deepen by experimental work on individual problems, contributing to deeper understanding of individual topics and acquiring experimental experience. They will be introduced and practiced in the separate use of advanced devices for measurement of physical quantities and in assembling the apparatus with the aim of experimental research. At the advanced physical practicum students have great autonomy in solving tasks, and each exercise is done in two consecutive terms, which allows them to form a working hypothesis after the first experimental results, that after further measurements can be confirmed or rejected. In this way, will develop a comprehensive ability to solve problems in future research.

COURSE CONTENT:

Students independently perform five of the following 10 exercises:

Free and forced oscillations: Using torsional pendulum with suffocation and excitation, students study the behavior of free oscillators, dumped oscillators and driven and dumped oscillators.

Coupled pendulums: Students study phenomena in coupled oscillation of the pendulum: the oscillation of the phase oscillation in antiphase, and the regime of shock.

Stefan-Boltzmann law of radiation: Students use Moll thermopile and incandescent lamps to experimentally determine energy exitance dependence on body temperature, and compare observations with the Stefan-Boltzmann law.

Franck-Hertz experiment: Students perform Franck-Hertz experiment on the apparatus with neon tubes.

Magnetic susceptibility of liquids: Students measure the magnetic susceptibility solution with different concentrations of paramagnetic salts.

Photoelectric effect and Planck's constant. Polarization of light: Students using the

photoelectric effect determine the value of Planck's constant. In the second part of exercise linear polarizers and λ / 4 tiles are used for polarizing light.

Maxwell-Boltzmann distribution of speed: Students use the apparatus to simulate the thermodynamic phenomena using glass balls to study the distribution of speed.

Chaotic oscillations in an electric oscillating circuit: Students examine the emergence of chaotic oscillations in the electrical oscillating circuit with non-linear element (diode).

Measurement of low resistance: Students learn to measure electrical resistance method with four relays, and by van der Pauw method.

Skin effect: Students measure the thickness of the conductive layer (the skin) in the metal bars.

Student makes each exercise in two consecutive terms.

LEARNING OUTCOMES:

Upon completion of the course, students will be able to:

- independently use measuring devices and apparatus in the field of mechanics, electromagnetism, optics, thermodynamics and quantum physics, to perform complex experiments;
- analyze the measured data using statistical methods and graph the results;
- present the results of their work in the form of a written report, which is structured as a scientific work, as well as a short oral report, which is structured as a lecture at a scientific conference;
- connect theoretical knowledge with performing exercises and functioning of the components of the apparatus;
- generalize the results of measurements and critically examine and interpret in the light of the well-known theory.

LEARNING MODE:

Students must be prepared in advance before arriving at a given exercise. Students independently compile apparatus and carry out measurements. On the second term students repeat measurements or carry out additional measurements and orally answer questions. Written report is submitted at next lab. At the end of the last practicum students orally present their results.

TEACHING METHODS:

Laboratory

METHODS OF MONITORING AND VERIFICATION:

The papers, preliminary exams, oral exams.

TERMS FOR RECEIVING THE SIGNATURE:

All exercises completed, papers submitted and seminars held.

EXAMINATION METHODS:

During the course students orally recite on every exercise and submit a written report after

each exercise that are also evaluated. At the end of the practicum assistants conclude the final assessment of the oral tests and written reports. Students orally present results on the last practicum before the practicum coordinator, who further examined then and concludes the final grade. By weight of certain factors the final grade is distributed on an oral answer 30%, written reports 40%, the final presentation 30%.
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1-4, Advanced physical practice 1**
COMPULSORY LITERATURE: **Preparations for the Exercises, for internal use** **Textbooks for General Physics 1, 2, 3 and 4**

COURSE: **Seismometry**	
YEAR OF STUDY: **III.**	
SEMESTER: **6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **2**	
COURSE OBJECTIVES: **Description and analyses of response of dynamic systems. Comparison of transfer function with frequency response and application on seismograph. Comparison with dynamic magnification of mechanical seismograph. Generalisation to the system of n-degrees. Achieve seismograph calibration skills and competency for using the seismograph by measuring the electromagnetic and broadband seismograph characteristics. Distinguishing seismograph types, and introduce the measurement of time as unavoidable factor in geophysical observations and measurements.**	
COURSE CONTENT: **Seismograph as a measurement system. Characteristics of static and dynamic measurement systems (transfer function, frequency response function, poles and zeros). Mechanical seismograph (indicator equation, dynamic magnification, main parts, construction), electromechanical seismograph (dynamic characteristics, main parts, construction). Experimental measurement and frequency response estimation, broadband seismographs. Accelerographs. Time and GPS.**	
LEARNING OUTCOMES: **After completing the course of Seismometry, the student should be able to:** **- Describe and analyze the responses (characteristics) of dynamical measurement systems,** **- Determine the transfer function and frequency characteristics of the RC-circuit and seismographs using Laplace and Fourier transforms, and generalise findings to the n-degree system,** **- Analyze the dynamical system using the poles and zeros of a transfer function,** **- Assemble electromagnetic seismograph from components, and calibrate it for a number of frequencies,** **- Calculate and graphically display the measured frequency response, and analyze the working range of the instrument.**	
LEARNING MODE:	

- **Derivation of the equations and analysis of examples.**
- **Assembling the instrument and measuring parameters following from derived equations.**
- **Graphical presentation of measured parameters and graph analyses.**

TEACHING METHODS:

- Lectures, discussion and derivation of the equations.
- Problem solving.
- Practical assembling the instruments under guidance.
- Making individual written report about measuring and results.

METHODS OF MONITORING AND VERIFICATION:

Solved homeworks, and written report. Oral exam.

TERMS FOR RECEIVING THE SIGNATURE:

Solved homework, completed practically measuring and positive written report on the measurement results and analysis.

EXAMINATION METHODS:

Oral exam.

COURSE(S) NEEDED FOR THIS COURSE:

General Physics 1-4, Initial Physical Laboratory 1, 2, Classical Mechanics 1, 2, Mathematical Methods of Physics 1, 2

Introduction to spectral analysis (completed)

COMPULSORY LITERATURE:

Scherbaum, F.: Of Poles and Zeros, Kluwer Academic Publishers, Dodrecht, Nederlands 1996.

Šantić, A. Elektronička instrumentacija, Školska knjiga, Zagreb 1988.

Skoko, D.: Osnove teorije seizmografa, Institut za zemljotresno inženerstvo i inženerska seizmologija na Univerzitetot "Kiril i Metodij", Skopje 1981.

COURSE: **Dynamic Meteorology I**	
YEAR OF STUDY: **III.**	
SEMESTER: **6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**4**
Exercises	**2**
Seminars	**0**
ECTS CREDITS: **8**	

COURSE OBJECTIVES:

To provide the students with a foundation for developing their knowledge in laws on statics, dynamics and kinematics of dry and moist atmosphere. To provide students with the ability to recognize different types of atmospheric motions as a consequence of physical processes on different temporal-spatial scales.

COURSE CONTENT:

General knowledge on Earth and atmosphere. Air parcel. Types of equilibrium processes. Processes in dry atmosphere. Thermodynamics of the dry air, water substance and moist air. Measures of air humidity. Processes of humid and saturated air. Hydrostatic equilibrium. Boussinesq approximation. Vertical cells. Fundamental and pseudo-forces. Equation of motion in spherical coordinates. Scale analysis of atmospheric processes. Primitive equations in isobaric, isentropic, sigma and system with generalized vertical coordinate. Natural coordinate system, gradient, geostrophic, cyclostrophic and inertial motion. Trajectories and streamlines. Bjerknes circulation theorem. Barotropic and baroclinic atmosphere, solenoids, thermal wind. Vorticity equation. Conservation of absolute vorticity. Shallow fluid. Potential vorticity. Lee cyclogenesis. Equation of divergence. Helmholtz theorem. Balance equation. Rossby waves in geostrophic and quasigeostrophic atmosphere. Rossby's radius of deformation. Fundamentals of general circulation of atmosphere. Zonal index. Fultz's experiments.

LEARNING OUTCOMES:

After completing the course and passing the exam it is expected that student can:
- **Name all forces that affect air parcels, and knows how to calculate their magnitudes**
- **Distinguish between fundamental and pseudo-forces**
- **Interpret terms in equations of motion**
- **Discuss magnitudes of the terms in equations of motions with respect to spatio-temporal scales of motion and identify those terms which can be neglected at particular spatio-temporal scale**
- **Name theoretical equilibrium processes and recognize which theoretical processes are good approximations of real atmospheric processes**

- **Distinguish between thermodynamic processes of a dry and moist air**
- **Recognize various equilibrium airflows and identify reasons why these airflows differ one from another**
- **Distinguish between various atmospheric disturbances in pressure field and categorize them based on (non)amplification of the amplitude of disturbance.**

LEARNING MODE:

- Class attendance and learning from class notes
- The study of mandatory and compulsory literature
- Solving homework tasks
- Active participation in the discussion of the homework results

TEACHING METHODS:

- lectures
- exercises
- assigned homework tasks
- websites
- the use of an intranet
- consultation

METHODS OF MONITORING AND VERIFICATION:

- regular attendance of lectures with an active approach
- monitoring the class attendance
- completed all assigned homework tasks via intranet

TERMS FOR RECEIVING THE SIGNATURE:

Regular attendance of lectures (at least 75%) and completed homework (at least 80%).

EXAMINATION METHODS:

Written and oral exam.

COURSE(S) NEEDED FOR THIS COURSE:

Introduction to geophysical fluid dynamics (completed)

COMPULSORY LITERATURE:

Holton, J. R., 2004: An introduction to dynamic meteorology. Elsevier Academic Press, Amsterdam, 535 str.

Bluestein, H. B., 1992: Synoptic-dynamic meteorology in midlatitudes, Vol. I: Principles of kinematics and dynamics. Oxford

University Press, New York, 431 str.

Bluestein, H. B., 1993: Synoptic-dynamic meteorology in midlatitudes, Vol. II: Observations and theory of weather systems.

Oxford University Press, New York, 594 str.

Kundu, P. K., 1990: Fluid mechanics. Academic Press, San Diego, 638 str.

Recent articles from professional journals.

COURSE: **Meteorological Measurements**	
YEAR OF STUDY: **III.**	
SEMESTER: **6.**	
TEACHING METHODS	CONTACT HRS PER WEEK
Lectures	**2**
Exercises	**1**
Seminars	**0**
ECTS CREDITS: **2**	

COURSE OBJECTIVES:

The students will be introduced to meteorological measurements and observations of various atmospheric phenomena and states. They will learn how to connect certain meteorological variables and their spatio-temporal changes with the atmospheric states and changes (causal-consecutive relations). Various types and functioning of meteorological measuring devices are addressed.

COURSE CONTENT:

Meteorological measurements and observations. Visual observations of meteorological phenomena, clouds, cloudiness and wind intensity. Meteorological symbols. Meteorological diaries. Ground and aerological instrumental measurements in the atmosphere: precipitation, temperature, pressure, humidity, wind, short- and long-wave solar radiation. Automatic weather stations. Remote and satellite measurements. Exchange and types of meteoinformations (charts, Internet). World meteorological Organisation (WMO).

LEARNING OUTCOMES:

After completion of the course the students will be able to:

1. **Measure and observe meteorological quantities and phenomena**
2. **Note measured quantities and observed phenomena (by symbols) into measurement diary**
3. **Distinguish the clouds by form, origin, composition and height**
4. **Calculate necessary corrections determining the atmospheric pressure with mercury barometer**
5. **Expose the work of classical and electronic meteorological instruments, radars and satellites**
6. **Expose the difference between classical and automatic weather stations**
7. **Distinguish dynamical and static characteristics of the meteorological measuring instruments**
8. **Understand the role of World Meteorological Organisation.**

LEARNING MODE: **1. Listening lectures studying note, literatures and Internet materials;** **2. Problem solving.**
TEACHING METHODS: **1. Presentation with discussion** **2. Problem solving** **3. Performing practical measurements and observations and presentation of results**
METHODS OF MONITORING AND VERIFICATION: **Colloquiums and oral exam.**
TERMS FOR RECEIVING THE SIGNATURE: **Clouds recognition colloquium.**
EXAMINATION METHODS: **Oral exam.**
COURSE(S) NEEDED FOR THIS COURSE: **General Physics 1-4, Mathematical Analysis 1, 2, Initial Physical Laboratory 2**
COMPULSORY LITERATURE: **Ludlum D. M.: National Audubon Society: Field Guide to North American Weather, Chantideer Press Inc. N.Y. 1997.** **Houhghton D. D. (ur.): Handbook of Applied Meteorology, Wiley, N.Y. 1985.**

List of all the changes that have been made since 2005 in the undergraduate study of geophysics

Changes made to the above study program can be divided into the following groups:

1. Change of teachers on courses (due to teachers election to a new scientific-educational / teaching professional position, due to the reduction of teachers teaching hours, or due to a teachers retirement)

2. Introduction of a new one-semester compulsory courses (63 385) Computer Science and Numerical Mathematics (for a free 3-hour classes per week in the fifth semester), load 3 ECTS credits, contact hrs per week 2 + 1, and therefore the redistribution of credits for the courses (45282) Theory of elasticity with applications in geophysics (4 instead of 5 ECTS credits), (66357) Introduction to spectral analysis (3 instead of 4 ECTS credits) and (66356) Introduction to Geophysical Fluid Dynamics (4 instead of 5 ECTS credits).

3. Change of the status of the college predecessor for course enrollment (45282) Theory of elasticity with applications in geophysics and (66357) Introduction to spectral analysis, the winter semester of the third year of the study (due to the relaxation of the conditions of entry of all 5th semester courses).

4. Minor changes in the course program (44430) Meteorological measurements with the aim of introducing modern knowledge, as well as amendments to the skills required for the practical application of the measurement data.