University of Debrecen
Faculty of Science and Technology
Institute of Physics

PHYSICS BSC PROGRAM

2021

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DEAN`S WELCOME

Welcome to the Faculty of Science and Technology!

This is an exciting time for you, and I encourage you to take advantage of all that the Faculty of Science and Technology UD offers you during your bachelor's or master's studies. I hope that your time here will be both academically productive and personally rewarding

Being a regional centre for research, development and innovation, our Faculty has always regarded training highly qualified professionals as a priority. Since the establishment of the Faculty in 1949, we have traditionally been teaching and working in all aspects of Science and have been preparing students for the challenges of teaching. Our internationally renowned research teams guarantee that all students gain a high quality of expertise and knowledge. Students can also take part in research and development work, guided by professors with vast international experience.

While proud of our traditions, we seek continuous improvement, keeping in tune with the challenges of the modern age. To meet the demand of the job market for professionals, we offer engineering courses with a strong scientific basis, thus expanding our training spectrum in the field of technology. Based on the fruitful collaboration with our industrial partners, recently, we successfully introduced dual-track training programmes in our constantly evolving engineering courses.

We are committed to providing our students with valuable knowledge and professional work experience, so that they can enter the job market with competitive degrees. To ensure this, we maintain a close relationship with the most important national and international companies. The basis for our network of industrial relationships are in our off-site departments at various different companies, through which market participants - future employers - are also included in the development and training of our students.

Prof. dr. Ferenc Kun
Dean

UNIVERSITY OF DEBRECEN

Date of foundation: 1912 Hungarian Royal University of Sciences, 2000 University of Debrecen

Legal predecessors: Debrecen University of Agricultural Sciences; Debrecen Medical University; Wargha István College of Education, Hajdúböszörmény; Kossuth Lajos University of Arts and Sciences

Number of Faculties at the University of Debrecen: 14

Faculty of Agricultural and Food Sciences and Environmental Management

Faculty of Child and Special Needs Education

Faculty of Dentistry

Faculty of Economics and Business

Faculty of Engineering

Faculty of Health

Faculty of Humanities

Faculty of Informatics

Faculty of Law

Faculty of Medicine

Faculty of Music

Faculty of Pharmacy

Faculty of Public Health

Faculty of Science and Technology

Number of students at the University of Debrecen: 29,045

Full time teachers of the University of Debrecen: 1,541

200 full university professors and 1,205 lecturers with a PhD.

FACULTY OF SCIENCE AND TECHNOLOGY

The Faculty of Science and Technology is currently one of the largest faculties of the University of Debrecen with about 3000 students and more than 200 staff members. The Faculty has got 6 institutes: Institute of Biology and Ecology, Institute of Biotechnology, Institute of Chemistry, Institute of Earth Sciences, Institute of Physics and Institute of Mathematics. The Faculty has a very wide scope of education dominated by science and technology (10 Bachelor programs and 12 Master programs), additionally it has a significant variety of teachers' training programs. Our teaching activities are based on a strong academic and industrial background, where highly qualified teachers with a scientific degree involve student in research and development projects as part of their curriculum. We are proud of our scientific excellence and of the application-oriented teaching programs with a strong industrial support. The number of international students of our faculty is continuously growing (currently ~650 students). The attractiveness of our education is indicated by the popularity of the Faculty in terms of incoming Erasmus students, as well.

THE ORGANIZATIONAL STRUCTURE OF THE FACULTY

Dean: Prof. Dr. Ferenc Kun, Full Professor
E-mail: ttkdekan@science.unideb.hu

Vice Dean for Educational Affairs: Prof. Dr. Gábor Kozma, Full Professor
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Vice Dean for Scientific Affairs: Prof. Dr. Sándor Kéki, Full Professor
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Consultant on External Relationships: Prof. Dr. Attila Bérczes, Full Professor
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Dean's Office
Head of Dean's Office: Ms. Katalin Tóth
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English Program Officer: Mr. Imre Varga – Applied Mathematics (MSc), Chemical Engineering (BSc/MSc), Chemistry (BSc/MSc), Earth Sciences (BSc), Electrical Engineering (BSc), Geography (BSc/MSc), Mathematics (BSc), Physics (BSc), Physicist (MSc), International Foundation Year, Intensive Foundation Semester
Address: 4032 Egyetem tér 1., Chemistry Building, A/101
E-mail: vargaimre@unideb.hu

English Program Officer: Mrs. Szilvia Gyulainé Szemerédi – Biochemical Engineering (BSc), Biology (BSc/MSc), Envirionmental Science (MSc), Hidrobiology Water Quality Management (MSc)
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DEPARTMENTS OF INSTITUTE OF PHYSICS

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4026 Debrecen, Bem tér 18/a,

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Mr. Dr. Gyula Zilizi, PhD, habil	Associate Professor	zilizi@science.unideb.hu	E207
Mr. Dr. István Csarnovics, PhD	Assistant Professor	csarnovics.istvan@science.unideb.hu	E214
Ms. Dr. Judit Darai, PhD, habil	Associate Professor	darai@science.unideb.hu	E116
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Mr. Bence Godó	Assistant Lecturer	godo.bence@science.unideb.hu	E201

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Mr. Dr. András Csehi, PhD	Assistant Professor	csehi.andras@science.unideb.hu	F10
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Mr. Dr. Gergő Pál, PhD	Assistant Professor		
Mr. Peter Badanko	Research Assistant	badanko.peter@gmail.com	

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Mr. Zsolt Szabó	Teacher of engineering	szabo.zsolt@science.unideb.hu	

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Name	Position	E-mail	room
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Dr. Zoltán Papp, PhD, habil	Associate Professor	zpapp@science.unideb.hu	

ACADEMIC CALENDAR

General structure of the academic semester (2 semesters/year):

Study period	1st week	Registration*	1 week
	2nd – 15th week	Teaching period	14 weeks
Exam period	directly after the study period	Exams	7 weeks

*Usually, registration is scheduled for the first week of September in the fall semester, and for the first week of February in the spring semester.

For further information please check the following link:

https://www.edu.unideb.hu/tartalom/downloads/University_Calendars_2021_22/University_calendar_2021-2022-Faculty_of_Science_and_Technology.pdf?_ga=2.196279020.1315409739.1629100510-488342717.1574682820

THE PHYSICS BACHELOR PROGRAM

Information about the Program

Name of BSc Program:	Physics BSc Program
Specialization available:	
Field, branch:	Science
Qualification:	Physicist
Mode of attendance:	Full-time
Faculty, Institute:	Faculty of Science and Technology Institute of Physics
Program coordinator:	Prof. Dr. Zoltán Erdélyi, University Professor
Duration:	6 semesters
ECTS Credits:	180

Objectives of the BSc program:

The aim of the Physics BSc program is to train professional physicists who have deep insight into physical processes. Relying on strong mathematics and informatics foundations, graduates of the program will be able to understand physical phenomena, apply physical theories, principles and laws, and to develop solutions based on applied science.

Professional competences to be acquired

A Physicist:

a) Knowledge:

- He/she has knowledge of the general and specialized principles, laws and possible applications of mathematics and informatics.
- He/she has knowledge of the physical theories and models based on scientific results.
- He/she is aware of the possible directions and limits of the development of Physics.
- He/she has knowledge of the fundamentals of the natural sciences as well as the practices based on this knowledge and has the ability to systematize them.
- He/she has knowledge regarding practical applications, laboratory works, methods, and tools, and could apply them and use them in his profession on a basic level.
- He/she has the knowledge needed to apply his field to solve practical problems related to natural processes, natural resources, living and inanimate system.
- He/she has the knowledge of the concepts and terminology of physics.
- He/she has the necessary knowledge to analyse the processes, systems, scientific problems in ways which are acceptable in current scientific practice.

b) Abilities:
- He/she has the ability to understand the physical phenomena, its data collection, processing and analysis, and the use of basic literature needed for these activities.
- He/she has the ability to apply physical theories, principles, and laws.
- He/she has the ability based on his or her knowledge of the field of physics to produce simple physical phenomena under laboratory conditions, to demonstrate and test them.
- He/she has the ability to evaluate, interpret and document of results of measurements.
- He/she has the ability to identify issues in the relevant field of expertise.
- He/she has the ability to apply the knowledge of physics to solve basic practical problems, including the ability to support this with calculations.
- He/she has the ability to plan and organize the physics-based part of development processes.
- He/she has the ability to collect and interpret relevant data based on his or her field, and based on this, can formulate a relevant opinion on social, scientific or ethical issues.
- He/she has the ability, on the basis of the physical knowledge, to use science-based argumentation.
- He/she has the ability to increase his or her knowledge and continue studies at a higher level.

c) Attitude:
- He/she tries to get to know the relationship between nature and man.
- During the practical and laboratory work he/she behaves in an environmentally conscious way.
- He/she is open to a professional exchange of views.
- He/she open to professional cooperation with specialists working in the field of social policy, economy, and environmental protection.
- He/she knows the example of the debating and incredulous natural scientist
- He/she authentically represents the scientific worldview and can convey it to a professional and non-professional audience.
- He/she is open to the direction of natural scientific and non-natural scientific advanced studies.
- He/she is committed to acquiring new competencies and expanding the scientific worldview, develops and deepens their professional knowledge

d) Autonomy and responsibility:
- He/she is capable of independently considering the basic professional issues and then answers them based on credible sources.
- He/she takes responsibility for the scientific world view.
- He/she takes responsibility in cooperation with a specialist in natural sciences and other fields.
- He/she consciously undertakes the ethical standards of a professional physicist.
- He/she evaluates the results of his own work in a realistic way.
- He/she evaluates the work of a subordinate employee responsibly.
- He/she is aware of the importance and consequences of scientific statements.
- He/she independently operates the laboratory equipment and tools used in research.

Completion of the BSc Program

The Credit System

Majors in the Hungarian Education System have generally been instituted and ruled by the Act of Parliament under the Higher Education Act. The higher education system meets the qualifications of the Bologna Process that defines the qualifications in terms of learning outcomes: statements of what students know and can do on completing their degrees. In describing the cycles, the framework uses the European Credit Transfer and Accumulation System (ECTS).
ECTS was developed as an instrument of improving academic recognition throughout the European Universities by means of effective and general mechanisms. ECTS serves as a model of academic recognition, as it provides greater transparency of study programs and student achievement. ECTS in no way regulates the content, structure and/or equivalence of study programs.
Regarding each major the Higher Education Act prescribes which professional fields define a certain training program. It contains the proportion of the subject groups: natural sciences, economics and humanities, subject-related subjects and differentiated field-specific subjects.

During the program students have to complete a total amount of 180 credit points. It means approximately 30 credits per semester. The curriculum contains the list of subjects (with credit points) and the recommended order of completing subjects which takes into account the prerequisite(s) of each subject. You can find the recommended list of subjects/semesters in chapter “Guideline”.

Model Curriculum of Physics BSc Program

	Semesters						ECTS credit points	Evaluation
	1.	**2.**	**3.**	**4.**	**5.**	**6.**		
	contact hours, types of teaching (l – lecture, p – practice), credit points							
Compulsory physics subject groups								
Bases of arts and sciences subject group								
Mathematics in physics *Erdélyi Zoltán*	15 l + 45 p /4 cr						4	mid-semester grade
Basics of measurement and evolution Katona Gábor	30 p / 2 cr						2	mid-semester grade
Basic environmental science *Nagy Sándor Alex*					15 l /1 cr		1	exam
Introduction to electronics subject group								
Laboratory Practicals in Electronics *Oláh László*				30 l / 3 cr	30 p / 2 cr		3+2	exam mid-semester grade
Linear algebra subject group								
Linear algebra *Gaál István*	30 l / 3 cr 30 p / 2 cr						3+2	exam mid-semester grade
Differential and integral calculus subject group								
Differential- and integral calculus *Bessenyei Mihály*	45 l / 4 cr 30 p / 2 cr						4+2	exam mid-semester grade
Differential- and integral calculus in several variable subject group								
Differential- and integral calculus in several variable *Páles Zsolt*		45 l / 4 cr 45 p / 3 cr					4+3	exam mid-semester grade
Bases of mechanics subject group								
Classical mechanics 1. *Trócsányi Zoltán* *Nándori István*	60 l / 6 cr 30 p / 3 cr						6+3	exam mid-semester grade
Basic Computer Skills in Physics subject group								
Basic Computer Skills in Physics *Tomán János*		15 l + 30 p / 2 cr					2	mid-semester grade
Laboratory practical: mechanics, optics, thermodynamics 1 *Katona Gábor*		30 p / 2 cr					2	mid-semester grade

Laboratory practical: mechanics, optics, thermodynamics 2 *Katona Gábor*			30 p / 2 cr				2	mid-semester grade
Thermodynamic subject group								
Thermodynamics *Trócsányi Zoltán* *Darai Judit*		60 l / 6 cr 30 p / 3 cr					6+3	exam mid-semester grade
Advanced mechanics subject group								
Classical mechanics 2. *Nagy Sándor*		30 l / 3 cr 30 p / 3 cr					3+3	exam mid-semester grade
Electromagnetism and optics subject group								
Optics *Dr. Csarnovics István*		15 l / 1 cr 15 p / 1 cr					1+1	exam mid-semester grade
Electromagnetism *Trócsányi Zoltán* *Daróczi Lajos*			60 l / 6 cr 30 p / 3 cr				6+3	exam mid-semester grade
Electrodynamics subject group								
Electrodynamics *Vibók Ágnes*				30 l / 3 cr 30 p / 3 cr			3+3	exam mid-semester grade
Condensed matters 1.subject group								
Condensed matters 1. *Cserháti Csaba*			30 l / 3 cr 30 p / 2 cr				3+2	exam mid-semester grade
Condensed matters 2. *Erdélyi Zoltán*					30 l / 3 cr 30 p / 2 cr		3+2	exam mid-semester grade
Condensed Matter Lab. Practices 1 *Cserháti Csaba*				30 p / 2 cr			2	mid-semester grade
Atomic, Nuclear and quantum physics subject group								
Atomic and quantum physics *Trócsányi Zoltán* *Nándori István*				30 l / 3 cr 15 p / 2 cr			3+2	exam mid-semester grade
Nuclear physics *Darai Judit*					30 l + 15 p / 4 cr		4	exam
Atomic and nuclear physics laboratory work 1 *Ujvári Balázs*					30 p / 2 cr		2	mid-semester grade

Quantum Mechanics and Fundamental interactions subject group								
Quantum Mechanics 1 *Nagy Sándor*					45 l / 4 cr 30 p / 3 cr		4+3	exam mid-semester grade
Fundamental interactions *Nándori István*						30 l + 30 p / 4 cr	4	exam
Statistical physics subject group								
Statistical physics *Kun Ferenc*						45 l / 5 cr 30 p / 3 cr	5+3	exam mid-semester grade
Advanced mathematics subject group								
Introduction to the theory of ordinary differential equations *Páles Zsolt*			30 l / 3 cr 30 p / 2 cr				3+2	exam mid-semester grade
Probability and statistics *Muzsnay Zoltán*			30 l / 3 cr 30 p / 2 cr				3+2	exam mid-semester grade
Materials and technology for microelectronics subject group								
Materials and technology for microelectronics (KV) *Csarnovics István*	:				45 l / 3 cr 30 p / 2 cr		3+2	exam mid-semester grade
Electronics subject group								
Analog and Applied Electronics (KV) *Zilizi Gyula*	.					30 l / 3 cr	3	exam
Digital Electronics (KV) *Zilizi Gyula*					30 l / 3 cr		3	exam
Applications of microcontrollers (KV) *Zilizi Gyula*					30 l / 2 cr		2	mid-semester grade
Computer simulation methods subject group								
Computer simulation methods (KV) *Kun Ferenc*					30 l / 2 cr 30 p / 2 cr		2+2	exam mid-semester grade
Special laboratory works subject group								
Atomic and nuclear physics laboratory work 2 (KV) *Csarnovics István*						30 p / 2 cr	2	mid-semester grade
Condensed Matter Lab. Practices 2 (KV) *Cserháti Csaba*						30 p / 2 cr	2	mid-semester grade
Statistical Data Analysis (KV) *Darai Judit*				30 l + 15 p / 4 cr			4	exam

Electron and atomic microscopy subject group								
Electron and atomic microscopy (KV) *Cserháti Csaba*				30 l / 3 cr			3	exam
Analythical spectroscopic methods (KV) *Csarnovics István*					30 l / 3 cr		3	exam
Environmental Physics subject group								
Environmental Physics 1 (KV) *Papp Zoltán*			30 l / 3 cr				3	exam
Nuclear measurement techniques subject group								
Nuclear measurement techniques (KV) *Papp Zoltán*						30 l / 3 cr 15 p / 1 cr	3+1	exam mid-semester grade
Programming subject group								
Programming (KV) *Dr. Kun Ferenc*			30 l / 2 cr 30 p / 2 cr				2+2	exam mid-semester grade
Computer Controlled Measurement and Process Control subject group								
Computer Controlled Measurement and Process Control (KV) *Oláh László*					60 p / 3 cr		3	mid-semester grade
Computer based measurement and process control (KV) *Zilizi Gyula*				30 l / 3 cr			3	exam
Vacuum science and technology subject group								
Vacuum science and technology (KV) *Daróczi Lajos*				30 p / 3 cr			3	exam
Modern analysis subject group								
Modern analysis (KV) *Novák-Gselmann Eszter*				30 l / 2 cr 30 p / 2 cr			3+2	exam mid-semester grade
Chemistry subject group								
Introduction to chemistry (KV) *Várnagy Katalin* *Tircsó Gyula*	30 l / 2 cr	30 p / 2 cr					2+2	exam mid-semester grade
Thesis						10 cr.	10	mid-semester grade, final exam

Optional courses								
Optional courses **9** cr								
Classical Mechanics III. *Sailer Kornél*				30 l / 3 cr 30 p / 2 cr			3+2	exam mid-semester grade
Modern optics *Csarnovics István*					30 l / 3 cr		3	exam
Image processing in technical and medical applications *Cserháti Csaba*					30 l / 3 cr		3	exam
Environmental Physics 2 *Papp Zoltán*				30 l / 3 cr			3	exam

Work and Fire Safety Course

According to the Rules and Regulations of University of Debrecen a student has to complete the online course for work and fire safety. Registration for the course and completion are necessary for graduation. For MSc students the course is only necessary only if BSc diploma has been awarded outside of the University of Debrecen.
Registration in the Neptun system by the subject: MUNKAVEDELEM
Students have to read an online material until the end to get the signature on Neptun for the completion of the course. The link of the online course is available on webpage of the Faculty.

Internship

NO internship is required for students majoring in Physics BSc.

Physical Education

According to the Rules and Regulations of University of Debrecen a student has to complete Physical Education courses at least in two semesters during his/her Bachelor’s training. Our University offers a wide range of facilities to complete them.

Pre-degree Certification

A pre-degree certificate is issued by the Faculty after completion of the bachelor’s (BSc) program. The pre-degree certificate can be issued if the student has successfully completed the study and exam requirements as set out in the curriculum, the requirements relating to Physical Education as set out in Section 10 in Rules and Regulations – with the exception of preparing thesis – and gained the necessary credit points (180). The pre-degree certificate verifies (without any mention of assessment or grades) that the student has fulfilled all the necessary study and exam requirements defined in the curriculum and the requirements for Physical Education. Students who obtained the pre-degree certificate can submit the thesis and take the final exam.

Thesis

The preparation of the thesis is an independent professional activity that relies partly on the student's studies and partly on additional knowledge of the literature of the field and can be done under the guidance of a consultant for a single semester. Such professional activities may include processing the literature of a field; reproduction and processing of previous results, but it is not necessary to present a separate research work. Students will be informed about the formal requirements of the thesis upon acceptance of the application.

Final Exam

(a) requirements for admission to the final examination;
Only that student can take the Final Exam who has already obtained the required 180 credits, completed the language requirements and submitted his/her thesis.
(b) final examination;
The final examination consists of an oral part only and it is devoted to testing complex interrelationships of the professional knowledge of the student. The topics of the Final Exam are based on the content of professional core subjects. The thesis defence is a part of the Final Exam but can be kept separate in time. Calculation of exam results based on the Rules and Regulations. A final exam has to be taken in front of the Final Exam Board. If a candidate does not pass his/her final exam by the termination of his/her student status, he/she can take his/her final exam after the termination of the student status on any of the final exam days of the relevant academic year according to existing requirements on the rules of the final exam.

Final Exam Board
Board chair and its members are selected from the acknowledged internal and external experts of the professional field. Traditionally, it is the chair and in case of his/her absence or indisposition the vice-chair who will be called upon, as well. The board consists of – besides the chair – at least two members (one of them is an external expert), and questioners as required. The mandate of a Final Examination Board lasts for one year.

Repeating a failed Final Exam
If any part of the final exam is failed it can be repeated according to the rules and regulations. A final exam can be retaken in the forthcoming final exam period. If the Board qualified the Thesis unsatisfactory a student cannot take the final exam and he has to make a new thesis. A repeated final exam can be taken twice on each subject.

Diploma

The diploma is an official document decorated with the coat of arms of Hungary which verifies the successful completion of studies in the Physics Bachelor Program. It contains the following data: name of HEI (higher education institution); institutional identification number; serial number of diploma; name of diploma holder; date and place of his/her birth; level of qualification; training program; specialization; mode of attendance; place, day, month and year issued. Furthermore, it has to contain the rector's (or vice-rector's) original signature and the seal of HEI. The University keeps a record of the diplomas issued.

In Physics Bachelor Program the diploma grade is calculated as the average grade of the results of the followings:

- Weighted average of the overall studies at the program (A)
- Average of grades of the thesis and its defense given by the Final Exam Board (B)
- Average of the grades received at the Final Exam for the two subjects (C)

Diploma grade = (A + B + C)/3

Classification of the award on the bases of the calculated average:

Excellent	4.81 – 5.00
Very good	4.51 – 4.80
Good	3.51 – 4.50
Satisfactory	2.51 – 3.50
Pass	2.00 – 2.50

Course Descriptions of Physics BSc Program

Title of course: Mathematics in Physics **Code**: TTFBE0119	**ECTS Credit points:** 4

Type of teaching, contact hours
- lecture: 1 hours/week
- practice: 3 hours/week
- laboratory: -

Evaluation: signature + grade for written test

Workload (estimated), divided into contact hours:
- lecture: 14 hours
- practice: 42 hours
- laboratory: -
- home assignment: 64 hours
- preparation for the exam: -

Total: 120 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: TTFBE0101, TTFBG0101

Topics of course

Short repetition from secondary school knowledge: power and root identities, functions and function transformations, vectors. Limit value, differential and integral calculus, matrices and determinants. Mass point movement in single and multiple dimensions.

Literature

Compulsory:
Moodle electronic notes
Recommended:
Bolyai-Books:
Bárczy, Barnabás: Differential Calculus (Differenciálszámítás)
Bárczy, Barnabás: Integral Calculus (Integrálszámítás)

Schedule:

1st week

Information, introduction.

Nonsense, identities, powers, rooting identities.

2nd week

Functions, function transformations. Univariate functions: straight, parabola, trigonometric, exponential, logarithmic, hyperbola; and their transformations. General shape of function transformation. Multivariable functions: representation of projections of multivariate functions in a lower dimension. Function properties: constraint, monotony, periodicity, extreme (local, glob-al), continuity. Inverse function.

3rd week

Vectors: concept, special vectors (unit, null), vector operations graphically, vector coordinates in orthonormal base, space vector, position vector, vector operations with coordinates, scalar form, vector product.

4th week

Limit value: sequences and rows, convergence; limit values. Differential calculus: derivative function, geometric meaning; deriving rules; derivatives of elementary functions.

5th week

Differential calculus: derivatives of higher order; extreme value calculation.

6th week

Differential calculus: derivation of multivariable functions, partial derivative.

7th week

Integral calculus: indefinite integral, primitive function; integration rules; indefinite integration of elementary functions.

8th week

Integral calculus: major integration methods.

9th week

Integral calculus: definite integral, geometric meanings; the core of integral calculus; integra-tion rules; special integrals (linear, surface, volumetric).

10th week

Physical quantities, units and prefixes. Physical dimension, dimension analysis. Significant digits.

11th week

Kinematics: one-dimensional movement, spatial coordinates, velocity, acceleration, path, displacement.

12th week

Kinematics: motion in three dimensions, position vector, displacement vector, velocity vector, acceleration vector, path.

13th week

Circular motion: learn the quantities and units to describe steady and variable circular motion, comparing them with the acquired kinematic quantities.

14th week

Summary, consultation.

Requirements:

During the semester students will receive homework assignments. The homework assignment to be submitted for a topic can be submitted within one week of its publication.

- for a signature

- each homework assignment must be at least 50% of the points
- during the semester, up to 3 can be unsuccessful (less than 50% of the score or not submitted)

- for a grade

The term mark is based on the arithmetic mean of the percentages of the tests completed during the semester: below 50% fail, 50-62% pass, 63-75% satisfactory, 76-88% good, above 88% excellent.

Person responsible for course: Prof. Dr. Zoltán Erdélyi, university professor, DSc

Lecturer: Dr. Gábor Somogyi, PhD

Title of course: Basics of measurement and evaluation **Code**: TTFBL0118	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: 1 hours/week
- laboratory: 1 hours/week

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 14 hours
- laboratory: 14 hours
- home assignment: 20 hours
- preparation for the exam: 12 hours

Total: 60 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: TTFBE0113, TTFBL0114

Topics of course

Documentation of measurements; measurement errors, uncertainties, standard deviation; graphical representation and evaluation; linear regression; linearization of non-linear formulas; least squares method; propagation of uncertainty

Literature

Compulsory: -
Recommended: Handouts provided on the course home page

Schedule:

1st week

Physical quantities; documentation of measurements; measurement errors; measurement uncertainty; examples; computer basics for documentation

2nd week

Distribution of measurement data; estimation of true value and standard deviation; uncertainty of measurement result; examples; evaluation with computer

3rd week

Numerical examples for standard deviation and uncertainty of measurement result; evaluation of simple measurement, documentation

4th week

Interdependent quantities, graphical representation; linear dependence, linear fit with computer; evaluation based on fit results; least squares

5th week

Examples for linear fit

6th week

Measurement task, documentation, evaluation

7th week

Written test 1;

Propagation of uncertainty

8th week

Examples for propagation of uncertainty

9th week

Measurement task, documentation, evaluation

10th week

Nonlinear dependence, linearization, evaluation with linear least squares method

11th week

Examples for nonlinear dependence

12th week

Measurement task, documentation, evaluation

13th week

Consultation

14th week

Written test 2

Requirements:

- for a signature

Presence on 75% of the classes.

- for a grade

The grade is computed from the two written tests.

Person responsible for course: Dr. Gábor Katona, assistant professor, PhD

Lecturer: János Tomán, assistant lecturer

Title of course: Basic Environmental Sciences **Code**: TTTBE0040_EN	**ECTS Credit points: 1**

Type of teaching, contact hours
- lecture: 1 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 14 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 16 hours

Total: 30 hours

Year, semester: 2st year, 2st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

What we call Environmental sciences. Natural values of the Earth, conservation of biodiversity. Effects of invasive species. Protection of habitats, prevention of species extinction. Short term and long term monitoring systems. Biomonitoring and MAB (Man and Biosphere programe). Fluvial and human transformed landscapes.

Literature

Compulsory:

H. Frances (2005): Global Environmental Issues. John Wiley & Sons, USA
ISBN: 978-0-470-09395-5

M. K. Wali, F. Evrendilek, M. S. Fennessy (2009): The Environment: Science, Issues, and Solutions. CRC Press ISBN: 9780849373879

J.M. Fryxell, A. R. E. Sinclair, G. Caughley (2014): Wildlife Ecology, Conservation, and Management. Wiley-Blackwell ISBN: 978-1-118-29106-1

Schedule:

1st week

Main parts of Environmental Siences, objects of Environmental Sciences

2nd week

Levels of living world.

3rd week

Basis of monitoring and biomonitoring systems

4th week

Levels of Ecology, ecological methods in environmental sciences

5th week

Ecological impacts of invasive plant and animal species in a changing world

6th week

Role of small habitat islands in human transformed landscapes – nature conservation, cultural and ecosystem services

7th week

Biodiversity

8th week

Indication

9th week

The world in maps

10th week

Rivers – fluival geomorfology

11th week

Sustainable development – World Conferences

12th week

Ecological footprint

13th week

Man and Biosphere program

14th week

Consultation or exam.

Requirements:

- for a signature
Attendance at lectures is recommended, but not compulsory.

- for a grade
The course ends in an written examination. 2 (Pass) grade: 50% of the maximum points available. If the score of any test is below 50%, students can take a retake test.

-an offered grade:
There are at least two tests during the semester, and the offered grade is the average of them.

Person responsible for course: Dr. Sándor Alex Nagy, associate professor, PhD

Lecturer: Dr. István Gyulai, assistant professor, PhD

Title of course: Introduction to Electronics
Code: TTFBL0120

ECTS Credit points: 2

Type of teaching, contact hours
- lecture: -
- practice: -
- laboratory: 2 hours/week

Evaluation: practical grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: -
- laboratory: 28 hours
- home assignment: 32 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE1120

Further courses built on it: -

Topics of course

Laboratory work of performing electronic measurements of analog and digital circuits:
- Frequency resonance measurements on RLC circuits. Determination of resistance by Wheatstone bridge. Measurements on power supply circuits. Determination of the dependence of salt solution conductivity
- Analog electronics: Specification of operational amplifiers, basic op-amp circuits: inverting, non-inverting, summing and differential amplifiers, voltage-current converters, integrator, differentiator, oscillator circuit.
- Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders; basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.

Literature

Compulsory:
- Oláh L.: Analog and digital electronics laboratory exercises, (laboratory textbook.)

Recommended:
- P. Horowitz: The art of electronics, Cambridge University Press, 1989

Schedule: (8*3.5 hour measurement program)

1st week

Informative course, scheduling lab measurements.

2nd week

Determination of resistance by Wheatstone bridge;

3rd week

Determination of the dependence of salt solution conductivity

4th week

Frequency resonance measurements on RLC circuits

5th week

Measurements on power supply circuits.

6th week

Specification of operational amplifiers, basic op-amp circuits: inverting, non-inverting, summing and differential amplifiers, voltage-current converters

7th week

Nonlinear circuits of operational amplifiers: integrator, differentiator, oscillator circuit, active filters.

8th week

Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders

9th week

Basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.

Requirements:

- for a signature

Participation at **laboratory classes** is compulsory. A student must attend the laboratory classes and perform all the listed electronic measurement tasks. Attendance at laboratory classes will be recorded by the class leader. Being late is equivalent with an absence. In case of absences, a medical certificate needs to be presented. Missed laboratory classes should be made up for at a later date, to be discussed with the tutor.

Before the laboratory class, students have to prepare at home by summarizing the theory of the properties and operation of the components and circuits of the upcoming measurements. The knowledge of the summarized theory is questioned and evaluated by the teacher at the beginning of the laboratory classes.

Students have to **submit all measurements task** at the end of the classes minimum on a pass level. Measurement tasks is evaluated by the teacher after every class.

- for a grade

The grade for the tasks is given according to the following table:

Percentage	Grade
0-49	fail (1)
50-59	pass (2)
60-69	satisfactory (3)
70-79	good (4)
80-100	excellent (5)

If the result of any task is below 50%, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Based on the result of the measurement tasks separately, the practical grade of the laboratory class is based on the average of the grades of the measuring tasks.

-an offered grade: -

Person responsible for course: Dr. László Oláh, assistant professor, PhD

Lecturer: Dr. László Oláh, assistant professor, PhD

Title of course: Introduction to Electronics **Code**: TTFBL0120	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: -
- laboratory: 2 hours/week

Evaluation: practical grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: -
- laboratory: 28 hours
- home assignment: 32 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE1120

Further courses built on it: -

Topics of course

Laboratory work of performing electronic measurements of analog and digital circuits:

- Frequency resonance measurements on RLC circuits. Determination of resistance by Wheatstone bridge. Measurements on power supply circuits. Determination of the dependence of salt solution conductivity
- Analog electronics: Specification of operational amplifiers, basic op-amp circuits: inverting, non-inverting, summing and differential amplifiers, voltage-current converters, integrator, differentiator, oscillator circuit.
- Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders; basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.

Literature

Compulsory:

- Oláh L.: Analog and digital electronics laboratory exercises, (laboratory textbook.)

Recommended:

- P. Horowitz: The art of electronics, Cambridge University Press, 1989

Schedule: (8*3.5 hour measurement program)

1st week

Informative course, scheduling lab measurements.

2nd week

Determination of resistance by Wheatstone bridge;

3rd week

Determination of the dependence of salt solution conductivity

4th week

Frequency resonance measurements on RLC circuits

5th week

Measurements on power supply circuits.

6^{th} week

Specification of operational amplifiers, basic op-amp circuits: inverting, non-inverting, summing and differential amplifiers, voltage-current converters

7^{th} week

Nonlinear circuits of operational amplifiers: integrator, differentiator, oscillator circuit, active filters.

8^{th} week

Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders

9^{th} week

Basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.

Requirements:

- for a signature

Participation at **laboratory classes** is compulsory. A student must attend the laboratory classes and perform all the listed electronic measurement tasks. Attendance at laboratory classes will be recorded by the class leader. Being late is equivalent with an absence. In case of absences, a medical certificate needs to be presented. Missed laboratory classes should be made up for at a later date, to be discussed with the tutor.

Before the laboratory class, students have to prepare at home by summarizing the theory of the properties and operation of the components and circuits of the upcoming measurements. The knowledge of the summarized theory is questioned and evaluated by the teacher at the beginning of the laboratory classes.

Students have to **submit all measurements task** at the end of the classes minimum on a pass level. Measurement tasks is evaluated by the teacher after every class.

- for a grade

The grade for the tasks is given according to the following table:

Percentage	Grade
0-49	fail (1)
50-59	pass (2)
60-69	satisfactory (3)
70-79	good (4)
80-100	excellent (5)

If the result of any task is below 50%, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Based on the result of the measurement tasks separately, the practical grade of the laboratory class is based on the average of the grades of the measuring tasks.

-an offered grade: -

Person responsible for course: Dr. László Oláh, assistant professor, PhD

Lecturer: Dr. László Oláh, assistant professor, PhD

Title of course: Linear algebra **Code**: TMMBE0815	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: oral exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 34 hours
- preparation for the exam: 28 hours

Total: 90 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it:

Topics of course

Basic notions in algebra. Determinants. Operations with matrices. Vector spaces, basis, dimension. Linear mappings. Transformation of basis and coordinates. The dimensions of the row space and the column space of matrices are equal. Sum and direct sum of subspaces. Factor spaces. Systems of linear equations. Matrix of a linear transformation. Operations with linear transformations. Similar matrices. Eigenvalues, eigenvectors. Characteristic polynomial. The existence of a basis consisting of eigenvectors.
Linear forms, bilinear forms, quadratic forms. Inner product, Euclidean space. Inequalities in Euclidean spaces. Orthonormal bases. Gram-Schmidt orthogonalization method. Orthogonal complement of a subspace. Complex vectorspaces with inner product: unitary spaces. Linear forms, bilinear forms and inner products. Adjoint of a linear transformation. Properties of the adjoint transformation. Selfadjoint transformations. Isometric/orthogonal transformations. Normal transformations.

Literature

Paul R. Halmos: Finite dimensional vector spaces, Benediction Classics, Oxford, 2015.
Serge Lang, Linear Algebra, Springer Science & Business Media, 2013.
Howard Anton and Chris Rorres, Elementary Linear Algebra, John Wiley & Sons, 2010

Schedule:

1st week

Determinants, matrix operations

SR: understand operations with matrices, determinant calculation

2nd week

Vector spaces, linear independence, basis, dimension

SR: understand the notions of basis and dimension

3rd week

Linear maps on vectors spaces, Transformations of bases and coordinates

SR: understand actions of linear maps

4th week

Rank of matrices. Sum and direct sum of subspaces. Factor space

SR: get skilled in rank calculation, understand sum of subspaces

5th week

Systems of linear equations. Cramer's rule, Gaussian elimination

SR: understand the theory of systems of linear equations

6th week

Invariant subspaces. Eigenvalues, eigenvectors

SR: understand eigenvalues and eigenvectors

7th week

Transforming the matrix of linear maps to diagonal form. The existence of a basis consisting of eigenvectors

SR: get skilled in construction bases with eigenvectors

8th week

Bilinear and quadratic forms, inner products, Euclidean spaces

SR: get acquainted with Euclidean spaces

9th week

Basis properties of Euclidean spaces

SR: learn the basic inequalities in Euclidean spaces

10th week

Orthogonality, Gram-Schmidt orthogonalization, orthogonal complement

SR: understand Gram-Schmidt algorithm

11th week

Adjoint of linear maps and its properties

SR: understand the transformation of adjunction

12th week

Self adjoint operators and their properties

SR: understand self adjoint operators

13th week

Orthogonal transformations and their properties.

SR: understand isometric operations

14th week

Normal transformations SR: understand normal transformations
Requirements: - *for a signature* - - *for a grade* - • Knowledge of definitions, theorems: grade 2; - • In addition, knowledge of the proofs of most important theorems: grade 3; - • In addition, knowledge of the proofs of theorems: grade 4; - • In addition, knowledge of connections of notions and statements: grade 5. - -*an offered grade:* -
Person responsible for course: Prof. Dr. István Gaál, university professor, DSc
Lecturer: Prof. Dr. István Gaál, university professor, DSc

Title of course: Linear algebra class work **Code**: TMMBG0815	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: written test

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 32 hours
- preparation for the exam:

Total: 60 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it:

Topics of course

Basic notions in algebra. Determinants. Operations with matrices. Vector spaces, basis, dimension. Linear mappings. Transformation of basis and coordinates. The dimensions of the row space and the column space of matrices are equal. Sum and direct sum of subspaces. Factor spaces. Systems of linear equations. Matrix of a linear transformation. Operations with linear transformations. Similar matrices. Eigenvalues, eigenvectors. Characteristic polynomial. The existence of a basis consisting of eigenvectors.

Linear forms, bilinear forms, quadratic forms. Inner product, Euclidean space. Inequalities in Euclidean spaces. Orthonormal bases. Gram-Schmidt orthogonalization method. Orthogonal complement of a subspace. Complex vectorspaces with inner product: unitary spaces. Linear forms, bilinear forms and inner products. Adjoint of a linear transformation. Properties of the adjoint transformation. Selfadjoint transformations. Isometric/orthogonal transformations. Normal transformations.

Literature

Paul R. Halmos: Finite dimensional vector spaces, Benediction Classics, Oxford, 2015.
Serge Lang, Linear Algebra, Springer Science & Business Media, 2013.
Howard Anton and Chris Rorres, Elementary Linear Algebra, John Wiley & Sons, 2010

Schedule:

1st week

Determinants

SR: get skilled in determinant calculation

2nd week

matrix operations SR: get skilled in matrix addition, multiplication, inversion *3rd week* Linear independence, basis of vector spaces SR: construct bases of vector spaces *4th week* Systems of linear equations SR: solving systems of linear equations *5th week* Linear transformations, kernel and image SR: calculate with linear transformations *6th week* Test SR: exercises from the preceding topics *7th week* Characteristic polynomial. Eigenvalues and eigenvectors SR: calculated with characteristic polynomial, eigenvectors, eigenvalues *8th week* Bilinear and quadratic forms, inner products, Euclidean spaces SR: get skilled in scalar product canculation *9th week* Basis properties of Euclidean spaces SR: Apply inequalities in Euclidean spaces *10th week* Orthogonality, Gram-Schmidt orthogonalization, orthogonal complement SR: get skilled to calculate orthonormed bases *11th week* orthogonal complement SR: calculated orthogonal complement of subspaces *12th week* Symmetric transformations SR: calculate canonical basis to self adjoint operations *13th week* Orthogonal transformations. SR: calculate canonical basis to orthogonal operations *14th week* Test SR: exercises from the preceding topics
Requirements:

- *for a signature* Two test are written during the semester. The joint result of the test is calculated in percentages - *- for a grade* - • 45%: grade 2; - • 60%: grade 3; - • 75%: grade 4 - • 85%: grade 5 - *-an offered grade:* -
Person responsible for course: Prof. Dr. István Gaál, university professor, DSc
Lecturer: Prof. Dr. István Gaál, university professor, DSc

Title of course: Differential and integral calculus **Code**: TTMBE0813	**ECTS Credit points: 4**
Type of teaching, contact hours - lecture: 3 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 42 hours - practice: - - laboratory: - - home assignment: - - preparation for the exam: 78 hours Total: 120 hours	
Year, semester: 1st year, 1st semester	
Its prerequisite(s):	
Further courses built on it: TTMBE0814; TTMBE0817; TTMBE0818; TTFBE0102; TTFBG0104.	

Topics of course

Limit of functions and its computation using limit of sequences. Cauchy's criterions; the relation between the limit and the operations, respectively the order. The relation between limit and uniform convergence, respectively continuity and uniform convergence; Dini's theorem. Right- and left-sided limits; points of discontinuity; classification of discontinuities of the first kind; limit properties of monotone functions. Elementary limits; the introduction of pi. Functions stemming from elementary functions. Differentiability and approximation with linear functions. Differentiability and continuity; differentiability and operations; the chain rule and the differentiability of the inverse function. Local extremum, Fermat principle. The mean value theorems of Rolle, Lagrange, Cauchy and Darboux. L'Hospital rules. Higher order differentiability; Taylor's theorem, monotonicity and differentiability, higher order conditions for extrema. Convex functions. The definition of antiderivatives; basic integrals, rules of integration. Riemann integral and criteria for integrability; properties of the integral and methods of integration. The main classes of integrable functions. Inequalities, mean value theorems for the Riemann integral. The Newton–Leibniz theorem and the properties of antiderivatives. The relation between Riemann-integrability and uniform convergence. Lebesgue's criterion. Improper Riemann integral and its criteria.

Literature

Compulsory:

1. W. Rudin: Principles of Mathematical Analysis. McGraw-Hill, 1964.
2. K. R. Stromberg: An introduction to classical real analysis. Wadsworth, California, 1981.

Recommended:

Schedule:

1st week

Limit of functions and its computation using limit of sequences. Cauchy's criterions; the relation between the limit and the operations, respectively the order.

2nd week

The relation between limit and uniform convergence, respectively continuity and uniform convergence; Dini's theorem.

3rd week

Right- and left-sided limits; points of discontinuity; classification of discontinuities of the first kind; limit properties of monotone functions.

4th week

Elementary limits; the introduction of pi. Functions stemming from elementary functions.

5th week

Differentiability and approximation with linear functions. Differentiability and continuity; differentiability and operations; the chain rule and the differentiability of the inverse function.

6th week

Local extremum, Fermat principle. The mean value theorems of Rolle, Lagrange, Cauchy and Darboux. L'Hospital rules. Higher order differentiability; Taylor's theorem.

7th week

Monotonicity and differentiability, higher order conditions for extrema. Convex functions.

8th week

The definition of antiderivatives; basic integrals, rules of integration.

9th week

Darboux integrals and their properties.

10th week

Riemann integral and its properties.

11th week

The main classes of integrable functions. Inequalities, mean value theorems for the Riemann integral. The Newton–Leibniz theorem and the properties of antiderivatives.

12th week

The relation between Riemann-integrability and uniform convergence. Applications. Improper Riemann-integral.

13th week

Lebesgue null sets. Modulus of continuity.

14th week

Lebesgue's criterion and its applications.

Requirements:

The course ends in an oral or written **examination**. Two assay questions are chosen randomly from the list of assays. In case one of them is incomplete, the examination ends with a fail. In lack of the knowledge of proofs, at most satisfactory can be achieved. The grade for the examination is given according to the following table:

Score	Grade
0-59%	fail (1)
60-69%	pass (2)
70-79%	satisfactory (3)
80-89%	good (4)

90-100% excellent (5) In general, the EDUCATION AND EXAMINATION RULES AND REGULATIONS have to be taken into account.
Person responsible for course: Dr. Mihály Bessenyei, associate professor, PhD
Lecturer: Dr. Mihály Bessenyei, associate professor, PhD

Title of course: Differential and integral calculus class work **Code**: TTMBG0813	**ECTS Credit points: 4**

Type of teaching, contact hours
- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 92
- preparation for the exam: -

Total: 120 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): TTMBE0813

Further courses built on it: TTMBE0814

Topics of course

Limit of functions and its computation using limit of sequences. Differentiability and operations; the chain rule and the differentiability of the inverse function. Local extremum, Fermat principle, mean value theorems. L'Hospital rules. Higher order differentiability; Taylor's theorem. Monotonicity, convexity, extrema. Basic integrals, rules of integration. Riemann integral and the Newton–Leibniz theorem. Inequalities for Riemann integral. Improper Riemann integral.

Literature

Compulsory:
1. W. Rudin: Principles of Mathematical Analysis. McGraw-Hill, 1964.
2. K. R. Stromberg: An introduction to classical real analysis. Wadsworth, California, 1981.

Recommended:

Schedule:

1st week
Computing limits and derivatives of functions and its computation using limit of sequences.

2nd week
Differentiability and operations; the chain rule and the differentiability of the inverse function.

3rd week
Higher order differentiability; Taylor's theorem.

4th week
The mean value theorems of Rolle, Lagrange, Cauchy and Darboux. L'Hospital rules.

5th week
Monotonicity, convexity, extrema of functions.

6th week
Summary

7th week

Midterm test.

8th week

Basic integrals, rules of integration.

9th week

Integration of partial fractions.

10th week

Applications of the integration of partial fractions.

11th week

Riemann sums and Riemann integral. The Newton–Leibniz theorem. Improper Riemann integrals.

12th week

Inequalities for Riemann integral.

13th week

Summary.

14th week

Endterm test.

Requirements:

Participation at **practice classes** is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can't make up any practice with another group. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence. In case of further absences, a medical certificate needs to be presented. Missed practice classes should be made up for at a later date, to be discussed with the tutor.

The course finishes with a grade, which is based on the total sum of points of the mid-term test (in the 7th week) and the end-term test (in the 14th week). One of the tests can be repeated. The final grade is given according to the following table:

Score	Grade
0-59%	fail (1)
60-69%	pass (2)
70-79%	satisfactory (3)
80-89%	good (4)
90-100%	excellent (5)

In general, the EDUCATION AND EXAMINATION RULES AND REGULATIONS have to be taken into account.

Person responsible for course: Dr. Mihály Bessenyei, associate professor, PhD

Lecturer: Dr. Mihály Bessenyei, associate professor, PhD

Title of course: Differential and integral calculus in several variables **Code**: TTMBE0814	**ECTS Credit points: 4**

Type of teaching, contact hours
- lecture: 3 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 42 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 78 hours

Total: 120 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): **TTMBE0813**

Further courses built on it:

Topics of course

The Banach contraction principle. Linear maps in normed spaces. The Fréchet derivative; chain rule, differentiability and operations. The mean value inequality of Lagrange. Inverse and implicit function theorems. Further notions of derivatives; the representation of the Fréchet derivative. Continuous differentiability and continuous partial differentiability; sufficient condition for differentiability. Higher order derivatives; Schwarz–Young theorem, Taylor's theorem. Local extremum and Fermat principle; the second order conditions for extrema. The Lagrange Multiplier Rule. The definition of the Riemann integral; the integral and operations, criteria for integrability, inequalities and mean value theorems for the Riemann integral. The relation between the Riemann integral and the uniform convergence. Lebesgue's theorem. Fubini's theorem. Jordan measure and its properties; integration over Jordan measurable sets. Fubini's theorem on simple regions, integral transformation. Functions of bounded variation, total variation, decomposition theorem of Jordan. The Riemann–Stieltjes integral and its properties. Integration by parts. Sufficient condition for Riemann–Stieltjes integrability and the computation of the integral. Curve integral; potential function and antiderivative. Necessary and sufficient conditions for the existence of antiderivatives.

Literature

Compulsory:-
Recommended:

W. Rudin: Principles of Mathematical Analysis. McGraw-Hill, 1964.
K. R. Stromberg: An introduction to classical real analysis. Wadsworth, California, 1981.

Schedule:

1st week Metric spaces. Limit of sequences and completeness. The Banach fixed point theorem. Characterization of Banach spaces among normed spaces. Compactness in normed spaces. The equivalence of the norms in finite dimensional normed spaces. Examples.

2nd week The norm of linear mappings, characterizations of bounded linear maps. The structure of the space of linear maps. Convergence of Neumann series. The topological structure of invertible linear self-maps in a Banach space. The open mapping theorem and its consequences.

3rd week The notion of Fréchet derivative and its uniqueness. The connection of differentiability and continuity. The Fréchet derivative of affine and bilinear maps. The Chain Rule and its consequences.

4th week The Hahn-Banach theorem for normed spaces and the Lagrange mean value inequality. Strict and continuous Fréchet differentiability. The inverse and implicit function theorems.

5th week The notions of directional and partial derivatives and their connection to Fréchet differentiability. The representation of the Fréchet derivative via partial derivatives. Sufficient condition for Fréchet differentiability, the characterization of continuous differentiability.

6th week Higher-order derivatives, the Schwarz-Young theorem and the Taylor theorem. Local minimum and maximum, the Fermat principle. Characterizations of positive definite and positive semidefinite quadratic forms. The second-order necessary and sufficient conditions of optimality. Constrained optimization and the Lagrange multiplier rule.

7th week Compact intervals in Euclidean spaces. Subdivision of intervals. The lower and upper integral approximating sums of bounded functions and their basic properties. The lower and upper Darboux integrals and their properties. The Darboux theorem. The interval additivity of the Darboux integrals.

8th week The notion of the Riemann integral and examples for non-integrability. The linearity and interval additivity of the Riemann integral. The Riemann criterion of integrability. Further criteria of integrability.

9th week Integrability and continuity. Sufficient conditions of integrability. Operations with Riemann integrable functions. Mean value theorem for the Riemann integral. Uniform convergence and integrability. The structure of the space of Riemann integrable functions.

10th week Computation of the Riemann integral, the Fubini theorem and its consequences. Null sets in the sense of Lebesgue and their properties. The characterization of Riemann integrability via the Lebesgue criterion.

11th week The Jordan measure and its properties. Characterization of Jordan measurability and Jordan null sets. The Riemann integral over Jordan measurable sets. Algebraic properties, connection integrability and continuity. The Fubini theorem on normal domains. The integral transformation theorem.

12th week Functions of bounded variations and their structure. The interval additivity if total variation and the Jordan decomposition theorem and its corollaries. The computation of the total variation.

13th week The Riemann-Stieltjes integral, its bilinearity and interval additivity. Integration by parts. Sufficient conditions for Riemann-Stieltjes integrability and the computation of the integral.

14th week Curves and the length of curves. The curve integral of vector fields. Antiderivative function (potential function) of vector fields. The Newton-Leibniz theorem. Differentiation of parametric integrals. The necessary and sufficient conditions for the existence of antiderivative function.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

- for a grade

The course ends in an **examination**. Before the examination students must have grade at least ‘pass’ on *Differential and integral calculus in several variables* practice (TTMBG0204-EN). The grade for the examination is given according to the following table:

Score	Grade
0-49	fail (1)
50-61	pass (2)
62-74	satisfactory (3)

75-87	good (4)
88-100	excellent (5)

If the average of the score of the examination is below 50, students can take a retake examination in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Prof. Dr. Zsolt Páles, university professor, DSc

Lecturer: Prof. Dr. Zsolt Páles, university professor, DSc

Title of course: Differential and integral calculus in several variables class work **Code**: TTMBG0814	**ECTS Credit points: 3**

Type of teaching, contact hours
- lecture: -
- practice: 3 hours/week
- laboratory: -

Evaluation: mid-term and end-term tests

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 42 hours
- laboratory: -
- home assignment: 24 hours
- preparation for the tests: 24 hours

Total: 90 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMBE0813

Further courses built on it:

Topics of course

The Fréchet derivative, directional derivative, partial derivative. Examples for differentiability and non-differentiability. Computation of the derivatives, chain rule. The inverse and implicit function theorems. Further notions of differentiability, the representation of the Fréchet derivative. Higher order derivatives; Schwarz–Young theorem, Taylor's theorem. Local extremum and Fermat principle; the second-order conditions for extrema. The Lagrange Multiplier Rule. The computation of the Riemann integral; the integral and operations, criteria for integrability. Fubini's theorem. Jordan measure and its properties; integration over Jordan measurable sets. Fubini's theorem on simple regions, integral transformation. Functions of bounded variation, total variation. The Riemann–Stieltjes integral, integration by parts. The computation of the integral. Curve integral; potential function and antiderivative.

Literature

Compulsory:-
Recommended:
W. Rudin: Principles of Mathematical Analysis. McGraw-Hill, 1964.
K. R. Stromberg: An introduction to classical real analysis. Wadsworth, California, 1981.

Schedule:

1st week Limit of vector-valued functions in several variables. Checking Fréchet differentiability, directional differentiability, partial differentiability by definition.

2nd week The representation of the derivative in terms of partial derivatives. Computation of the directional and partial derivatives. Applications of the Chain Rule.

3rd week The inverse and implicit function theorems, implicit differentiation. Higher-order derivatives and differentials. Applications of the Taylor theorem.

4th week The Fermat principle for local minimum and maximum. Characterization of positive definite and positive semidefinite quadratic forms. The second-order necessary and sufficient conditions of optimality.

5th week Optimization problems with equality and inequality constraints and applications of the Lagrange multiplier rule.

6th week Survey of the results and methods of the first 5 weeks.

7th week Mid-term test.

8th week Computation of the Riemann-integral with the help of the Fubini theorem. The Jordan measure of bounded sets.

9th week Computation of the Riemann-integral with the help of the integral transformation theorem.

10th week Functions of bounded and of unbounded variations. The computation of total variation.

11th week The Riemann-Stieltjes integral and the curve integral.

12th week Existence and non-existence of the primitive function (potential function) of vector fields.

13th week Survey of the results and methods of the 8th-12th weeks.

14th week End-term test.

Requirements:

- for a signature

Participation at **practice classes** is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can't make up any practice with another group. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence. In case of further absences, a medical certificate needs to be presented. Missed practice classes should be made up for at a later date, to be discussed with the tutor. Active participation is evaluated by the teacher in every class. If a student's behaviour or conduct doesn't meet the requirements of active participation, the teacher may evaluate his/her participation as an absence because of the lack of active participation in class.

During the semester there are two tests: the mid-term test in the 7th week and the end-term test in the 14th week. Students have to sit for the tests.

- for a grade

The minimum requirement for the average of the mid-term and end-term tests is 50%.

Score	Grade
0-49	fail (1)
50-61	pass (2)
62-74	satisfactory (3)
75-87	good (4)
88-100	excellent (5)

If the average of the scores of the tests is below 50, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Prof. Dr. Zsolt Páles, university professor, DSc

Lecturer: Prof. Dr. Zsolt Páles, university professor, DSc

Title of course: Classical mechanics 1 **Code**: TTFBE0101	**ECTS Credit points:** 6
Type of teaching, contact hours - lecture: 4 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 56 hours - practice: - - laboratory: - - home assignment: 68 hours - preparation for the exam: 56 hours Total: 180 hours	
Year, semester: 1st year, 1st semester	
Its prerequisite(s): TTFBE0119, TTFBG0101	
Further courses built on it: TTFBE0103, TTFBG0103	

Topics of course

Law of inertia, definitions of inertial reference frame, point of inertia. Exparimental laws of two-body interactions. Definitions of mass and momentum, law of conservation of momentum. Definition of force. Newton's 3rd law. Force laws of elastic interaction and gravitation. Cavendish' experiment. Force laws of friction and drag. Coulomb, Lorentz and Van der Waals forces. Independence of forces. Law of dynamics (Newton's 2nd law). Galilei's relativity principle. Solution of equation of motion for simple cases: motion in homogeneous gravitational field, ballistic motion, case of linear force law (spring). Damped oscillation. Solution of equation of motion for simple cases: forced oscillation, motion in case of central force, meaning and calculation of the 1st cosmic speed. Kepler's 1st law. Constrained motions, definition of constrain, discussion of mathematical pendulum. Kinetic and static friction, motion on a slope. Bulk and surface forces, definition of force density. Solution of equation of motion for simple cases: forced oscillation, motion in case of central force, meaning and calculation of the 1st cosmic speed. Kepler's 1st law. Constrained motions, definition of constrain, discussion of mathematical pendulum. Kinetic and static friction, motion on a slope. Bulk and surface forces, definition of force density. Generalization of Newton's laws for motion of extended bodies. Definition of mass density, Definition of current of momentum and energy. Derivation of the equation of motion of a raket and its solution. Law of dynamics in accelerating reference frames, definition of fictitious force. Fictitious forces on the rotating Earth. Kepler's 2nd law. Theorem of conservation of angular momentum for the motion of a point-like object. Definition of rotational inertia. Solution of the mathematical pendulum using the theorem of conservation of angular momentum. Angular momentum of a system of particles, generalization of the theorem of conservation of angular momentum. Computation and properties of rotational inertia of rigid bodies. Definition of angular momentum of rigid bodies with respect to an axis or a point. Conditions of equilibrium of rigid bodies. Equivalent substitution of weight. Discussion of rotation of a rigid body around a fixed axis: torsion pendulum, physical pendulum. Motion of a rigid body in a plane. Decomposition of angular momentum into orbital and rotational components and their respective equations of motion; roll. Classification and discussion of the motion of the spinning top. Classification of collisions. Solution of collision in one dimension. Definitions of kinetic energy and work, proof of work-energy theorem in the case of a particle. Definition of power. Derivation of the work-energy theorem in case of system of particles and rigid bodies in case of motion in a plane. Definition of potential energy. Law of conservation of mechanical energy. Definition of potential energy and computation of potential energy of an object in gravitational field. The 2nd cosmic speed. Kepler's 3rd law. Relation between potential energy and force law. Classification of equilibrium positions. Definition of gravitational field, computation of gravitational field of a sphere with homogeneous mass distribution. Equilibrium of elastic bodies. Definitions of tensile, shearing stresses and strains. Case of uniform compression. Definition of elastic potential energy density. Equilibrium of liquids and gases, Pascal's laws, definition of hydrostatic pressure, law of Archimedes. Law of Boyle and Mariotte. Air pressure, barometric formula. Classification of flows. Equation of continuity. Bernoulli's equation and its applications. Friction in liquids: viscous flow and Newton's law of viscosity. Laminar flow in a tube. Turbulent flow. Drag formula. Classification of elastic waves. Speed of waves, definition of the wave function, wave equation in one dimension. Energy transport in moving elastic waves. Wave function of and energy relations in moving sinusoidal waves. Reflection of waves in one dimension from the boundary of the medium. Wave function of standing waves and energy relations in them. Wave in two and three dimensions: wave functions, wave equations, interference, diffraction and refraction of waves. Principle of Huygens and Fresnel. Doppler's effect. Physical characterization of perception of sound. Definition of the decibel unit. Wave of light. Speed of light. Principle of special relativity. Lorentz transformations.

Literature

Compulsory:

- Zoltán Trócsányi: Classical mechanics, lecture note in electronic format

Recommended:

- Robert Resnick, David Halliday, Keneth S. Krane, Physics I: Chapters 1-21 John Wiley & Sons, Inc.

Schedule:

1st week

Law of inertia, definitions of inertial reference frame, point of inertia. Exparimental laws of two-body interactions. Definitions of mass and momentum, law of conservation of momentum. Definition of force. Newton's 3rd law. Force laws of elastic interaction and gravitation. Cavendish' experiment.

2nd week

Force laws of friction and drag. Coulomb, Lorentz and Van der Waals forces. Independence of forces. Law of dynamics (Newton's 2nd law). Galilei's relativity principle. Solution of equation of motion for simple cases: motion in homogeneous gravitational field, ballistic motion, case of linear force law (spring). Damped oscillation.

3rd week

Solution of equation of motion for simple cases: forced oscillation, motion in case of central force, meaning and calculation of the 1st cosmic speed. Kepler's 1st law. Constrained motions, definition of constrain, discussion of mathematical pendulum. Kinetic and static friction, motion on a slope. Bulk and surface forces, definition of force density.

4th week

Generalization of Newton's laws for motion of extended bodies. Definition of mass density, Definition of current of momentum and energy. Derivation of the equation of motion of a rocket and its solution. Law of dynamics in accelerating reference frames, definition of fictitious force. Fictitious forces on the rotating Earth. Kepler's 2nd law. Theorem of conservation of angular momentum for the motion of a point-like object. Definition of rotational inertia. Solution of the mathematical pendulum using the theorem of conservation of angular momentum.

5th week

Angular momentum of a system of particles, generalization of the theorem of conservation of angular momentum. Computation and properties of rotational inertia of rigid bodies. Definition of angular momentum of rigid bodies with respect to an axis or a point. Conditions of equilibrium of rigid bodies. Equivalent substitution of weight.

6th week

Discussion of rotation of a rigid body around a fixed axis: torsion pendulum, physical pendulum. Motion of a rigid body in a plane. Decomposition of angular momentum into orbital and rotational components and their respective equations of motion; roll.

7th week

Classification and discussion of the motion of the spinning top. Classification of collisions. Solution of collision in one dimension. Definitions of kinetic energy and work, proof of work-energy theorem in the case of a particle. Definition of power. Derivation of the work-energy theorem in case of system of particles and rigid bodies in case of motion in a plane. Definition of potential energy.

8th week

Law of conservation of mechanical energy. Definition of potential energy and computation of potential energy of an object in gravitational field. The 2nd cosmic speed. Kepler's 3rd law. Relation between potential energy and force law. Classification of equilibrium positions. Definition of gravitational field, computation of gravitational field of a sphere with homogeneous mass distribution.

9th week

Equilibrium of elastic bodies. Definitions of tensile, shearing stresses and strains. Case of uniform compression. Definition of elastic potential energy density. Equilibrium of liquids and gases, Pascal's laws, definition of hydrostatic pressure, law of Archimedes. Law of Boyle and Mariotte. Air pressure, barometric formula.

10th week

Classification of flows. Equation of continuity. Bernoulli's equation and its applications. Friction in liquids: viscous flow and Newton's law of viscosity. Laminar flow in a tube. Turbulent flow. Drag formula. Classification of elastic waves. Speed of waves, definition of the wave function, wave equation in one dimension.

11th week

Energy transport in moving elastic waves. Wave function of and energy relations in moving sinusoidal waves. Reflection of waves in one dimension from the boundary of the medium. Wave function of standing waves and energy relations in them.

12th week

Wave in two and three dimensions: wave functions, wave equations, interference, diffraction and refraction of waves. Principle of Huygens and Fresnel.

13th week

Doppler's effect. Physical characterization of perception of sound. Definition of the decibel unit. Speed of light, light waves. Principle of special relativity. Lorentz transformations.

14th week

Summary, discussion of questions emerging during the semester.

Requirements:

- for a signature

Participation in the adjoint **practice class work** is compulsory and its successful completion (scoring at least 50% on homework assignments) is required for a signature for the lectures. - *for a grade* - Knowledge of definitions, laws and theorems: grade 2; - In addition, knowledge of particle properties experimental methods and results: grade 3; - In addition, knowledge of the proofs of theorems: grade 4; In addition, knowledge of applications: grade 5. -*an offered grade:* -
Person responsible for course: Dr. István Nándori, associate professor, PhD
Lecturer: Dr. István Nándori, associate professor, PhD

Title of course: Classical mechanics I class work **Code**: TTFBG0101	**ECTS Credit points:** 4

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: signature + grade for written test

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 92 hours
- preparation for the exam: -

Total: 120 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): TTFBE0101

Further courses built on it: -

Topics of course

Problems of collisions of point-like object in one and two dimensions using conservation of momentum and Newtons's 3rd law. Application of Newtons's 2nd law to simple cases of force laws: spring, gravitational and central force problems. Solution of the equation of motion with constraints: mathematical pendulum, motion on inclined plane, motion in presence of friction. Solution of the equation of motion with constraints: mathematical pendulum, motion on inclined plane, motion in presence of friction. Finding the center of mass of rigid bodies in simple cases. Applications of Newtons's 2nd law of motion in accelerating reference frames. Application of the angular momentum theorem; calculation of the angular momentum of rigid bodies with respect to a fixed axis and to a fixed reference point. Calculation of the moment of inertia of rigid bodies in simple cases; Steiner's theorem. Problems for static equilibrium of rigid bodies, dynamics of rigid bodies rotating about a fixed axis, calculation of orbital and spin angular momentum. Rolling motion. Application of the work-energy theorem in simple cases. Calculation of the kinetic and the potential energy; problems for application of conservation of mechanical energy. Calculation of the potential energy for various force laws. Problems related to the second cosmic velocity; calculation of the elastic stress, the equivalent spring constant and Young's modulus. Problems of static equilibrium of gases and liquids (hydrostatics and aerostatics). Applications of Pascal's laws, hydrostatic pressure, Archimedes law, Boyle–Mariotte law, barometric formula. Problems for fluid mechanics: continuity equation, Bernoulli equation, Newton law of viscosity. Solution of problems of waves: wave speed, wave function, wave equation, energy types and their relations in traveling and standing waves. Doppler formula. Application of Lorentz' transformation formulas and their kinematical consequences in solving problems of relativistic kinematics.

Literature

Compulsory:
Robert Resnick, David Halliday, Keneth S. Krane, Physics I: Chapters 1-21 John Wiley & Sons, Inc..
Recommended:
-

Schedule:

1st week

Problems of collisions of point-like object in one and two dimensions using conservation of momentum and Newtons's 3rd law.

2nd week

Application of Newtons's 2nd law to simple cases of force laws: spring, gravitational and central force problems.

3rd week

Solution of the equation of motion with constraints: mathematical pendulum, motion on inclined plane, motion in presence of friction.

4th week

Finding the center of mass of rigid bodies in simple cases. Applications of Newtons's 2nd law of motion in accelerating reference frames.

5th week

Application of the angular momentum theorem; calculation of the angular momentum of rigid bodies with respect to a fixed axis and to a fixed reference point.

6th week

Calculation of the moment of inertia of rigid bodies in simple cases; Steiner's theorem. Problems for static equilibrium of rigid bodies, dynamics of rigid bodies rotating about a fixed axis, calculation of orbital and spin angular momentum. Rolling motion.

7th week

In class test.

8th week

Application of the work-energy theorem in simple cases. Calculation of the kinetic and the potential energy; problems for application of conservation of mechanical energy. Calculation of the potential energy for various force laws.

9th week

Problems related to the second cosmic velocity; calculation of the elastic stress, the equivalent spring constant and Young's modulus.

10th week

Problems of static equilibrium of gases and liquids (hydrostatics and aerostatics). Applications of Pascal's laws, hydrostatic pressure, Archimedes law, Boyle–Mariotte law, barometric formula.

11th week

Problems for fluid mechanics: continuity equation, Bernoulli equation, Newton law of viscosity.

12th week

Solution of problems of waves: wave speed, wave function, wave equation, energy types and their relations in traveling and standing waves. Doppler formula.

13th week Application of Lorentz' transformation formulas and their kinematical consequences in solving problems of relativistic kinematics. *14th week* In class test.
Requirements: *- for a signature* Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature. *- for a grade* The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.
Person responsible for course: Dr. István Nándori, associate professor, PhD
Lecturer: Dr. István Nándori, associate professor, PhD

Title of course: Computer basics for physics applications **Code**: TTFBE0113	**ECTS Credit points:** 2

Type of teaching, contact hours
- lecture: 1 hours/week
- practice: -
- laboratory: 2 hours/week

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 14 hours
- practice: -
- laboratory: 28 hours
- home assignment: 8 hours
- preparation for the exam: 10 hours

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTFBE0101, TTFBL0118

Further courses built on it: -

Topics of course

Getting familiar with the working principles of Excel, understanding the relative and absolute cell coordinates, use of R1C1 view. Use of tables, objects, functions. Plotting data sets, applying statistical analysis, use of data-analysing and equation solving extensions. Application of WolframAlpha, Scilab and other mathematical softwares to solve mathematical problems. Matrix algebra, numerical derivation, numerical integration, interpolation, histogram. Solving simple physics problems with the computer.

Literature

Compulsory:
- Written materials uploaded to the Moodle learning platform,
- Engineering with Excel, 4th Edition by Ronald W. Larsen; Pearson, 2013,
- Scilab for very Beginners by Scilab Enterprises, 2013

Recommended:
- Introduction to Scilab by Scilab Enterprises, 2010

Schedule:

1st week

Introduction to the rules of the course and to the subject. Getting familiar with Excel, im-portant keyboard shortcuts, mouse commands, relative and absolute cell-references, R1C1 view. Simple arithmetics and the use of built-in functions.

2nd week

Function transformations using parameters, different diagrams for plotting data, plot format-ting

3rd week

Importing and exporting data, statistical analysis on data. Activation and use of data analysis extension in Excel.

4th week

Activating the equation solver extension of Excel and apply it for function fitting and regres-sion.

5th week Interpolation and extrapolation, smoothing, online and offline mathematical applications. 6th week Numerical derivation and integration 7th week Practicing and connecting different parts of the learned information. 8th week In-class test 9th week Basics of Scilab, introduction, Scilab's working principles, variables, functions, matrices, arithmetics, the very basics of plotting 10th week Programming in Scilab, defining functions, cycles, file management, plotting 11th week Different plotting methods for datasets. 12th week Solving simple physics problems numerically with Scilab 13th week Practicing. 14th week In-class test.
Requirements: *- for a signature* - During the semester solving at least 70% of the given homeworks successfully is a requirement for the signature. - *- for a grade* The course mark is calculated by a weighted average based on a) the solutions uploaded at the end of the practices and b) the results of mid-semester tests. The weights are a:b = 1:4. The grade is: fail (1) if below 50%, sufficient (2) if between 50-62%, average (3) if between 63-75%, good (4) if between 76-88%, excellent (5) if above 88%. *-an offered grade:* -
Person responsible for course: János Tomán, assistant lecturer
Lecturer: János Tomán, assistant lecturer

Title of course: Laboratory practical: mechanics, optics, thermodynamics 1 **Code**: TTFBL0114	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice:
- laboratory: 2 hours/week (aggregated as 4hours/week)

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice:
- laboratory: 20 hours
- home assignment: 40 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTFBE0101 and TTFBL0118

Further courses built on it: TTFBL0115

Topics of course

Laboratory measurements in mechanics, thermodynamics and optics

Literature

Compulsory:
Handouts provided on the course home page
Recommended:
Any university textbook on the topic of the upcoming measurement

Measurements:
Measurements with pendulums
Elastic moduli
Measurements with sound waves
Refractive index and dispersion
Measurements with lenses

Requirements:

- for a signature

Presence on all of the measurements and submission of laboratory report.

- for a grade
The grade is computed from the laboratory report and occasional written and oral discussion in the topic of the measurement.

Person responsible for course: Dr. Gábor Katona, assistant professor, PhD
Lecturer: Dr Gábor Katona, assistant professor, PhD Dr. László Tóth, assistant lecturer, PhD

Title of course: Laboratory practical: mechanics, optics, thermodynamics 2 **Code**: TTFBL0115	**ECTS Credit points:** 2
Type of teaching, contact hours - lecture: - - practice: - laboratory: 2 hours/week (aggregated as 4hours/week)	
Evaluation: mid-semester grade	
Workload (estimated), divided into contact hours: - lecture: - - practice: - laboratory: 20 hours - home assignment: 40 hours - preparation for the exam: - Total: 60 hours	
Year, semester: 2nd year, 1st semester	
Its prerequisite(s): TTFBE0102, TTFBE0103 and TTFBL0114	
Further courses built on it: -	

Topics of course
Laboratory measurements in mechanics, thermodynamics and optics
Literature
Compulsory: Handouts provided on the course home page *Recommended:* Any university textbook on the topic of the upcoming measurement

Measurements: Microscope and Telescope Viscosity Measurement of basic thermodynamic parameters Diffraction Measurement of a selected phenomenon with given set of devices, without measurement guide
Requirements: *- for a signature* Presence on all of the measurements and submission of laboratory report. *- for a grade* The grade is computed from the laboratory report and occasional written and oral discussion in the topic of the measurement.

Person responsible for course: Dr Gábor Katona, assistant professor, PhD
Lecturer: Dr. Gábor Katona, assistant professor, PhD Dr. László Tóth, assistant lecturer

Title of course: Thermodynamics **Code**: TTFBE0103	**ECTS Credit points:** 6

Type of teaching, contact hours

- lecture: 4 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 56 hours
- practice: -
- laboratory: -
- home assignment: 68 hours
- preparation for the exam: 56 hours

Total: 180 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTFBE0101, TTFBE0813, TTFBG0102

Further courses built on it: **TTFBE0103**

Topics of course

Lorentz transformations and their kinematical consequences: relativity of sections and time intervals, applications of Lorentz-transformations. Relativistic addition of velocity components. Relativistic dynamics: relativistic generalization of momentum and equation of motion; relativistic generalization of the work-energy theorem and energy. Equivalence of mass and energy, concept of internal energy. Thermal equilibrium, empirical temperature scales. Laws of Gay and Lussac, introduction of the the ideal-gas scale. State variables, equations of state for gases (in ideal-gas and Van der Waals approximations), condensed matter, elastic spring. Experimental observations leading to the recognition of the atomic structure of matter: Dalton's laws, Avogadro's law. Amount of substance. Characteristic size of a molecule. Brown-motion. Potential energy of the molecular interaction, concept of surface tension and surface energy. Relation between surface curvature and pressure, contact angle, capillarity. Statement of the 1st law of thermodynamics; interpretation of internal energy, ordered and disordered means of energy transfer. General concept of temperature. Finding the dependence of internal energy on state variables: friction calorimeter, heat capacity, specific heat. Mixing calorimeter; Dulong-Petit rule. Enthalpy, specific heat at constant pressure. Finding the dependence of the internal energy of gases on state variables, flow calorimeter. Free expansion on throttling; dependence of the enthalpy of gases on state variables. Internal energy of the ideal gas. Quasi-static adiabatic change of state, adiabatic lines of the ideal gas. Kinetic model of gases, kinetic interpretation of pressure and temperature. Law of equipartition, understanding the values of molar heat capacities of gases on the bases of equipartition. Freeze-out of degrees of freedom in gases. Molar heat capacity of condensed matter. Probability distribution and its density function. Maxwell-distribution of velocity components and magnitude. Stern's experiment. Distribution of concentration of gas in force field, barometric formula. Energy distribution of oscillators with continuous and discrete energy, interpretation of the freeze out of degrees of freedom based on the quantum assumption. Planck's formula and other quantum assumptions. Reversible and irreversible processes. The concept of heat engines. Ideal Joule-engine, thermal efficiency, rate of energy loss. Heat engines of Clausius-, Otto-, Diesel-type. Refrigerators. Ideal Carnot-engine, reversible engine. Stirling-engine. Concept of perpetual engine of the 2nd kind. Phenomenological formulation of the 2nd law of thermodynamics. Definition of the thermodynamic temperature scale. Simulation game to describe mixing; notion of macro and micro states. Statistical fluctuation. Simulation of energy distribution in the Einstein-model of condensed matter. Statistical formulation of the 2nd law. Statistical temperature and statistical entropy. Maximum efficiency of heat engines, relation between the statistical and thermodynamic temperature, thermodynamic entropy. Adiabatic quasi-static (constant entropy) process. Computation of the change of entropy from macroscopic parameters. Formulation of the 2nd law to certain processes of open systems, free energy and free enthalpy. Various formulations of the 1st law for reversible processes of homogeneous substances. Use of the equation of state to derive the dependence of the internal energy on state variable. Phase transitions, equilibrium of phases; phase transition temperature and latent heat. Liquid-vapour isotherms, evaporation and boiling. Sublimation, phase diagram, triple point. Change of entropy in phase transitions, chemical potential. Equation of Clausius and Clapeyron. Critical temperature, liquefying gases, condensation refrigerators. Liquefying gases of low critical temperature. Multicomponent systems, mixing entropy. Free enthalpy of solvents with low concentration, decrease of freezing, increase boiling temperatures. Transport phenomena. Current and current density. Convective and conductive transport. Operation of the vapour turbine. Mean free path and cross section. Stationary diffusion, Fick's law. Derivation of Fick's law using gas kinetics. Conductive heat transfer, Fourier's law. Viscosity, Newton's law of viscosity.

Literature

Compulsory:
- Zoltán Trócsányi: Thermodynamics, lecture note in electronic format

Recommended:
- Robert Resnick, David Halliday, Keneth S. Krane, Physics I: Chapters 22-26 John Wiley & Sons, Inc.

Schedule:

1st week

Lorentz transformations and their kinematical consequences: relativity of sections and time intervals, applications of Lorentz-transformations. Relativistic addition of velocity components.

2nd week

Relativistic dynamics: relativistic generalization of momentum and equation of motion; relativistic generalization of the work-energy theorem and energy. Equivalence of mass and energy, concept of internal energy.

3rd week

Thermal equilibrium, empirical temperature scales. Laws of Gay and Lussac, introduction of the the ideal-gas scale. State variables, equations of state for gases (in ideal-gas and Van der Waals approximations), condensed matter, elastic spring.

4th week

Experimental observations leading to the recognition of the atomic structure of matter: Dalton's laws, Avogadro's law. Amount of substance. Characteristic size of a molecule. Brown-motion. Potential energy of the molecular interaction, concept of surface tension and surface energy. Relation between surface curvature and pressure, contact angle, capillarity.

5th week

Statement of the 1st law of thermodynamics; interpretation of internal energy, ordered and disordered means of energy transfer. General concept of temperature. Finding the dependence of internal energy on state variables: friction calorimeter, heat capacity, specific heat. Mixing calorimeter; Dulong-Petit rule.

6th week

Enthalpy, specific heat at constant pressure. Finding the dependence of the internal energy of gases on state variables, flow calorimeter. Free expansion and throttling; dependence of the enthalpy of gases on state variables. Internal energy of the ideal gas. Quasi-static adiabatic change of state, adiabatic lines of the ideal gas.

7th week

Kinetic model of gases, kinetic interpretation of pressure and temperature. Law of equipartition, understanding the values of molar heat capacities of gases on the bases of equipartition. Freeze-out of degrees of freedom in gases. Molar heat capacity of condensed matter. Probability distribution and its density function. Maxwell-distribution of velocity components and magnitude.

8th week

Stern's experiment. Distribution of concentration of gas in force field, barometric formula. Energy distribution of oscillators with continuous and discrete energy, interpretation of the freeze out of degrees of freedom based on the quantum assumption. Planck's formula and other quantum assumptions.

9th week

Reversible and irreversible processes. The concept of heat engines. Ideal Joule-engine, thermal efficiency, rate of energy loss. Heat engines of Clausius-, Otto-, Diesel-type. Refrigerators. Ideal Carnot-engine, reversible engine.

10th week

Stirling-engine. Concept of perpetual engine of the 2nd kind. Phenomenological formulation of the 2nd law of thermodynamics. Definition of the thermodynamic temperature scale. Simulation game to describe mixing; notion of macro and micro states. Statistical fluctuation. Simulation of energy distribution in the Einstein-model of condensed matter. Statistical formulation of the 2nd law.

11th week

Statistical temperature and statistical entropy. Maximum efficiency of heat engines, relation between the statistical and thermodynamic temperature, thermodynamic entropy. Adiabatic quasi-static (constant entropy) process. Computation of the change of entropy from macroscopic parameters.

12th week

Formulation of the 2nd law to certain processes of open systems, free energy and free enthalpy. Various formulations of the 1st law for reversible processes of homogeneous substances. Use of the equation of state to derive the dependence of the internal energy on state variable.

13th week

Phase transitions, equilibrium of phases; phase transition temperature and latent heat. Liquid-vapour isotherms, evaporation and boiling. Sublimation, phase diagram, triple point. Change of entropy in phase transitions, chemical potential. Equation of Clausius and Clapeyron. Critical temperature, liquefying gases, condensation refrigerators. Liquefying gases of low critical temperature.

14th week

Mean free path and cross section. Stationary diffusion, Fick's law. Derivation of Fick's law using gas kinetics. Conductive heat transfer, Fourier's law. Viscosity, Newton's law of viscosity. Summary, discussion of questions emerging during the semester.

Requirements:

- *for a signature*

Participation in the adjoint **practice class work** is compulsory and its successful completion (scoring at least 50% on homework assignments) is required for a signature for the lectures.

- *for a grade*

The course ends in an **examination**. And the final grade is given according to the result of the examination

- Knowledge of definitions, laws and theorems: grade 2;
- In addition, knowledge of the proofs of most important theorems: grade 3;
- In addition, knowledge of the proofs of theorems: grade 4;
- In addition, knowledge of applications: grade 5.

-*an offered grade* is not possible.

Person responsible for course: Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS

Lecturer: Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS

Title of course: Thermodynamics class work
Code: TTFBG0102

ECTS Credit points: 3

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 62 hours
- preparation for the exam: -

Total: 90 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTFBE0102

Further courses built on it: -

Topics of course

Use of temperature scales and state equations to solve problems. Use of curvature pressure, interface energy and contact angle to calculate equilibrium fluid level. Problems to calculate changes in internal energy. Problems to calculate the enthalpy change, applying the quasi-static adiabatic state change equations. Application of the probability density function to solve problems. Calculating the efficiency of the Otto- and Diesel-cycle processes, the coefficent of performance of refrigerators. Problems for calculating macro and micro states. Problems to determine entropy change from macroscopic data. Problems to calculate free energy and free enthalpy. Applying Clausius-Clapeyron equation to solve tasks. Problems to use the mean free path and Fick's law. Applying law of heat conduction (Fourier's law) to solve tasks.

Literature

Robert Resnick, David Halliday, Keneth S. Krane, Fundamentals of Physics, John Wiley & Sons, Inc.

Schedule:

1st week Use of temperature scales and state equations to solve problems.

2nd week Use of curvature pressure, interface energy and contact angle to calculate equilibrium fluid level.

3rd week Problems to calculate changes in internal energy.

4th week Problems to calculate changes in internal energy.

5th week . Problems to calculate the enthalpy change, applying the quasi-static adiabatic state change equations.
6th week Application of the probability density function to solve problems.
7th week Application of the probability density function to solve problems.
8th week Calculating the efficiency of the Otto- and Diesel-cycle processes, the coefficent of performance of refrigerators.
9th week Problems for calculating macro and micro states.
10th week Problems to determine entropy change from macroscopic data.
11th week Problems to calculate free energy and free enthalpy.
12th week Applying Clausius-Clapeyron equation to solve tasks.
13th week Problems to use the mean free path and Fick's law.
14th week Applying law of heat conduction (Fourier's law) to solve tasks..

Requirements:

- for a signature
Participation at classes is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course.

- for a grade
Submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature. The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

Person responsible for course: Dr. Darai Judit, associate professor, PhD

Lecturer: Dr. Darai Judit, associate professor, PhD

Title of course: Classical mechanics 2 Code: TTFBE0104	ECTS Credit points: 3

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 62 hours

Total: 90 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTFBE0101, TTFBG0104, TTMBE0815

Further courses built on it: -

Topics of course

Kinematics of system of particles and contiuous systems. Waves. Generalized coordinates and constraints. Periodic waves. Linear superposition and interference. Physical state. The principle of least action. Lagrange's equations, and the uniqueness of the solution. Newton's first law. Coordinate transformations (spatial translation and rotation, time translation, Galilean transformation). Symmetries. Galilean relativity. Space inversion and time reversal symmetries. Lagrange functions (free particle, free system of particles, generalized potential energy). Pair potential, interaction with external fields. Lagrange's equation of the first kind, method of Lagrange multipliers. Symmetries and conservation laws. Noether's theorem. Momentum, angular momentum, conservation of energy. Conservation of the center of mass. Momentum, angular momentum, energy in laboratory systems and in center of mass systems. Newton's second law (forces), law of action and reaction, conservation theorem for the linear momentum of a system of particles. Equilibrium in mechanics. Closed systems and mechanically closed systems. Work-energy theorem. Potential energy, conservative forces, fields, equipotential surfaces, force lines. Energy conservation. Energy balance, types of work done. Motion of free particles, drag, frictions. One dimensional motion of a particle in external potential (bound states, scattering states, turning points), potential wells and barriers. Harmonic oscillator, damped harmonic oscillator, driven harmonic oscillator, over- and undercritical damping, resonance. Pendulum. Hamilton equations of motion, Legendre transform. Continuous systems as a system of coupled harmonic oscillators. Infinitesimal strain theory, deformation tensor. Stress tensor, Hooke's law, static deformations of continuous systems. Ideal fluid flow, Euler equations, classification of flows. Viscous fluids. Navier-Stokes equations.

Literature

Compulsory:
H. Goldstein, C. Poole, J. Safko, Classical Mechanics (Addison Wesley, 2001)
Recommended:
-

Schedule:

1st week

Kinematics of system of particles and contiuous systems. Waves. Generalized coordinates and constraints.

2nd week

Periodic waves. Linear superposition and interference.

3rd week

Physical state. The principle of least action. Lagrange's equations, and the uniqueness of the solution. Newton's first law. Coordinate transformations (spatial translation and rotation, time translation, Galilean transformation).

4th week

Symmetries. Galilean relativity. Space inversion and time reversal symmetries. Lagrange functions (free particle, free system of particles, generalized potential energy). Pair potential, interaction with external fields.

5th week

Lagrange's equation of the first kind, method of Lagrange multipliers.

6th week

Symmetries and conservation laws. Noether's theorem. Momentum, angular momentum, conservation of energy. Conservation of the center of mass. Momentum, angular momentum, energy in laboratory systems and in center of mass systems.

7th week

Newton's second law (forces), law of action and reaction, conservation theorem for the linear momentum of a system of particles. Equilibrium in mechanics. Closed systems and mechanically closed systems.

8th week

Work-energy theorem. Potential energy, conservative forces, fields, equipotential surfaces, force lines. Energy conservation. Energy balance, types of work done.

9th week

Motion of free particles, drag, frictions. One dimensional motion of a particle in external potential (bound states, scattering states, turning points), potential wells and barriers.

10th week

Harmonic oscillator, damped harmonic oscillator, driven harmonic oscillator, over- and undercritical damping, resonance. Pendulum.

11th week

Hamilton equations of motion, Legendre transform.

12th week

Continuous systems as a system of coupled harmonic oscillators. Infinitesimal strain theory, deformation tensor.

13th week Stress tensor, Hooke’s law, static deformations of continuous systems. *14th week* Ideal fluid flow, Euler equations, classification of flows. Viscous fluids. Navier-Stokes equations.
Requirements: - for a grade Knowledge of definitions, laws and theorems: grade 2; In addition, knowledge of particle properties experimental methods and results: grade 3; In addition, knowledge of the proofs of theorems: grade 4; In addition, knowledge of applications: grade 5.
Person responsible for course: Dr. Sandor Nagy, associate professor, PhD
Lecturer: Prof. Dr. Kornel Sailer, professor emeritus, DSc

Title of course: Classical mechanics 2 class work Code: TTFBG0104	ECTS Credit points: 3

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: signature + grade for written test

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 62 hours
- preparation for the exam: -

Total: 90 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTFBG0104, TTMBE0813

Further courses built on it: -

Topics of course

Problems related to circular motion, solution of the harmonic oscillator, simple problems with composition of harmonic motions. Wave motion, wave equations, and their solutions. Calculations with Lagrange functions of simple systems. Constraints, problems related to Lagrange's equation of the first kind. Derivation of momentum, angular momentum, energy from the Lagrange function, continuous symmetries and conservation laws, conservation of the center of mass. Problems related to potential energies and conservative forces. Motion of particle in a potential. Investigation of the harmonic oscillator, damped oscillator, driven oscillator. Usage of Hamilton equations of motion, and Legendre transform. Problems related to deformation of bodies.

Literature

Compulsory:

H. Goldstein, C. Poole, J. Safko, Classical Mechanics (Addison Wesley, 2001)

Recommended:

-

Schedule:

1st week

Problems related to circular motion, solution of the harmonic oscillator, simple problems with composition of harmonic motions.

2nd week

Wave motion, wave equations, and their solutions.

3rd week

Calculations with Lagrange functions of simple systems.

4th week

In class test.

5th week

Constraints, problems related to Lagrange's equation of the first kind.

6th week

Derivation of momentum, angular momentum, energy from the Lagrange function, continuous symmetries and conservation laws, conservation of the center of mass.

7th week

Constraints, problems related to Lagrange's equation of the second kind.

8th week

Problems related to potential energies and conservative forces.

9th week

In class test.

10th week

Motion of particle in a potential.

11th week

Investigation of the harmonic oscillator, damped oscillator, driven oscillator.

12th week

Usage of Hamilton equations of motion, and Legendre transform.

13th week

Problems related to deformation of bodies.

14th week

In class test.

Requirements:

- for a signature

Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature.

- for a grade

The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

Person responsible for course: Dr. Sandor Nagy, associate professor, PhD, habil

Lecturer: Prof. Dr. Kornel Sailer, professor emeritus, DSc

Title of course: Optics Code: TTFBE0103	ECTS Credit points: 1

Type of teaching, contact hours

- lecture: 1 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 14 hours
- practice: -
- laboratory: -
- home assignment: 6 hours
- preparation for the exam: 10 hours

Total: 30 hours

Year, semester: 1rt year, 2nd semester

Its prerequisite(s): TTFBE0101

Further courses built on it: -

Topics of course

Light rays and waves. The speed of light. The nature and propagation of light. The terminology of photometry. Basic laws of geometrical optics: superposition of waves, interference diffractions, absorption, scattering. Thin lenses, thick lenses, spherical mirrors. Mirror and lenses defects. Optical devices: camera, microscope, eye, lope. Main phenomena of physical optics: interference, coherence. Interference on double shit. Establish the main elements of the interference. Intensity dispersion in the case of two slit experiment. Interference in thin layers, Newtonian rings. Interferometers: Michelson, the coherence of laser source, holography. Diffraction, Huygens-Fresnel law, Fresnel diffraction, Fraunhofer diffraction. The conditions of diffraction. Interference and diffraction on two slit. Optical gratings, their parameters, and terminology. Diffraction and reflection on particles. X-ray diffraction and their application. The polarization of light. The parameters and terminology of polarization. Brewster law and Fresnel equation. Double refraction. Optical filters, linear polarized light. Elliptically polarized light. Interference of polarized light. Optical activity. The polarization of reflected light. Resolution of optical devices.

Literature

Compulsory:

1. Eugene Hecht, Optics, 5th edition, Pearson education, 2016.
2. Francis A. Jenkins, Harvey E. White, Fundamentals of Optics, McGraw-HillPrimis Custom Publishing, 2001

Schedule:

1st week

Light as a wave, wave equation, and its solutions. Parameters of light. The speed of light.

2nd week

The main parameters of light: wavelength, wavenumber, and frequency. The terminology of photometry.

3rd week

Refraction and diffraction of light. Basic laws of geometrical optics.

4th week

Main elements of geometrical optics: mirrors, lenses. Main parameters and possible defects.

5th week

Thin and thick lenses, their laws and parameters.

6th week

Optical systems: eye, camera, microscope, lope.

7th week

Main phenomena of physical optics: interference, coherence. Interference on double shit.

8th week

Interference in thin layers, Newtonian rings. Interferometers: Michelson, the coherence of laser source, holography.

9th week

Diffraction, Huygens-Fresnel law, Fresnel diffraction.

10th week

The conditions of diffraction. Interference and diffraction on two slit. Fraunhofer diffraction.

11th week

Optical gratings, their parameters, and terminology.

12th week

Diffraction and reflection on particles. X-ray diffraction and their application.

13th week

The polarization of light. The parameters and terminology of polarization. Brewster law and Fresnel equation. Double refraction. Optical filters.

14th week

Linear polarized light. Elliptically polarized light. Interference of polarized light. Optical activity. The polarization of reflected light. Resolution of optical devices.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

During the semester there are two tests: the mid-term test in the 8th week and the end-term test in the 15th week. Students have to sit for the tests

- for a grade

The course ends in an **examination**. Based on the average of the grades of the designing tasks and the examination, the exam grade is calculated as an average of them:

- the average grade of the two designing tasks
- the result of the examination

The minimum requirement for the mid-term and end-term tests and the examination respectively is 60%. Based on the score of the tests separately, the grade for the tests and the examination is given according to the following table:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

-an offered grade:
it may be offered for students if the average grade of the two designing tasks is at least satisfactory (3) and the average of the mid-term and end-term tests is at least satisfactory (3). The offered grade is the average of them.

Person responsible for course: Dr. István Csarnovics, assistant professor, PhD

Lecturer: Dr. István Csarnovics, assistant professor, PhD

Title of course: Optics class work **Code**: TTFBG0103-EN	**ECTS Credit points:** 1

Type of teaching, contact hours
- lecture: -
- practice: 1 hours/week
- laboratory: -

Evaluation: signature and grade for class work

Workload (estimated), divided into contact hours:
- lecture: 14 hours
- practice: -
- laboratory: -
- home assignment: 16 hours
- preparation for the exam: -

Total: 30 hours

Year, semester: 1rt year, 2nd semester

Its prerequisite(s): TTFBE0101-EN

Further courses built on it: -

Topics of course

Light rays and waves. The speed of light. The nature and propagation of light. The terminology of photometry. Basic laws of geometrical optics: superposition of waves, interference diffractions, absorption, scattering. Thin lenses, thick lenses, spherical mirrors. Mirror and lenses defects. Optical devices: camera, microscope, eye, lope. Main phenomena of physical optics: interference, coherence. Interference on double shit. Establish the main elements of the interference. Intensity dispersion in the case of two slit experiment. Interference in thin layers, Newtonian rings. Interferometers: Michelson, the coherence of laser source, holography. Diffraction, Huygens-Fresnel law, Fresnel diffraction, Fraunhofer-diffraction. The conditions of diffraction. Interference and diffraction on two slit. Optical gratings, their parameters, and terminology. Diffraction and reflection on particles. X-ray diffraction and their application. The polarization of light. The parameters and terminology of polarization. Brewster law and Fresnel equation. Double refraction. Optical filters, linear polarized light. Elliptically polarized light. Interference of polarized light. Optical activity. The polarization of reflected light. Resolution of optical devices.

Literature

Compulsory:

1. Eugene Hecht, Optics, 5th edition, Pearson education, 2016.
2. Francis A. Jenkins, Harvey E. White, Fundamentals of Optics, McGraw-HillPrimis Custom Publishing, 2001

Schedule:

1st week

Light as a wave, wave equation, and its solutions. Parameters of light. The speed of light.

2nd week

The main parameters of light: wavelength, wavenumber, and frequency. The terminology of photometry.

3rd week

Refraction and diffraction of light. Basic laws of geometrical optics.

4th week

Main elements of geometrical optics: mirrors, lenses. Main parameters and possible defects.

5th week

Thin and thick lenses, their laws and parameters.

6th week

Optical systems: eye, camera, microscope, lope.

7th week

Main phenomena of physical optics: interference, coherence. Interference on double shit.

8th week

Interference in thin layers, Newtonian rings. Interferometers: Michelson, the coherence of laser source, holography.

9th week

Diffraction, Huygens-Fresnel law, Fresnel diffraction.

10th week

The conditions of diffraction. Interference and diffraction on two slit. Fraunhofer diffraction.

11th week

Optical gratings, their parameters, and terminology.

12th week

Diffraction and reflection on particles. X-ray diffraction and their application.

13th week

The polarization of light. The parameters and terminology of polarization. Brewster law and Fresnel equation. Double refraction. Optical filters.

14th week

Linear polarized light. Elliptically polarized light. Interference of polarized light. Optical activity. The polarization of reflected light. Resolution of optical devices.

Requirements:

- for a signature

Participation in **practice classes** is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can’t make up any practice with another group. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence. In case of further absences, a medical certificate needs to be presented. Missed practice classes should be made up for at a later date, to be discussed with the tutor. Active participation is evaluated by the teacher in every class. If a student’s behavior or conduct doesn’t meet the requirements of active participation, the teacher may evaluate his/her participation as an absence because of the lack of active participation in class.

During the semester there are two tests: the mid-term test in the 8th week and the end-term test in the 15th week. Students have to sit for the tests

- for a grade

The course ends in grade for the class, practice work. Based on the average of the grades of the designing tasks and the two tests, the grade is calculated as an average of them:

- the average grade of the two designing tasks
- the result of the two tests

The minimum requirement for the mid-term and end-term tests and the examination respectively is 60%. Based on the score of the tests separately, the grade for the tests and the examination is given according to the following table:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Dr. István Csarnovics, assistant professor, PhD

Lecturer: Dr. István Csarnovics, assistant professor, PhD

Title of course: Electromagnetism **Code**: TTFBE0105	**ECTS Credit points:** 6
Type of teaching, contact hours - lecture: 4 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 56 hours - practice: - - laboratory: - - home assignment: 28 hours - preparation for the exam: 96 hours Total: 180 hours	
Year, semester: 2nd year, 1st semester	
Its prerequisite(s): TTFBE0102	
Further courses built on it: TTFBE0107, TTFBE0108, TTFBE0120	

Topics of course

Basic concepts and phenomena of electrostatics. Electric charge, force between charges. Coulomb's law. Electric charge and matter. The concept of electric field. Gauss's law. The basic characteristics of the static electric field: Electrostatic potential. The electric dipole moment, the electric field of a system of charges, the principle of superposition. Conductors and insulators. The distribution of electric charge on an isolated conductor, corona discharge. Capacitance and capacitors. Energy density of the electrostatic field. Dielectrics, electric polarization, susceptibility, displacement vector. Electric current and electric resistance, current density. Resistivity and conductivity. Ohm's law and Joule's law. The microscopic view of the electronic conduction in solids. Electronic circuits, the electromotive force. Kirchhoff's rules, an RC circuit. The mechanism of the electronic conduction of liquids and gases. The concept of the magnetic field and the definition of magnetic field inductance vector. Magnetic force acting on a current or a moving charge. The magnetic field induced by a current or a moving charge Biot–Savart's and Amper's law. Magnetic properties of matter. Dia-, para- and ferromagnetic materials. An atomic view of the magnetism of matter, the Einstein de Haas experiment. Motion of charged particles in electric and magnetic field. Mass spectrometers and particle accelerators. The Hall effect. Faradays law of induction. Lenz's rule. The properties of the induced electric field. Self-induction. RL circuits, mutual induction. Energy stored in the magnetic field. Electromagnetic oscillations. Free and damped oscillations in LC and RLC circuits, forced oscillations, coupled oscillations, resonance. Alternating current circuits. Motors and generators, the transformer. The three phase alternating current. The concept of displacement current and induced magnetic field. The Ampere-Maxwell law. Maxwell's equations in differential and integral forms. Potentials and the wave equation. Electromagnetic waves. Dipole radiation, electromagnetic plane waves. Energy and momentum in the electromagnetic radiation.

Literature

Compulsory:
Robert Resnick, David Halliday, Keneth S. Krane, Physics Volume 2, John Wiley & Sons, Inc.
Recommended:

Schedule:

1st week

Basic concepts and phenomena of electrostatics. Electric charge, force between charges. Conductors, insulators. Physical unit of electric charge. Quantum of electric charge. Conservation of electric charge. Charge density. Coulomb's law. Electric charge and matter. The concept of electric field.

2nd week

The electric dipole moment, the electric field of a system of charges, the principle of superposition. Determination of the electric field of static charges, electric dipoles and continuous charge distributions. The motion of a point charge and a dipole in static electric field. Conductors in statics electric field. Gauss's law. The basic characteristics of the static electric field. Applications of the Gauss's law.

3rd week

Work done by the static electric field. Electrostatic potential, voltage. Potential of static charges, electric dipoles and continuous charge distributions. Potential energy of a system of charges. Conductors and insulators. The distribution of electric charge on an isolated conductor, corona discharge.

4th week

Capacitance and capacitors. Capacitors in series and in parallel. Energy density of the electro-static field. Dielectrics, electric polarization, Gauss's law in dielectrics, susceptibility, displacement vector, energy density of the static electric field in dielectrics, piezoelectric effect.

5th week

Electric current and electric resistance, current density. Equation of continuity. Resistivity and conductivity. Ohm's law. Specific resistance, specific conductance. The microscopic view of the electronic conduction in solids. The mechanism of the electronic conduction of liquids and gases.

6th week

Electronic circuits, the electromotive force. Kirchhoff's rules, work and power in electronic circuits, Joule's law, an RC circuit.

The concept of the magnetic field and the definition of magnetic field inductance vector. Magnetic force acting on a current or a moving charge.

7th week

Magnetic dipole. The magnetic field induced by a current or a moving charge Biot–Savart's and Amper's law. Unit of electric current. Work done by magnetic field.

8th week

Flux of static magnetic field. Scalar and vector potentials. Motion of charged particles in electric and magnetic field. Mass spectrometers and particle accelerators. The Hall effect. Focusing charged particle beams by static electric and magnetic fields.

9th week

Magnetic properties of matter, magnetic susceptibility, Dia-, para- and ferromagnetic materials. An atomic view of the magnetism of matter, the Einstein de Haas experiment. Permanent magnets.

10th week

Faradays law of induction. Lenz's rule. The properties of the induced electric field. Self-induction. RL circuits, mutual induction. Energy stored in the magnetic field.

11th week

Electromagnetic oscillations. Free and damped oscillations in LC and RLC circuits, forced oscillations, coupled oscillations, resonance.

12th week

Alternating current circuits. RLC circuits, impedance, phase shift, complex calculations, AC power. Motors and generators, the transformer. The three phase alternating current.

13th week

The concept of displacement current and induced magnetic field. The Ampere-Maxwell law. Maxwell's equations in differential and integral forms. Potentials and the wave equation.

14th week

Electromagnetic waves. Dipole radiation, electromagnetic plane waves. Energy and momentum in the electromagnetic radiation. Polarization. Propagation of energy and momentum in electromagnetic waves.

Requirements:

- for a signature

- Signature requires the correct solution of at least 50% of homework assignments.

- for a grade

- Knowledge of definitions, laws and theorems: grade 2;
- In addition, knowledge of the proofs of most important theorems: grade 3;
- In addition, knowledge of the proofs of theorems: grade 4;
- In addition, knowledge of applications: grade 5.

-an offered grade:

-

Person responsible for course: Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS

Lecturer: Dr. László Oláh, assistant professor, PhD

Title of course: Electromagnetism class work **Code**: TTFBG0105	**ECTS Credit points:** 4

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: signature + grade for written test

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 92 hours
- preparation for the exam: -

Total: 120 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): (p) TTFBE0105

Further courses built on it: -

Topics of course

Analyzing and solving problems on topics of the Electromagnetism lecture course:
Basic concepts and phenomena of electrostatics. Electric charge, force between charges. Coulomb's law. Electric charge and matter. The concept of electric field. Gauss's law. The basic characteristics of the static electric field: Electrostatic potential. The electric dipole moment, the electric field of a system of charges, the principle of superposition. Conductors and insulators. The distribution of electric charge on an isolated conductor, corona discharge. Capacitance and capacitors. Energy density of the electrostatic field. Dielectrics, electric polarization, susceptibility, displacement vector. Electric current and electric resistance, current density. Resistivity and conductivity. Ohm's law and Joule's law. The microscopic view of the electronic conduction in solids. Electronic circuits, the electromotive force. Kirchhoff's rules, an RC circuit. The mechanism of the electronic conduction of liquids and gases. The concept of the magnetic field and the definition of magnetic field inductance vector. Magnetic force acting on a current or a moving charge. The magnetic field induced by a current or a moving charge Biot–Savart's and Amper's law. Magnetic properties of matter. Dia-, para- and ferromagnetic materials. An atomic view of the magnetism of matter, the Einstein de Haas experiment. Motion of charged particles in electric and magnetic field. Mass spectrometers and particle accelerators. The Hall effect. Faradays law of induction. Lenz's rule. The properties of the induced electric field. Self-induction. RL circuits, mutual induction. Energy stored in the magnetic field. Electromagnetic oscillations. Free and damped oscillations in LC and RLC circuits, forced oscillations, coupled oscillations, resonance. Alternating current circuits. Motors and generators, the transformer. The three phase alternating current. The concept of displacement current and induced magnetic field. The Ampere-Maxwell law. Maxwell's equations in differential and integral forms. Potentials and the wave

equation. Electromagnetic waves. Dipole radiation, electromagnetic plane waves. Energy and momentum in the electromagnetic radiation.

Literature

Compulsory:
Robert Resnick, David Halliday, Keneth S. Krane, Physics Volume 2, John Wiley & Sons, Inc.
Recommended:
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Schedule:

1st week

Basic concepts and phenomena of electrostatics. Electric charge, force between charges. Conductors, insulators. Physical unit of electric charge. Quantum of electric charge. Conservation of electric charge. Charge density. Coulomb’s law. Electric charge and matter.

2nd week

The concept of electric field. The electric field of a system of charges, the principle of superposition. Determination of the electric field of static charges, and equilibrium conditions. The motion of a point charge in static electric field.

3rd week

Determination of the electric field of continuous charge distributions.

4th week

The electric dipole moment. Determination of the electric field of an electric dipole.

Gauss’s law. Applications of the Gauss’s law: electric field of continuous symmetrical charge distributions.

5th week

Calculation of the work done by the static electric field. Electrostatic potential, voltage. Poten-tial of static charges, electric dipoles and continuous charge distributions. Potential energy of a system of charges.

6th week

The distribution of electric charge on an isolated conductor. Determination of the electric po-tential of charged conductors. Capacitance and capacitors. Capacitors in series and in parallel. Energy density of the electrostatic field of a capacitor without and with dielectrics.

7th week

Electric current and electric resistance, current density. Equation of continuity. Resistivity and conductivity. Ohm’s law. Specific resistance, specific conductance.

Electronic circuits, the electromotive force. Kirchhoff’s rules, work and power in electronic circuits, Joule’s law, an RC circuit. Comparison of the electronic conduction in solids and in liquids.

8th week

Static magnetic field. Determination of magnetic field inductance vector. Magnetic force act-ing on a current or a moving charge. The motion of a point charge in static magnetic field. Speed selectors. Mass spectrometers and particle accelerators.

9th week

Magnetic dipole. The magnetic field induced by a current or a moving charge. Applications of Biot–Savart's and Amper's laws for simple current configurations.

10th week

Flux of static magnetic field. Flux calculations. Faradays law of induction. Lenz's rule. Calculation of the induced electric field and electric current. Self induction, mutual induction, induc-tion calculations for simple configurations.

11th week

Energy stored in the magnetic field of a simple coil. Calculation of the energy density of the magnetic field. Ferromagnetic materials. Magnetic hysteresis measurements. Analysis of RL circuits.

12th week

Alternating current circuits. RLC circuits, impedance, phase shift, complex calculations, AC power. The three phase alternating current. Electronic components connected in series and in parallel.

13th week

Electromagnetic oscillations. Differential equation of a series RLC circuit. Solutions for free and damped oscillations in LC and RLC circuits, and forced oscillations in an RLC circuit. Resonance..

14th week

In class test.

Requirements:

- for a signature

Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature.

- for a grade

The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

Person responsible for course: Dr. Lajos Daróczi, associate professor, PhD

Lecturer: Dr. Ferenc Cserpák, assistant professor, PhD,
Dr. László Oláh, assistant professor, PhD

Title of course: Electrodynamics **Code**: TTFBE0108	**ECTS Credit points:** 3
Type of teaching, contact hours - lecture: 2 hours/week - practice: - - laboratory: -	
Evaluation: oral exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: - - laboratory: - - home assignment: 34 hours - preparation for the exam: 28 hours Total: 90 hours	
Year, semester: 2^{nd} year, 2^{nd} semester	
Its prerequisite(s): TTFBE0105	
Further courses built on it: -	

Topics of course

Electrical and magnetic basic quantities. Maxwell equations in vacuum (differential and integral forms). Maxwell equations in macroscopic media. Boundary conditions. Continuity equation. Relaxation time. Completeness of Maxwell equations. Energy and momentum of the electromagnetic field. Poynting vector. Ponderomotive forces. Electromagnetic potentials in homogeneous isotropic insulators and conductors. Gauge transformations. Lorentz and Coulomb gauges. Electrostatics. Poisson and Laplace equations. Boundary value problems in electrostatics. Potential created by a static charge distribution. Electric field of conducting sphere. Point charge in the presence of a grounded conducting sphere. Dipole moments. Polarization of dielectric. Magnetostatics. Direct currents (DC). Basic equations. Ohm's law. Kirchhoff's laws. Law of Biot and Savart. Electromagnetic induction. Basic equations of the electromagnetic field. Alternating currents (AC). RL circuit. RLC circuit. Calculation of scalar and vector potentials. Basic equations of rapidly changing electromagnetic fields. D'Alembert's equation. Telegrapher's equations. Electromagnetic waves. Solutions of the wave equation. Retarded potentials. Electromagnetic waves in homogeneous isotropic insulators. Point dipole and antenna radiation. Electromagnetic waves in homogeneous, isotropic conductors. Cavities.

Literature

Compulsory:

- Jackson: Classical Electrodynamics (WILE&SONS, 1985).

Recommended:

-

Schedule:

1st week

Electrical and magnetic basic quantities. Coulomb's law. Gauss's law. Faraday's law of induction. Maxwell equations (differential and integral forms).

2nd week

Homogeneous, isotropic and anisotropic media. Maxwell equations in macroscopic media. Continuity equation. Relaxation time. Completeness of Maxwell equations.

3rd week

Boundary conditions. Energy of the electromagnetic field. Poynting vector.

4th week

Momentum of the electromagnetic field. Ponderomotive forces.

5th week

Electromagnetic potentials in homogeneous isotropic insulators and conductors. Gauge transformations. Lorentz and Coulomb gauges.

6th week

Electrostatics. Poisson and Laplace equations. Potential created by a static charge distribution.

7th week

Boundary value problems in electrostatics. Electric field of conducting sphere. Point charge in the presence of a grounded conducting sphere.

8th week

Dipole moments. Polarization of dielectric.

9th week

Magnetostatics. Direct currents (DC). Basic equheoremations. Ohm's law. Kirchhoff's laws.

10th week

Law of Biot and Savart. Electromagnetic induction. Basic equations of the electromagnetic field.

11th week

Alternating currents (AC). RL circuit. RLC circuit.

12th week

Basic equations of rapidly changing electromagnetic fields. D'Alembert's equation. Telegrapher's equations. Electromagnetic waves.

13th week

Solutions of the wave equation. Retarded potentials. Electromagnetic waves in homogeneous isotropic insulators.

14th week

Point dipole and antenna radiation. Electromagnetic waves in homogeneous, isotropic conductors. Cavities.

Requirements:

- for a signature

- Signature requires the correct solution of at least 50% of homework assignments.

- for a grade

- Knowledge of definitions, laws and theorems: grade 2; - In addition, knowledge of particle properties experimental methods and results: grade 3; - In addition, knowledge of the proofs of theorems: grade 4; In addition, knowledge of applications: grade 5. -*an offered grade:* -
Person responsible for course: Prof. Dr Ágnes Vibók, university professor, DSc
Lecturer: Prof. Dr Ágnes Vibók, university professor, DSc Peter Badanko, research assistant

Title of course: Electrodynamics class work **Code**: TTFBG0108	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: signature + written exam

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 32 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 2nd year, 2nd semester

Its prerequisite(s): TTFBE0105

Further courses built on it: -

Topics of course

Vector calculus. Vector differential operations. Simple tasks from electrostatics. Coulomb's law. Calculation of electrical potentials. Gauss's theorem. Solving the basic equations of electrostatics (Poisson and Laplace equations). Green's theorem. Point charge in the presence of a grounded conducting sphere. Conducting sphere in a uniform electric field. Selected advanced boundary value problems in electrostatics. Direct current. Ohm's law. Kirchhoff's laws. Solving simple DC linear circuit problems. Direct current II. Solving some advanced DC linear circuit problems. Law of Biot and Savart. Electromagnetic induction. Calculating magnetic field using vector potentials. Alternating currents (AC). RL circuits. RLC circuits. Electromagnetic waves. D'Alembert's equation. Telegrapher's equation..

Literature

Compulsory:

- Jackson: Classical Electrodynamics (WILE&SONS, 1985).

Recommended:

-

Schedule:

1st week

Vector calculus. Vector differential operations.

2nd week

Simple tasks from electrostatics. Coulomb's law. Gauss's theorem.

3rd week

Solving the basic equations of electrostatics. Poisson and Laplace equations.

4th week

Green's theorem. Point charge in the presence of a grounded conducting sphere.

5th week

Conducting sphere in a uniform electric field. Selected advanced boundary value problems in electrostatics I

6th week

Selected advanced boundary value problems in electrostatics.

7th week

In class test.

8th week

Direct current I. Ohm's law. Kirchhoff's laws. Solving basic DC linear circuit problems.

9th week

Direct current II. Solving some advanced DC linear circuit problems.

10th week

Law of Biot and Savart. Electromagnetic induction. Calculating magnetic field using vector potentials.

11th week

Alternating currents (AC). RL circuits.

12th week

RLC circuits.

13th week

Electromagnetic waves. Solving D'Alembert's and Telegrapher's equations.

14th week

In class test.

Requirements:

- for a signature

Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature.

- for a grade

The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

-an offered grade:

-

Person responsible for course: Prof. Dr Ágnes Vibók, university professor, DSc

Lecturer: Prof. Dr Ágnes Vibók, university professor, DSc

Peter Badanko, research assistant

Title of course: Condensed matter I **Code**: TTFBE0106	**ECTS Credit points:** 3
Type of teaching, contact hours - lecture: 2 hours/week - practice: - - laboratory: -	
Evaluation: oral exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: - - laboratory: - - home assignment: 34 hours - preparation for the exam: 28 hours Total: 90 hours	
Year, semester: 2nd year, 1st semester	
Its prerequisite(s): TTFBE0102, TTFBE0103	
Further courses built on it: TTFBG0106	

Topics of course

Bondings: atomic structure, binding forces and binding energy, primary bonds (ionic, covalent, metallic), secondary bonds (van der Waals, hydrogen). Crystal lattices: unit cells, crystalline structure of metals, crystalline systems and crystal types (primitive, bcc, fcc, hcp), crystallographic points, directions, Miller indices, linear and planar atomic density, close packing, single crystals, polycrystalline materials, bases of diffraction. Crystal faults: most important crystal faults, interstitial atom, vacancy, edge and screw dislocation, alloy, solid solution, phase and grain boundary. Diffusion: Definition and basic laws of diffusion, steady state diffusion equation, and its solution under simple initial conditions, time-dependent diffusion equation, and its solution in simple initial and boundary conditions. Elastic materials: elastic characteristics of the material, Hooke's law, relationship between elasticity constants, stress-strain diagram, yield strength, tensile strength, hardness, tangential form of Hooke's law for isotropic substances. Dislocation and deformation, deformation: characterization of dislocations, sliding planes, slip plane in single and polycrystalline material, deformation with twinning, increase of material strength, re-crystallization. Ceramics and polymers: structure of ceramics, silicates and glasses, crystalline defects and diffusion in ceramics, elastic properties of ceramics; polymeric molecules (molecular weight, shape, structure, configuration), thermoplastic and thermosetting polymers, copolymers, crystalline polymers, mechanical properties of polymers. Magnetic properties: the basic concepts of magnetism, the relationship between magnetism and material structure, dia, para, ferro, ferrite and antiferro magnetism, the effect of temperature on magnetic materials (Curie and Neel temperature), magnetic domains. Modern material testing and characterization methods: optical and scanning electron microscopes (transmission and scanning electron microscopy, scanning probe microscopes) and their various modes, X-ray diffractometry.

Literature

Compulsory:

William D. Callister, Jr. David G. Rethwisch Materials Science and Engineering, An Introduction, Willey

Recommended:

C.Kittel: Introduction to Solid State Physics

M.A. Omar: Elementary Solid State Physics, Priciples and Applications

Schedule:

1st week

The place and role of material science, material properties, classification of substances

2nd week

Bondings: atomic structure, binding forces and binding energy, primary bonds (ionic, covalent, metallic), secondary bonds (van der Waals, hydrogen).

3rd week

Crystal lattices: unit cell, crystalline structure of metals, crystal systems and crystal types, basic cubic structures (primitive, bcc, fcc, hcp).

4th week

Crystallographic points, directions, planes (Miller indices), linear and planar atomic density, close wraps, single crystals, polycrystalline materials, bases of diffraction.

5th week

Crystal defects: most important crystal defects, interstitial atom, vacancy, edge and screw dislocation, alloy, solid solution, phase and grain boundary.

6th week

Diffusion: the description of the phenomenon and its basic laws, steady state diffusion equation and its solution in simple initial conditions, time-dependent diffusion equation and its solution in simple initial and boundary conditions.

7th week

Interdiffusion: Presentation of the phenomenon and its technical significance, time-dependent diffusion equation and its solution in case of mutual diffusion.

8th week

Elastic materialss: elastic characteristics of the material, Hooke's law, relationship between elasticity constants, breakdown diagram, yield strength, tensile strength, hardness.

9th week

Tensor form of the Hooke law for isotropic substances.

10th week

Dislocations and deformation: characterization of dislocations, sliding planes, slip plane in single and polycrystalline material, deformation with twinning, increase of material strength, re-crystallization.

11th week

Ceramics and polymers: structure of ceramics, silicates and glasses, crystalline defects and diffusion in ceramics, elastic properties of ceramics; polymeric molecules (molecular weight, shape, structure, configuration), thermoplastic and thermosetting polymers, copolymers, crystalline polymers, mechanical properties of polymers.

12th week

Magnetic properties: the basic concepts of magnetism, the relationship between magnetism and material structure, dia, para, ferro, ferrite and antiferro magnetism, the effect of temperature on magnetic materials (Curie and Neel temperature), magnetic domains.

13th week

Modern material testing and characterization methods: optical and scanning electron microscopes (transmission and scanning electron microscopy, scanning probe microscopes) and their various modes, X-ray diffractometer.

14th week

Summary, discussion of questions emerging during the semester.

Requirements:

- for a signature

Attendance of the **lectures** is not compulsory, but highly recommended. Participation in the adjoint **practice class work** is compulsory and its successful completion (scoring at least 50% on homework assignments) is required for a signature for the lectures.

- for a grade

- *Examination is a prerequisite for successful completion of the subject-related class work.*
- *Examination of the relevant laws, batches and definitions of the topic: sufficient;*
- *In addition, knowledge of the main steps of the main theories of theory and law: medium;*
- *In addition, the deduction of the deductions with less help and the overview of the relationships are good;*
- *In addition, the unassigned derivation and the ability to apply them are excellent.*

-*an offered grade* is not possible.

Person responsible for course: Dr. Csaba Cserháti, associate professor, PhD

Lecturer: Dr. Csaba Cserháti, associate professor, PhD

Title of course: Condensed matter I class work **Code**: TTFBG0106	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 34 hours
- preparation for the test: 28 hours

Total: 90 hours

Year, semester: 2st year, 1st semester

Its prerequisite(s): TTFBE0102, TTFBE0103

Further courses built on it: TTFBE0106

Topics of course

Bondings: atomic structure, binding forces and binding energy, primary bonds (ionic, covalent, metallic), secondary bonds (van der Waals, hydrogen). Crystal lattices: unit cells, crystalline structure of metals, crystalline systems and crystal types (primitive, bcc, fcc, hcp), crystallographic points, directions, Miller indices, linear and planar atomic density, close packing, single crystals, polycrystalline materials, bases of diffraction. Crystal faults: most important crystal faults, interstitial atom, vacancy, edge and screw dislocation, alloy, solid solution, phase and grain boundary. Diffusion: Definition and basic laws of diffusion, steady state diffusion equation, and its solution under simple initial conditions, time-dependent diffusion equation, and its solution in simple initial and boundary conditions. Elastic materials: elastic characteristics of the material, Hooke's law, relationship between elasticity constants, stress-strain diagram, yield strength, tensile strength, hardness, tangential form of Hooke's law for isotropic substances. Dislocation and deformation, deformation: characterization of dislocations, sliding planes, slip plane in single and polycrystalline material, deformation with twinning, increase of material strength, re-crystallization. Ceramics and polymers: structure of ceramics, silicates and glasses, crystalline defects and diffusion in ceramics, elastic properties of ceramics; polymeric molecules (molecular weight, shape, structure, configuration), thermoplastic and thermosetting polymers, copolymers, crystalline polymers, mechanical properties of polymers. Magnetic properties: the basic concepts of magnetism, the relationship between magnetism and material structure, dia, para, ferro, ferrite and antiferro magnetism, the effect of temperature on magnetic materials (Curie and Neel temperature), magnetic domains. Modern material testing and characterization methods: optical and scanning electron microscopes (transmission and scanning electron microscopy, scanning probe microscopes) and their various modes, X-ray diffractometry.

Literature

Compulsory:

William D. Callister, Jr. David G. Rethwisch Materials Science and Engineering, An Introduction, Willey

Recommended:

Schedule:

1st week

Material properties, classification of substances.

2nd week

Bondings: atomic structure, binding forces and binding energy, primary bonds (ionic, covalent, metallic), secondary bonds (van der Waals, hydrogen).

3rd week

Crystal lattices: unit cell, crystalline structure of metals, crystal systems and crystalline types (primitive, bcc, fcc, hcp).

4th week

Crystallographic points, directions, planes (Miller indices), linear and planar atomic density, close packed crystalls, single crystals, polycrystalline materials, bases of diffraction.

5th week

In class test.

6th week

Most important crystal defects, interstitial atom, vacancy, edge and screw dislocation, alloy, solid solution, phase and grain boundary.

7th week

Diffusion: Solving the steady state diffusion equation for simple initial conditions, solving the time-dependent diffusion equation for simple initial and boundary conditions.

8th week

Solving the time-dependent diffusion equation for interdiffusion, the Darken equation.

9th week

In class test.

10th week

The elastic characteristics of the material, the Hooke-law, the relation between the elasticity constants, stress-strain diagram, yield strength, tensile strength, hardness.

11th week

Use of the tensor form of the Hooke law for isotropic substances.

12th week

Characterization of dislocations, sliding planes, deformation with twinning, increase of the strength of the material, re-crystallization, calculations.

13th week

In class test.

14th week

Summary, discussion of questions emerging during the semester.

Requirements:

Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature. The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

Person responsible for course: Dr. Csaba Cserháti associate professor, PhD

Lecturer: Dr. Gábor Katona, assistant professor, PhD

Dr. Csaba Cserháti, associate professor, PhD

Title of course: Condensed matter II **Code**: TTFBE0109	**ECTS Credit points:** 3

Type of teaching, contact hours
- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 62 hours

Total: 90 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): TTFBE0106, TTFBE0110

Further courses built on it: TTFBL0219

Topics of course

Phase diagrams: solubility limit, phases, microstructure, phase balance, single and isomorph binary-phase diagrams, eutectic alloys, Gibbs phase rule, phase sequence, intermediate phases, compound phases. Lattice Vibrations: elastic waves in continuum, vibration modes, density of state od a continuous medium, specific heat (Einstein model, Debye model); the phonon; wave motion on a chain of identical atoms, one-dimensional crystal from two types of atoms, thermal conductivity; un-elastic scattering of X-ray, scattering of neutron radiation and visible light on a lattice. Free-electron model of metals: specific electrical conductivity and Ohm-law; the temperature dependence of the electrical resistance, heat capacity of the conductive electrons; Fermi surface; thermal conductivity in metals; Hall effect; the limits of the free-electron model. Energy bands in solids: wave functions in periodic lattice, Bloch theorem, Brillouin zones; origin of a prohibited band; Kronig-Penney model; semiconductors: intrinsic semiconductors, holes, conductivity; extrinsic semiconductors, doping; semiconductor devices, diodes, transistors. Dielectrics: ferrous and piezoelectric materials. Optical properties: optical properties of metals, optical properties of non-metallic materials, refraction reflection, reflection, absorption, transmission, color, insulators transparency and opacity, luminescence, light guidance; optical devices, photodiodes, solar cells, optical fibers.

Literature

Compulsory:
C.Kittel: Introduction to Solid State Physics
Recommended:
William D. Callister, Jr. David G. Rethwisch Materials Science and Engineering, An Introduction, Willey
M.A. Omar: Elementary Solid State Physics, Priciples and Applications

Schedule:

1st week

Information, introduction.

Phase diagrams: introduction, solubility limit, phases, microstructure, phase equilibrium, single and isomorphic two-component phase diagrams.

2nd week

Phase diagrams: determination of phase composition, amount of microstructure in isomorphic alloys, mechanical properties of isomorphous alloys, binary eutectic systems.

3rd week

Phase diagrams: equilibrium phase diagram of intermediate and compound phases, eutectic and peritic reactions, Gibbs phase rule, status of Fe-C, change of microstructure in the state of the Fe-C state.

4th week

Lattice vibrations: description of one-dimensional elastic waves in continuous medium, vibra-tion modes, defining the density of states; calculation of the specific heat based on the Einstein and the Debye model; introducing the concept of phonon.

5th week

Lattice vibrations: description of wave motion on a chain of the same atoms and one-dimensional crystal with two types of atoms.

6th week

Lattice vibrations: interpretation of thermal conductivity; unelastic scattering of X-ray, neutron radiation and visible light on a lattice.

7th week

Free-electron model of metals: specific electrical conductivity and Ohm-law; the temperature dependence of the electrical resistance, heat capacity of the conductive electrons

8th week

Fermi surface; thermal conductivity in metals; Hall effect; the limits of the free-electron model.

9th week

Energy bands in solids: the foundation of the energyband theory through the description of the wave functions in the periodic lattice, introduction of the Bloch theorem, the Brillouin zones.

10th week

Band theory of solid states: The origin of band theory a description of the Kronig-Penney model.

11th week

Semiconductors: intrinsic semiconductors, holes, conductivity; extrinsic semiconductors, doping.

12th week

How do the simple semiconductor devices – eg diode, transistor, solar cells – work.

13th week

Dielectrics: ferrous and piezoelectric materials.

14th week

Optical properties of solid state materials: metals, non-metallic materials, refraction reflection, reflection, absorption, transmission, color, insulators transparency and opacity, luminescence, light guidance; optical devices, photodiodes, solar cells, optical fibers.

Requirements:

- for a signature

Attendance of the **lectures** is not compulsory, but highly recommended. Participation in the adjoint **practice class work** is compulsory and its successful completion (scoring at least 50% on homework assignments) is required for a signature for the lectures.

- for a grade

The course ends in an **examination**. And the final grade is given according to the result of the examination

- Knowledge of definitions, laws and theorems: grade 2;

- In addition, knowledge of the proofs of most important theorems: grade 3; - In addition, knowledge of the proofs of theorems: grade 4; - In addition, knowledge of applications: grade 5. -*an offered grade* is not possible.
Person responsible for course: Prof. Dr. Zoltán Erdélyi, university professor, DSc
Lecturer: Prof. Dr. Zoltán Erdélyi, university professor, DSc Dr. Csaba Cserháti, associate professor, PhD Dr. Gábor Katona, assistant professor, PhD

Title of course: Condensed matter II clw **Code**: TTFBE0109	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 62 hours
- preparation for the exam: -

Total: 90 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): (p) TTFBE0109

Further courses built on it:

Topics of course

The classwork follows the topic of the Condensed matter II lecture.
Phase diagrams: solubility limit, phases, microstructure, phase balance, single and isomorph binary-phase diagrams, eutectic alloys, Gibbs phase rule, phase sequence, intermediate phases, compound phases. Lattice Vibrations: elastic waves in continuum, vibration modes, density of state od a continuous medium, specific heat (Einstein model, Debye model); the phonon; wave motion on a chain of identical atoms, one-dimensional crystal from two types of atoms, thermal conductivity; un-elastic scattering of X-ray, scattering of neutron radiation and visible light on a lattice. Free-electron model of metals: specific electrical conductivity and Ohm-law; the temperature dependence of the electrical resistance, heat capacity of the conductive electrons; Fermi surface; thermal conductivity in metals; Hall effect; the limits of the free-electron model. Energy bands in solids: wave functions in periodic lattice, Bloch theorem, Brillouin zones; origin of a prohibited band; Kronig-Penney model; semiconductors: intrinsic semiconductors, holes, conductivity; extrinsic semiconductors, doping; semiconductor devices, diodes, transistors. Dielectrics: ferrous and piezoelectric materials. Optical properties: optical properties of metals, optical properties of non-metallic materials, refraction reflection, reflection, absorption, transmission, color, insulators transparency and opacity, luminescence, light guidance; optical devices, photodiodes, solar cells, optical fibers.

Literature

Compulsory:
C.Kittel: Introduction to Solid State Physics
Recommended:
William D. Callister, Jr. David G. Rethwisch Materials Science and Engineering, An Introduction, Willey
M.A. Omar: Elementary Solid State Physics, Priciples and Applications

Schedule:

1st week

Phase diagrams: determination of solubility and phase equilibrium.

2nd week

Phase diagrams: determination of phase composition and quantity.

3rd week

Phase diagrams: identification of equilibrium, intermediate and compound phases, application of the Gibbs phase rule.

4th week

Test

5th week

Lattice vibration: one-dimensional elastic waves in continuous medium, calculation of state density, examples on wave motion on a chain of the same atoms and one-dimensional crystal with two types of atoms.

6th week

Lattice vibration: examples on inelastic scattering of X-ray, neutron radiation and visible light on a lattice.

7th week

Free-electron model of metals: calculation specific electrical conductivity and Ohm-law; the temperature dependence of the electrical resistance.

8th week

Calculation of Fermi surface and Hall potential difference.

9th week

Test

10th week

Energy bands in solids: supporting material to understand the quantum mechanical description – as the students learn quantum mechanics parallel with this course.

11th week

Semiconductors: calculation of charge carrier density in intrinsic semiconductors; calculation of electric conductivity in intrinsic and extrinsic semiconductors; calculation of doping.

12th week

Presentation of some semiconductor devices.

13th week

Test

14th week

Summary of the semester.

Requirements:

- for a signature

Participation in the **practice class work** is compulsory and its successful completion (scoring at least 50% on homework assignments) is required for a signature.

- for a grade

The final grade is based on the arithmetic mean of the percentages of the tests completed during the semester:

- below 50%: grade 1;
- 50-62%: grade 2;
- 63-75%: grade 3;
- 76-88%: grade 4;
- 88-100%: grade 5.

-*an offered grade* is not possible.
Person responsible for course: Prof. Dr. Zoltán Erdélyi, university professor, DSc
Lecturer: Prof. Dr. Zoltán Erdélyi, university professor, DSc Dr. Csaba Cserháti, associate professor, PhD Dr. Gábor Katona, assistant professor, PhD Dr. László Tóth, assistant lecturer, PhD

Title of course: Condensed Matter Lab.Practice I. **Code**: TTFBL0116	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: -
- laboratory: 1 hours/week

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 16 hours
- laboratory: 16 hours
- home assignment: 28 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3st year, 1st semester

Its prerequisite(s): TTFBE0106

Further courses built on it: -

Topics of course

The students
During the 4-hour laboratory work, the students get acquainted with the measurements from the subject of condensed materials to enhance their practical knowledge in the subject.
During the course, four of the following eight measurements must be selected by the student: Determining the temperature dependence of magnetism, measuring coercive force and hysteresis. Measurement of hardness and tensile strength. The basics of differential thermal analysis. Testing the temperature dependence of electrical resistance. Diffusion measurement in liquid phase. Measuring Barkhausen noise

Literature

Compulsory: There are instructions of 10-20 pages produced by the Institute.
Recommended:
-

Schedule:

1st week
Information, introduction, accident, work safety education, discussion of lab-schedule

2nd week
Investigating the temperature dependence of magnetism

3rd week
Measuring coercive force and hysteresis.

4th week

Measurement of hardness and tensile strength *5th week* The basics of differential thermal analysis *6th week* Measurement of the temperature dependence of electrical resistance. *7th week* Measurement of diffusion in liquid phase. *8th week* Measurement of Barkhausen-noise.
Requirements: • the basic knowledge of the laboratory practice theory, the measurement, the preparation of a measurement report in electronic form: sufficient; • accurate knowledge of the theory of exercises, carrying out the measurement, making a measurement report in electronic form: medium; • Basic knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: good; • accurate knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: excellent.
Person responsible for course: Dr. Csaba Cserháti, associate professor, PhD
Lecturer: Dr. Bence Parditka, Dr. László Tóth

Title of course: Atomic and quantum physics **Code**: TTFBE0107	**ECTS Credit points:** 3
Type of teaching, contact hours - lecture: 2 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: - - laboratory: - - home assignment: 34 hours - preparation for the exam: 28 hours Total: 90 hours	
Year, semester: 2nd year, 2nd semester	
Its prerequisite(s): TTFBE0105, TTFBG0107	
Further courses built on it: -	

Topics of course

Wave properties of light: refraction, diffraction and interference, Young's two-slit diffraction experiment. Quantum aspects of light: electromagnetic radiation (spectral radiance), Reyleigh-Jeans' law, Planck's law. Quantum aspects of light: application of Planck's law and its consequences. Interpretation of Wien's and Stefan-Boltzmann's laws. Direct observation of the quantum properties of light: photo effect, Compton scattering. X-ray diffraction, the Bragg's law. De-Broglie hypothesis of matter waves. Discovery of the electron. Davisson-Germer experiment. Rutherford 's experiment. Cross section of Rutherford scattering. Discovery of the atomic nucleus. Derivation of the differential cross section formula of Rutherford scattering on point-like and extended target. Atomic spectra of Hydrogen-like atoms. Rydberg-Balmer formula. Bohr's postulates. Correspondence principle and the energy levels of the electron inside the atom. Franck-Hertz experiment. Fine structure of the atomic spectra. Effects of magnetic field on the atomic spectra (Zeeman splitting, Larmor-frequency) and electric field on the atomic spectra (Stark effect). Einstein - de Haas experiment, Stern-Gerlach experiment and the spin angular momentum the electron. Characteristic X-ray radiation, induced radiation, lasers. The periodic table of elements. Basics of quantum mechanics: states and measurements. Spin - state vector representation. Spin - density matrix representation.

Literature

Compulsory:

- Zoltán Trócsányi: Atomic and quantum physics, lecture note in electronic format

Recommended:

- Robert Resnick, David Halliday, Keneth S. Krane, Physics II: Chapters 45-54 John Wiley & Sons, Inc.

Schedule:

1st week

Wave properties of light: refraction, diffraction and interference, Young's two-slit diffraction experiment.

2nd week

Quantum aspects of light: electromagnetic radiation (spectral radiance), Rayleigh-Jeans' law, Planck's law, application of Planck's law and its consequences. Interpretation of Wien's and Stefan-Boltzmann's laws.

3rd week

Direct observation of the quantum properties of light: photo effect, Compton scattering.

4th week

X-ray diffraction, the Bragg's law. De-Broglie hypothesis of matter waves. Discovery of the electron. Davisson-Germer experiment.

5th week

Rutherford 's experiment. Derivation of the differential cross section formula of Rutherford scattering on point-like target.

6th week

Cross section of Rutherford scattering on a point-like and extended target. Discovery of the atomic nucleus.

7th week

Atomic spectra of Hydrogen-like atoms. Rydberg-Balmer formula. Bohr's postulates. Correspondence principle and the energy levels of the electron inside the atom. Franck-Hertz experiment.

8th week

Fine structure of atomic spectra. Effects of magnetic field on the atomic spectra (Zeeman splitting, Larmor-frequency) and electric field on the atomic spectra (Stark effect). Einstein - de Haas experiment, Stern-Gerlach experiment and the spin of the electron.

9th week

Characteristic X-ray radiation, induced radiation, lasers.

10th week

The periodic table of elements.

11th week

Basics of quantum mechanics: states and measurements.

12th week

Spin - state vector representation.

13th week

Spin – density matrix representation.

14th week

Summary, discussion of questions emerging during the semester.

Requirements:

- for a signature

Attendance of the **lectures** is not compulsory, but highly recommended. Participation in the adjoint **practice class work** is compulsory and its successful completion (scoring at least 50% on homework assignments) is required for a signature for the lectures.

- *for a grade*

The course ends in an **examination**. And the final grade is given according to the result of the examination

- Knowledge of definitions, laws and theorems: grade 2;
- In addition, knowledge of the proofs of most important theorems: grade 3;
- In addition, knowledge of the proofs of theorems: grade 4;
- In addition, knowledge of applications: grade 5.

-*an offered grade* is not possible.

Person responsible for course: Dr. István Nándori, associate professor, PhD

Lecturer: Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS
Dr. István Nándori, associate professor, PhD

Title of course: Atomic and quantum physics class work **Code**: TTFBG0107	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: 1 hours/week
- laboratory: -

Evaluation: mid-semester exam

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 14 hours
- laboratory: -
- home assignment: 31 hours
- preparation for the exam: -

Total: 45 hours

Year, semester: 2^{nd} year, 2^{nd} semester

Its prerequisite(s): TFBE0107

Further courses built on it: -

Topics of course

Problems on refraction and interference. Problems on electromagnetic radiation (spectral radiance) and the application of Wien's and Stefan-Boltzmann's laws. Application of Planck's law. Problems on the photo effect and Compton's scattering. Application of Bragg's law and de-Broglie's hypothesis of matter waves. Determination of the trajectory of the alpha particle in case of Rutherford's scattering. Calculation of the differential cross section. Application of the Rydberg-Balmer formula. Solution of the Landau-Lifshitz-Gilbert equation for static applied magnetic field. Application of Zeeman's splitting formula. Problems on characteristic X-ray radiation and the application of Moseley's law. Understanding of inverse population and negative temperature. Problems related to the periodic table of elements. Simple quantum mechanical problems. Problems related to the spin.

Literature

Compulsory:

- Robert Resnick, David Halliday, Keneth S. Krane, Physics II, John Wiley & Sons, Inc..

Recommended:

-

Schedule:

1st week

Problems on refraction, diffraction and interference.

2nd week

Problems on electromagnetic radiation (spectral radiance) and the application of Wien's and Stefan-Boltzmann's laws.

3rd week

Application of Planck's law.

4th week

Problems of photo effect and Compton's scattering.

5th week

Problems of photo effect and Compton's scattering.

6th week

Problems of photo effect and Compton's scattering.

7th week

Calculation of the differential cross section.

8th week

Application of the Rydberg-Balmer formula.

9th week

Solution of the Landau-Lifshitz-Gilbert equation for static applied magnetic field. Application of the Zeeman's splitting formula.

10th week

Problems of characteristic X-ray radiaion and the application of Moseley's law. Understanding of inverse population and negative temperature.

11th week

Problems related to the periodic table of elements.

12th week

Simple quantum mechanical problems.

13th week

Problems related to the spin.

14th week

Test.

Requirements:

- for a signature

Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature.

- for a grade

The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

-an offered grade:

-

Person responsible for course: Dr. István Nándori, associate professor, PhD

Lecturer: Dr. István Nándori, associate professor, PhD

Title of course: Nuclear physics **Code**: TTFBE0112	**ECTS Credit points:** 4

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: 1 hours/week
- laboratory: -

Evaluation: signature + exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: 14 hours
- laboratory: -
- home assignment: 38 hours
- preparation for the exam: 40 hours

Total: 120 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE0107

Further courses built on it: TTFBL0117,

Topics of course

Discovery of radioactivity. The characteristics of alpha decay, the Geiger-Nuttal rule, the fine structure of the spectrum. Interpretation with the tunnel effect. The concept of parity, parity violation, the universal weak interaction. Electromagnetic transitions of the nucleus. Transitional probabilities, isomeric states, internal conversion, Mössbauer effect. Essential properties of the nucleus. Size, charge, mass and binding energy, electromagnetic multipole momentum. Nuclear reactions, cross section, conservation laws. Compound nucleus model. Direct reactions, the optical model. Fission, neutron slowing down and diffusion, nuclear chain reaction, fission reactors. Termonuclear reactions, fusion devices. Excited states of the nucleus, one particle and collective excitations, giant multipole resonances. Nuclear models: liquid drop, shell, Fermi gas models. Nuclear forces, phenomenological approximation, the deuteron. The role of meson in the interpretation of nuclear forces. Results of low and high energy scattering experiments.

Literature

B. L. Cohen: Concepts of Nuclear Physics (McGraw-Hill, 1971)

Schedule:

1st week Discovery of radioactivity. The characteristics of alpha decay, the Geiger-Nuttal rule, the fine structure of the spectrum. Interpretation with the tunnel effect.

2nd week The concept of parity, parity violation, the universal weak interaction.

3rd week Electromagnetic transitions of the nucleus. Transitional probabilities, isomeric states, internal conversion, Mössbauer effect.

4th week Essential properties of the nucleus: size, charge.

5th week Essential properties of the nucleus: mass and binding energy, electromagnetic multipole momentum.

6th week Nuclear reactions: cross section, conservation laws.

7th week Nuclear reactions: Compound nucleus model. Direct reactions, the optical model.

8th week Fission, neutron slowing down and diffusion, nuclear chain reaction, fission reactors.

9th week Termonuclear reactions, fusion devices.

10th week Excited states of the nucleus, one particle and collective excitations, giant multipole resonances.

11th week Nuclear models: liquid drop and Fermi gas models.

12th week Nuclear models: shell model.

13th week Nuclear forces, phenomenological approximation, the deuteron. The role of meson in the interpretation of nuclear forces. Results of low and high energy scattering experiments.

14th week Summary, discussion.

Requirements:

- for a signature
Attendance at **lectures** is recommended, but not compulsory.

Participation at **practice classes** is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course.

- for a grade
The course ends in an **examination**.

Person responsible for course: Dr. Darai Judit, associate professor, PhD

Lecturer: Dr. Krasznahorkay Attila, scientific advisor

Title of course: Atom and nuclear physics laboratory work 1 **Code**: TTFBL0117-EN	**ECTS Credit points:** 2

Type of teaching, contact hours
- lecture: -
- practice: -
- laboratory: 2 hours/week

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: -
- laboratory: 28 hours
- home assignment: 32 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE0106-EN, TTFBE0107-EN

Further courses built on it: -

Topics of course

The spectra of atoms and molecules. Optical filters. Application of optical gratings and prisms. The h/e ratio. The Stefan-Boltzmann law. The Wien law.
Calibration and measurements with nuclear physics detectors. Characteristics of the gas and scintillation detectors. Nuclear decays and their properties, production of alpha, beta and gamma particles.

Literature

Compulsory:
1. Ujvári Balázs – Laboratory work – Nuclear Physics.
2. Csarnovics István – Laboratory works - Atom physics and optics.

Schedule:

1st week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

2nd week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

3rd week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

4th week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

5th week

Evaluation of the experimental results and fabrication of the report.

6th week
The presentation of the report of the experimental results.

7th week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

8th week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

9th week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

10th week
Experimental verification of Stefan-Boltzmann law. Investigation of light sources and optical filters. Determination of the recovery time of the Geiger-Müller counter, scintillation spectrometry

11th week

Evaluation of the experimental results and fabrication of the report.

12th week
The presentation of the report of the experimental results.

13th week
Optional consultations.

14th week
Catch up laboratory work

Requirements:

- for a signature

Participation in laboratory works is compulsory. A student must attend the laboratory works and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can't make up any practice with another group. Attendance at laboratory works will be recorded by the laboratory work leader. Being late is equivalent to an absence. In case of further absences, a medical certificate needs to be presented. Missed laboratory works should be made up for at a later date, to be discussed with the tutor. Students are required to bring the reports to each laboratory works. Active participation is evaluated by the teacher in every class. If a student's behavior or conduct doesn't meet the requirements of active participation, the teacher may evaluate his/her participation as an absence because of the lack of active participation in class.

Students have to **submit all the four designing reports** as a scheduled minimum on a sufficient level.

- for a grade

The course ends in a presentation of the report of the experimental results and with a grade for it. Based on the average of the grades of the designing tasks, the grade is calculated as an average of them:

- the average grade of the four designing tasks

The grade for the tasks is given according to the following table:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any task is below 60, students can take a retake the report in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Dr. Balázs Ujvári, assistant professor, PhD

Lecturer: Dr. István Csarnovics, assistant professor, PhD,

Dr. Balázs Ujvári, assistant professor, PhD.

Title of course: Quantum mechanics **Code**: TTFBE0110	**ECTS Credit points:** 4

Type of teaching, contact hours

- lecture: 3 hours/week
- practice: -
- laboratory: -

Evaluation: oral examination

Workload (estimated), divided into contact hours:

- lecture: 42 hours
- practice: -
- laboratory: -
- home assignment: 42 hours
- preparation for the exam: 56 hours

Total: 150 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE0104, TTFBE0107, TTFBG0110

Further courses built on it: -

Topics of course

Experiments that lead to quantum mechanics, the Stern-Gerlach experiment. Introduction of the quantum mechanical state, ket space, bar space, operators. Base kets and matrix representation. The physical quantites as operators. Measurement, observables, and uncertainty relations. Operators with continuous spectra, position, translation, momentum. Wave function. Introduction of the time evolution, Schrödinger equation, stationary states. Schrödinger picture, Heisenberg picture. Introduction of the Heisenberg equation of motion, free particles, Ehrenfest theorem. The harmonic oscillator, and its time evolution. Wave mechanics, continuity equation. Infinitesimal and finite rotations in quantum mechanics. Rotation in spin 1⁄2 systems. Euler rotation. Density operator, ensemble averages, pure and mixed ensembles, time evolution of ensembles. Angular momentum operator, eigenvaues, eigenvectors. Orbital angular momentum, spherical harmonics. The hidrogen atom. Entangled states, EPR paradox, Bell's inequality. Continuous and discrete symmetries. Identical particles, Pauli exclusion principle. Periodic table.

Literature

Compulsory:

J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley, 2011)

Recommended:

-

Schedule:

1st week

Experiments that lead to quantum mechanics, the Stern-Gerlach experiment.

2nd week

Introduction of the quantum mechanical state, ket space, bar space, operators. Base kets and matrix representation.

3rd week

The physical quantites as operators. Measurement, observables, and uncertainty relations.

4th week

Operators with continuous spectra, position, translation, momentum. Wave function.

5th week

Introduction of the time evolution, Schrödinger equation, stationary states.

6th week

Schrödinger picture, Heisenberg picture. Introduction of the Heisenberg equation of motion, free particles, Ehrenfest theorem.

7th week

The harmonic oscillator, and its time evolution.

8th week

Wave mechanics, continuity equation. Infinitesimal and finite rotations in quantum mechanics.

9th week

Rotation in spin 1⁄2 systems. Euler rotation. Density operator, ensemble averages, pure and mixed ensembles, time evolution of ensembles.

10th week

Angular momentum operator, eigenvaues, eigenvectors.

11th week

Orbital angular momentum, spherical harmonics.

12th week

The hidrogen atom.

13th week

Entangled states, EPR paradox, Bell's inequality.

14th week

Continuous and discrete symmetries. Identical particles, Pauli exclusion principle. Periodic table.

Requirements:

- for a grade

Knowledge of definitions, laws and theorems: grade 2;
In addition, knowledge of particle properties experimental methods and results: grade 3;
In addition, knowledge of the proofs of theorems: grade 4;
In addition, knowledge of applications: grade 5.

Person responsible for course: Dr. Sándor Nagy, associate professor, PhD

Lecturer: Dr. Sándor Nagy, associate professor, PhD

Title of course: Quantum mechanics, class work **Code**: TTFBG0104	**ECTS Credit points:** 3
Type of teaching, contact hours - lecture: - - practice: 2 hours/week - laboratory: -	
Evaluation: mid-semester grade	
Workload (estimated), divided into contact hours: - lecture: - - practice: 28 hours - laboratory: - - home assignment: 62 hours - preparation for the exam: - Total: 90 hours	
Year, semester: 3rd year, 1st semester	
Its prerequisite(s): TTFBE0110	
Further courses built on it: -	

Topics of course

Properties of the Hilbert space. The ket and the bra space, reprezentation of operators, operators acting on states. Observables, operators, uncertainty principle. Properties of operators of continuous spectra, examples, position, momentum. Solution of the Schrödinger equation for free particles and for simple potential forms. Usage of the Heisenberg equation of motion for free particles and for position dependent potentials. Problems related to the harmonic oscillator, eigenvalues, eigenvectors, selection rules. Solving problems in connection with rotations. Examples for pure and mixed states. Properties of the angular momentum operator. Problems related to the orbital angular momentum and the spherical harmonics. Problems related to the hydrogen atom, selection rules. Operators acting on entangled states. Calculation of expectation values for the Bell inequality.

Literature

Compulsory:
J. J. Sakurai, Modern Quantum Mechanics (Addison-Wesley, 2011)
Recommended:
-

Schedule:

1st week

Properties of the Hilbert space.

2^{nd} week

The ket and the bra space, reprezentation of operators, operators acting on states.

3^{rd} week

Observables, operators, uncertainty principle.

4^{th} week

Properties of operators of continuous spectra, examples, position, momentum.

5^{th} week

Solution of the Schrödinger equation for free particles and for simple potential forms.

6^{th} week

Usage of the Heisenberg equation of motion for free particles and for position dependent potentials.

7^{th} week

Problems related to the harmonic oscillator, eigenvalues, eigenvectors, selection rules.

8^{th} week

In class test.

9^{th} week

Solving problems in connection with rotations. Examples for pure and mixed states.

10^{th} week

Properties of the angular momentum operator.

11^{th} week

Problems related to the orbital angular momentum and the spherical harmonics.

12^{th} week

Problems related to the hidrogen atom, selection rules.

13^{th} week

Operators acting on entangled states. Calculation of expectation values for the Bell inequality.

14^{th} week

In class test.

Requirements:

- for a signature

Presence on 75% of the classes and submission of correct solution to at least 50% of homework problems is the minimum for obtaining signature.

- for a grade

The grade is computed as arithmetic mean of the solutions of homework assignments presented in class and the score of the written examination. The grade of the latter is: fail if below 50%, sufficient if between 50-62%, average if between 63-75%, good if between 76-88%, excellent if above 88%.

Person responsible for course: Dr. Sándor Nagy, associate professor, PhD

Lecturer: Dr. Sándor Nagy, associate professor, PhD

Title of course: Fundamental interactions **Code**: TTFBE0121	**ECTS Credit points:** 5
Type of teaching, contact hours - lecture: 2 hours/week - practice: 2 hours/week - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: 28 hours - laboratory: - - home assignment: 70 hours - preparation for the exam: 54 hours Total: 180 hours	
Year, semester: 3nd year, 2nd semester	
Its prerequisite(s): TTFBE0110	
Further courses built on it: -	

Topics of course
Four fundamental interactions and their force carriers. Classifications of elementary and compound particles, and their properties (lifetime, mass, charge, spin, parity). Conservation laws: electric charge, lepton and barion numbers, angular momentum, conservation of energy and momenta in four-vector formalism and its usage in particle scattering processes. Introduction to Classical Field Theory based on the model of linear chain of coupled oscillators. Lagrangian formalism for Classical Field Theory, the principle of least action. Symmetries in Classical Field Theory, the Noether-theorem. Internal symmetries and their relation to fundamental interactions. Quark model and the standard model of elementary particles; particle families. Beta-decay. Properties of neutrinos. Discovery of neutrino oscillations. Measurement of luminosity, distance and velocity of celestial bodies of the Universe. The cosmologic principle, the Hubble-expansion and the critical Universe. Friedmann-equations and their solutions. Discovery of cosmic microwave background radiation, the interpretation of its origin and its properties. Barionic acoustic oscillations and the distances of SN1 supernovae. Inflationary cosmology.
Literature
Compulsory: - István Nándori, Zoltán Trócsányi: Fundamental Interactions, lecture note in electronic format *Recommended:* - Leon M. Lederman: The God Particle: If the Universe Is the Answer What is the Question? ISBN 0-385-31211-3

- Horváth Dezső, Trócsányi Zoltán: Introduction into particle physics, electronic textbook.

Schedule:

1st week

Four fundamental interactions and their force carriers. Classifications of elementary and compound particles, and their properties (lifetime, mass, charge, spin, parity).

2nd week

Conservation laws: electric charge, lepton and barion numbers, angular momentum, conservation of energy and momenta in four-vector formalism and its use in particle scattering processes.

3rd week

Introduction to Classical Field Theory based on the model of linear chain of coupled oscillators. Lagrangian formalism for Classical Field Theory, the principle of least action.

4th week

Symmetries in Classical Field Theory, the Noether-theorem.

5th week

Internal symmetries and their relation to fundamental interactions.

6th week

Quark model and the standard model of elementary particles; particle families. Beta-decay. Properties of neutrinos. Discovery of neutrino oscillations.

7th week

Measurement of luminosity, distance and velocity of celestial bodies of the Universe.

8th week

The cosmologic principle, the Hubble-expansion and the critical Universe.

9th week

Friedmann-equations and their solutions.

10th week

Discovery of cosmic microwave background radiation, the interpretation of its origin and its properties.

11th week

Barionic acoustic oscillations and the distances of SN1 supernovae.

12th week

Nucleo-synthesis of light elements, cosmological standard model.

13th week

Inflationary cosmology.

14th week

Summary, discussion of questions emerging during the semester.

Requirements:

- for a signature

- Signature requires the correct solution of at least 50% of homework assignments.

- for a grade

- Knowledge of definitions, laws and theorems: grade 2;
- In addition, knowledge of particle properties experimental methods and results: grade 3;
- In addition, knowledge of the proofs of theorems: grade 4;

In addition, knowledge of applications: grade 5.
-*an offered grade:*
-

Person responsible for course: Dr. István Nándori, associate professor, PhD

Lecturer: Dr. István Nándori, associate professor, PhD

Title of course: Statistical Physics **Code**: TTFBE0216	**ECTS Credit points:** 5
Type of teaching, contact hours - lecture: 3 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 42 hours - practice: - - laboratory: - - home assignment: 60 hours - preparation for the exam: 48 hours Total: 150 hours	
Year, semester: 3rd year, 2nd semester	
Its prerequisite(s): -	
Further courses built on it:-	

Topics of course

Goal of statistical physics, importance of statistical description. Basic notions and relations of the theory of probability.

Micro- and macro-states. Classical mechanics of many-particle systems: phase point, phase space, trajectory. Hamiltonian dynamics. Canonical transformations. Liouville theorem.

The measure and features of information, the missing information, unbiased estimates. Shannon's information entropy, the maximum entropy principle. Entropy of many particle systems of classical mechanics. Fundamental postulates of statistical physics. Direction of macroscopic processes.

Derivation of multi-variable functions. Constraints, conditional extreme value calculations of two- and multi-variable functions. Lagrange multiplicators and their physical interpretation. Legendre-transforms.

Statistical equilibrium, statistical ensembles. Conditions of equilibrium, equilibrium of closed systems. Statistical averages, ensemble average, time average, ergodicity hypothesis. Density of states. Density of states of classical and quantum mechanical systems.

Micro-canonical ensemble, phase density, partition function and entropy. Extensive and intensive quantities, thermodynamic relations. Canonical ensemble. Canonical phase density, internal energy and entropy. Canonical temperature. Relation of free energy and internal energy. Probability density of the energy of the system, energy fluctuations and their dependence on the system size. Thermal equilibrium. Equivalence of micro-canonical and canonical ensembles.

Thermodynamic quantities. Macro-canonical ensemble. Phase density and partition function of macro-canonical ensemble. Probability distribution of the particle number, particle number fluctuations and their dependence on the system size. Chemical potential. T-p ensembles. Equivalence of statistical ensembles in the thermodynamic limit.

Thermodynamic potentials from the energy and from the entropy. Quasi-static processes, pressure, work, heat, first law of thermodynamics. Second and third laws of thermodynamics.

Canonical ensemble of the classical ideal gas, partition function, equation of state. Probability distribution of the velocity and energy of particles, the Maxwell-Boltzmann distribution. Quantum ideal gases, relation of classical and quantum mechanical descriptions. Quantum statistics, bosons and fermions. Degenerate Fermi-gas. Degenerate Bose-gas, Bose-Einstein condensation. Properties of Bose-Einstein condensates. Specific heat of solids. Degenerate free-electron gas. Classical limits of quantum statistics.

Literature

Compulsory:

- R. Kubo, Statistical mechanics with examples (The University of Tokyo, 1982).
- L.E. Reichl, A modern course in statistical physics (Wiley, New York, 2010).
- K. Huang, Statistical Mechanics (Wiley, New York, 1998).

Recommended:

- R. H. Swendsen, An Introduction to Statistical Mechanics and Thermodynamics (Oxford University Press, 2012).

Schedule:

1st week

Goal of statistical physics, importance of statistical description. Basics of the theory of probability: discrete and continuous stochastic variables. Expected value and scatter. Probability density and distribution functions. Distribution of the function of a stochastic variable. Frequently used distributions, gamma-function and its properties. Volume of a sphere in arbitrary dimensions.

2nd week

Micro- and macro-states. Classical mechanics of many-particle systems: phase point, phase space, trajectory. Hamiltonian dynamics, equation of motion. Canonical transformations. Liouville theorem and its consequence.

3rd week

The measure and features of information, the missing information, unbiased estimates. Shan-non's information entropy, the maximum entropy principle. Entropy of many particle systems of classical mechanics. Fundamental postulates of statistical physics. Direction of macroscop-ic processes.

4th week

Derivation of multi-variable functions. Constraints, conditional extreme value calculations of two- and multi-variable functions. Lagrange multiplicators and their physical interpretation. Legendre-transforms.

5th week

Statistical equilibrium, statistical ensembles. Conditions of equilibrium, equilibrium of closed systems. Statistical averages, ensemble average, time average, ergodicity hypothesis. Density of states. Density of states of classical and quantum mechanical systems.

6th week

Micro-canonical ensemble, phase space density, partition function and entropy. Extensive and intensive quantities, thermodynamic relations

7th week

Mid-term test. Canonical ensemble. Canonical phase space density, internal energy and entropy. Canonical temperature. Relation of free energy and internal energy

8th week

Probability density of the energy of systems in thermal equilibrium, energy fluctuations and their dependence on the system size. Thermal equilibrium. Equivalence of micro-canonical and canonical ensembles. Derivation of thermodynamic relations in the canonical ensemble.

9th week

Macro-canonical ensemble. Phase density and partition function of macro-canonical ensem-ble. Probability distribution of the particle number, particle number fluctuations and their de-pendence on the system size. Chemical potential.

10th week

T-p ensembles. Equivalence of statistical ensembles in the thermodynamic limit.

Thermodynamic potentials from the energy and from the entropy.

11th week

Quasi-static processes, pressure, work, heat, first law of thermodynamics. Second and third laws of thermodynamics.

12th week

Canonical ensemble of the classical ideal gas, partition function, equation of state. Probability distribution of the velocity and energy of particles, the Maxwell-Boltzmann distribution. Quantum ideal gases, relation of classical and quantum mechanical descriptions.

13th week

Quantum statistics, bosons and fermions. Degenerate Fermi-gas. Degenerate free-electron gas.

14th week

End-term test. Degenerate Bose-gas, Bose-Einstein condensation. Properties of Bose-Einstein condensates. Specific heat of solids. Classical limits of quantum statistics.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory. Condition to obtain signature is the successful (grade 2 or higher) accomplishment of one of the two tests according to semester assessment timing.

During the semester two tests are written: the mid-term test in the 7th week and the end-term test in the 14th week. Students' participation at the tests is mandatory.

The minimum requirement for the mid-term and end-term tests is 60%. Based on the total score of the two tests, the grade is determined according to the following scheme:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60%, students can get a retake opportunity according to the EDUCATION AND EXAMINATION RULES AND REGULATIONS of the university.

- for a grade

The course ends in an **examination**. Obtaining signature is a precondition for exam eligibility. Successful completion of the practical class of Statistical Physics (grade 2 or higher) is also a precondition for exam eligibility. Results of two tests are counted in the final grade at a 60% weight. The remaining 40% of the grade is based on a written exam where evaluation is performed according to the above scoring scheme.

-an offered grade:

it may be offered for students if the average grade of the two theoretical tests during the semester is at least satisfactory (3) and the average of the mid-term and end-term tests is at least satisfactory (3). The offered grade is the average of the theoretical tests.

Person responsible for course: Prof. Dr. Kun Ferenc, university professor, DSc

Lecturer: Prof. Dr. Kun Ferenc, university professor, DSc

Title of course: Statistical Physics **Code**: TTFBG0216	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 36 hours
- preparation for the tests: 26 hours

Total: 90 hours

Year, semester: 3rd year, 2nd semester

Its prerequisite(s): -

Further courses built on it:-

Topics of course

Basic relations of probability theory. Discrete and continuous stochastic variables.

Classical mechanics description of many-particle systems, Hamiltonian dynamics. Canonical transformations. Phase space volume, phase space density, Liouville theorem on simple examples.

The measure and properties of information, the missing information, unbiased estimates. Shannon's information entropy, the maximum entropy principle. Entropy of discrete and continuous stochastic variables. Entropy of classical mechanical systems through examples.

Derivation of multi-variable functions. Constraints, conditional extreme value calculus of two- and multi-variable functions. Lagrange-multiplicators and their physical interpretation. Legendre-transforms.

Number of micro-states, density of states and its properties. Density of states of classical and quantum mechanical systems illustrated by examples.

Application of the micro-canonical ensemble to fundamental model systems of statistical physics. Derivation of thermodynamic relations. Application of the canonical ensemble to fundamental models of statistical physics. Probability distributions of physical quantities in the canonical ensemble. Energy distribution, fluctuations of energy and its dependence on the system size. Temperature, thermal equilibrium. Derivation of thermodynamic relations. Equivalence of the canonical and micro-canonical ensembles. Application of the grand-canonical ensemble to fundamental models of statistical physics. Distribution of particle, fluctuation of the particle number and its dependence on the system size. Chemical potential, equilibrium. T-p ensembles, derivation of thermodynamic potentials.

Canonical ensemble of the classical ideal gas, partition function, equation of state. Probability distribution of the velocity and energy of particles, the Maxwell-Boltzmann distribution. Quantum ideal gases, relation of classical and quantum mechanical descriptions. Quantum statistics, bosons and fermions. Degenerate Fermi-gas. Degenerate Bose-gas, Bose-Einstein condensation. Properties of Bose-Einstein condensates. Specific heat of solids. Degenerate free-electron gas. Classical limits of quantum statistics.

Literature

Compulsory:

- R. Kubo, Statistical mechanics with examples (The University of Tokyo, 1982).
- L.E. Reichl, A modern course in statistical physics (Wiley, New York, 2010).
- K. Huang, Statistical Mechanics (Wiley, New York, 1998).

Recommended:

- R. H. Swendsen, An Introduction to Statistical Mechanics and Thermodynamics (Oxford University Press, 2012).

Schedule:

1st week

Basics of probability theory: discrete and continuous stochastic variables. Expected value and scatter. Probability density and distribution functions. Distribution of the function of a stochas-tic variable. Frequently used distributions, the gamma-function and its properties. Volume of a sphere in arbitrary dimensions. Stirling formula.

2nd week

Micro- and macro-states. Classical mechanics of many-particle systems: phase point, phase space, trajectory. Hamiltonian dynamics, equation of motion. Canonical transformations. Liouville theorem and its consequence, demonstration in simple systems.

3rd week

The measure and properties of information, the missing information, unbiased estimates. Shannon’s information entropy, the maximum entropy principle. Entropy of many particle systems of classical mechanics. Calculation of entropy of simple systems.

4th week

Derivation of multi-variable functions. Constraints, conditional extreme value calculations of two- and multi-variable functions. Lagrange multiplicators and their physical interpretation. Legendre-transforms with examples.

5th week

Density of states. Density of states of classical and quantum mechanical systems: particle in a box, linear harmonic oscillator, rotator. Normal system. Description of simple quantum me-chanical systems.

6th week

Micro-canonical ensemble, phase space density, partition function and entropy. Extensive and intensive quantities, determination of thermodynamic relations. Derivation of the thermody-namic relations of fundamental model systems of statistical physics, two-state system, harmonic oscillators.

7th week

Mid-term test. Canonical ensemble in fundamental model systems. Canonical phase space density, internal energy and entropy. Canonical temperature. Relation of free energy to internal energy. Derivation of thermodynamic relations in the canonical ensemble. Comparison of the micro-canonical and canonical ensembles.

8th week

Probability density of the energy of systems in thermal equilibrium, energy fluctuations and their dependence on the system size. Energy fluctuations of two-state systems, fluctuations of occupation number of states. Two-dimensional oscillator.

9th week

Further analysis of the canonical ensemble. Equilibrium of two sub-systems, distribution of energy between sub-systems.

10th week

Grand-canonical ensemble. Phase density and partition function of the macro-canonical en-semble. Probability distribution of the particle number, particle number fluctuations and their dependence on the system size. Chemical potential. Analysis of fundamental model systems in the canonical ensemble: semi-permeable wall in a gas, absorbing wall in a gas container.

11th week

T-p ensembles. Equivalence of statistical ensembles in the thermodynamic limit.

Thermodynamic potentials from the energy and from the entropy.

12th week

Canonical ensemble of the classical ideal gas, partition function, equation of state. Basics of kinetic gas theory. Probability distribution of the velocity and energy of particles, the Maxwell-Boltzmann distribution. Quantum ideal gases, relation of classical and quantum mechanical descriptions.

13th week

Quantum statistics, bosons and fermions. Degenerate Fermi-gas. Degenerate free-electron gas. Ideal Fermi-gas at zero temperature.

14th week

End-term test. Degenerate Bose-gas, Bose-Einstein condensation. Properties of Bose-Einstein condensates. Specific heat of solids. Classical limits of quantum statistics.

Requirements:

- for a term grade

Attendance of practical classes is mandatory. Three classes can be missed during the semester.

During the semester two tests are written: the mid-term test in the 7th week and the end-term test in the 14th week. Students' participation at the tests is mandatory.

The minimum requirement for the mid-term and end-term tests is 60%. Based on the total score of the two tests, the grade is determined according to the following scheme:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60%, students can get a retake opportunity according to the EDUCATION AND EXAMINATION RULES AND REGULATIONS of the university.

Person responsible for course: Prof. Dr. Kun Ferenc, university professor, DSc

Lecturer: Prof. Dr. Kun Ferenc, university professor, DSc

Title of course: Introduction to the theory of ordinary differential equations **Code**: TTMBE0817	**ECTS Credit points:** 3
Type of teaching, contact hours - lecture: 2 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: - - laboratory: - - home assignment: - - preparation for the exam: 62 hours Total: 90 hours	
Year, semester: 2rd year, 1st semester	
Its prerequisite(s): **TTMBE0814**	
Further courses built on it:	

Topics of course

Differential equations solvable in an elementary way. Cauchy problem; solution, maximal solution, locally and globally unique solution. Lipschitz condition; the theorem on global-local existence and uniqueness. Continuous dependence on the initial value. The Arzelà–Ascoli theorem and Peano's theorem. First order linear systems of differential equations; fundamental matrix, Liouville's formula, variation of constants. The construction of fundamental matrices of linear systems of differential equations with constant coefficients. Higher order (linear) differential equations and the Transition Principle; Wronski determinant and Liouville's formula. Fundamental sets of solutions of higher order linear differential equations with constant coefficients. Stability; Gronwall–Bellmann lemma and the stability theorem of Lyapunov. Elements of calculus of variations: the Du Bois-Reymond lemma and the Euler–Lagrange equations. Applications.

Literature

Compulsory/Recommended:

E. A. Coddington, N. Levinson: Theory of Ordinary Differential Equations. McGraw-Hill, 1955.

Schedule:

1st week

Ordinary explicit differential equations of first order solvable in an elementary way.

Separable, linear and exact equations. The Euler multiplicator.

2nd week

The notion of the Cauchy problem with respect to ordinary explicit differential equation systems of first order. Solution, complete solution, unique solution. Sufficient condition for the existence of the complete solution, global and local solvability.

3rd week

Complete metric spaces. The parametric version of the Banach fixed-point theorem. Weighted function spaces; The Cauchy problem and its equivalent integral equation.

4th week

Lipschitz properties. Global existence and uniqueness theorem. Continuous dependence on initial value; local existence and uniqueness theorem.

5th week

Compact operators; Schauder's fixed point theorems. Compact subsets of the space of continuous functions on intervals. Equicontinuity and uniform boundedness. Arzelà–Ascoli theorem.

6th week

Peano's existence theorem.

7th week

Linear differential equation systems of first order and their existence and uniqueness. Fundamental system and fundamental matrix; Liouville's formula. The method of constant variation.

8th week

The general theory of linear differential equation systems with constant coefficients: spectral radius, expression of analytic functions of matrices, the fundamental system of linear differential equation systems of first order with constant coefficient.

9th week

The general theory of explicit differential equations of higher order: transmission principle, Global existence and uniqueness theorem. Cauchy problem for higher order linear differential equations. The concept and the existence of the fundamental system; Wronski-determinant and Liouville formula.

10th week

Equivalent characterization of the fundamental system of a higher order linear linear differential equation. The constant variation method. The fundamental system of higher order homogeneous linear differential equations with constant coefficients.

11th week

Elements of stability theory. Definition of unstable, stable and asymptotically stable solution. Stability of the null-solution of homogeneous linear differential equation systems with constant coefficients.

12th week

The Gronwall–Bellmann lemma and the stability theorem of Lyapunov.

13th week

Elements of calculus of variation. The set of admissible functions and its topology. The differentiation of the perturbed basic functional and the Du-Bois-Reymond lemma.

14th week

The Euler-Lagrange differential equations. Applications: the problem of minimal surface solid of revolution, the Poincaré half-circle model of Bolyai–Lobachevsky's geometry. The Lagrange discussion of classical mechanics.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

- for a grade

The course ends in an **examination**. Before the examination students must have grade at least ‘pass’ on ordinary differential equations practice (TTMBG0206-EN).

The grade for the examination is given according to the following table:

Score	Grade
0-49	fail (1)
50-61	pass (2)
62-74	satisfactory (3)
75-87	good (4)
88-100	excellent (5)

If the average of the score of the examination is below 50, students can take a retake examination in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Prof. Dr. Zsolt Páles, university professor, DSc

Lecturer: Prof. Dr. Zsolt Páles, university professor, DSc

Title of course: Introduction to the theory of ordinary differential equations class work **Code**: TTMBG0817	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 14 hours
- preparation for the tests: 18 hours

Total: 60 hours

Year, semester: 2^{nd} year, 1st semester

Its prerequisite(s): TTMBG0814

Further courses built on it:

Topics of course

Differential equations solvable in an elementary way. Linear differential equation systems of first order; fundamental matrix, Liouville formula, constant variation. Construction of the fundamental matrix of linear differential equation systems with constant coefficients. Higher order (linear) differential equations and transmission principles; Wronski determinant and Liouville formula. Fundamental system of linear differential equations with constant coefficients. Elements of calculus variation: Du Bois-Reymond lemma and Euler-Lagrange equation.

Literature

Compulsory/Recommended:

E. A. Coddington, N. Levinson: Theory of Ordinary Differential Equations. McGraw-Hill, 1955.

Schedule:

1^{st} week

Differential equations solvable in an elementary way. Separable equations.

2^{nd} week

Differential equations of type that can be traced back into a separable equation (linear substitution, homogeneous equations).

3^{rd} week

Types that can be traced back into a separable equation (linear fractional substitution).

4th week

Differential equations that can be solved in an elementary way: first order linear equations. Bernoulli and Riccati equations.

5th week

Differential equations that can be solved in an elementary way: exact equations, Euler's multipliers.

6th week

Summarize, practice and deepen the foregoing.

7th week

Test

8th week

First order homogeneous linear differential equation systems with constant coefficients. Construction of the fundamental system. Expression of analytic functions of matrices.

9th week

First order inhomogeneous linear differential equation systems with constant coefficient. The constant variation method

10th week

Higher order linear equations with constant coefficients. Transmission principle, Characteristic polynomial, reduced constant variation, test function.

11th week

Higher linear linear equations with variable coefficients. Wronski determinant, Liouville formula and D'Alembert reduction.

12th week

Elements of calculus of variation. The Euler-Lagrange differential equations.

13th week

Summarize, practice and deepen the foregoing.

14th week

Test

Requirements:

- for a signature

Participation at **practice classes** is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can't make up any practice with another group. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence. In case of further absences, a medical certificate needs to be presented. Missed practice classes should be made up for at a later date, to be discussed with the tutor. Active participation is evaluated by the teacher in every class. If a student's behaviour or conduct doesn't meet the requirements of active participation, the teacher may evaluate his/her participation as an absence because of the lack of active participation in class.

During the semester there are two tests: the mid-term test in the 7th week and the end-term test in the 14th week. Students have to sit for the tests.

- *for a grade*

The minimum requirement for the average of the mid-term and end-term tests is 50%. The score is the average of the scores of the two tests and the grade is given according to the following table:

Score	Grade
0-49	fail (1)
50-61	pass (2)
62-74	satisfactory (3)
75-87	good (4)
88-100	excellent (5)

If the average of the scores is below 50, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Prof. Dr. Zsolt Páles, university professor, DSc

Lecturer: Prof. Dr. Zsolt Páles, university professor, DSc

Title of course: Probability and statistics **Code**: TTMBE0818	**ECTS Credit points: 3**

Type of teaching, contact hours
- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 28
- preparation for the exam: 34 hours

Total: 90 hours

Year, semester: 2st year, 1st semester

Its prerequisite(s): TTMBE0813

Further courses built on it:

Topics of course

Probability spaces. Conditional probability, chain rule, Bayes' theorem. Random variables and cumulative distribution function. Expected value and variance. Notable discrete ad continuous random variables. Laws of large numbers. Central limit theorem. Statistical estimators: unbiasedness, efficiency, consistency. Maximum likelihood estimation. Statistical hypothesis tests: u-test, t-test, $\chi 2$-test. Construction of confidence intervals.

Literature

Compulsory: -
Recommended:
J. Bain: Introduction to Probability and Mathematical StatisticsThomas,
Marco Taboga: Lectures on Probability Theory and Mathematical Statistics

Schedule:

1st week

The σ-algebra of events. The mathematical concept of probability. Classical propability spaces.

2nd week

Geometric probability. Basic properties of probability.

3rd week

Conditional probability. Chain rule and Bayes' theorem. Independence of events.

4th week

Random variables, cumulative distribution function. Discrete and continuous random variables.

5th week

Random vector variables. Independence of random variables. Sum of independent random variables and convolution.

6th week

Expected value of random variables and of functions of random variables.

7th week

Variance of random variables. Schwarz inequality. Covariance and correlation coefficient.

8th week

Notable discrete distributions: binomial distribution, hypergeometric distribution, Poisson distribution and geometric distribution.

9th week

Notable continuous distributions: uniform distribution, exponential distribution and normal distribution. Notable distributions derived from normal distribution: χ^2 and Student distribution.

10th week

Markov's and Chebyshev's inequality, the weak law of large numbers and Borel's strong law of large numbers. The general central limit theorem and the Moivre—Laplace theorem as a special case.

11th week

Statistical field, often used statistics. Statistical estimators: unbiasedness, efficiency, consistency.

12th week

The empirical distribution function and the fundamental theorem of mathematical statistics. Estimators for the probability density function, expected value and variance. Maximum likelihood estimation.

13th week

Statistical tests: u-test, t-test, χ^2-tests.

14th week

Construction of confidence intervals for the expected value and the variance of a normal distribution.

Requirements:

Only students who have the grade from the practical part can take part of the exam. The exam is written. The grade is given according to the following table:

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-74	satisfactory (3)
75-86	good (4)
87-100	excellent (5)

Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD

Lecturer: Dr. Zoltán Muzsnay, associate professor, PhD

Title of course: Probability and statistics **Code**: TTMBG0818	**ECTS Credit points: 2**

Type of teaching, contact hours
- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 32
- preparation for the exam: -

Total: 60 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0813

Further courses built on it:

Topics of course

Probability spaces. Conditional probability, chain rule, Bayes' theorem. Random variables and cumulative distribution function. Expected value and variance. Notable discrete ad continuous random variables. Laws of large numbers. Central limit theorem. Statistical estimators: unbiasedness, efficiency, consistency. Maximum likelihood estimation. Statistical hypothesis tests: u-test, t-test, $\chi 2$-test. Construction of confidence intervals.

Literature

Compulsory: -
Recommended:
J. Bain: Introduction to Probability and Mathematical StatisticsThomas,
Marco Taboga: Lectures on Probability Theory and Mathematical Statistics

Schedule:

1st week

The σ-algebra of events. The mathematical concept of probability. Classical propability spaces.

2nd week

Geometric probability. Basic properties of probability.

3rd week

Conditional probability. Chain rule and Bayes' theorem. Independence of events.

4th week

Random variables, cumulative distribution function. Discrete and continuous random variables.

5th week

Random vector variables. Independence of random variables. Sum of independent random variables and convolution.

6th week

Expected value of random variables and of functions of random variables.

7th week

Variance of random variables. Schwarz inequality. Covariance and correlation coefficient.

8th week

In class test. Notable discrete distributions: binomial distribution, hypergeometric distribution, Poisson distribution and geometric distribution.

9th week

Notable continuous distributions: uniform distribution, exponential distribution and normal distribution. Notable distributions derived from normal distribution: χ^2 and Student distribution.

10th week

Markov's and Chebyshev's inequality, the weak law of large numbers and Borel's strong law of large numbers. The general central limit theorem and the Moivre—Laplace theorem as a special case.

11th week

Statistical field, often used statistics. Statistical estimators: unbiasedness, efficiency, consistency.

12th week

The empirical distribution function and the fundamental theorem of mathematical statistics. Estimators for the probability density function, expected value and variance. Maximum likelihood estimation.

13th week

Statistical tests: u-test, t-test, χ^2-tests.

14th week

Construction of confidence intervals for the expected value and the variance of a normal distribution. In class test.

Requirements:

- for a signature

Participation at practice classes is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course.

- for a grade

During the semester one test is written. The grade is given according to the following table:

Score	Grade
0-49	fail (1)
50-59	pass (2)
60-74	satisfactory (3)
75-84	good (4)
85-100	excellent (5)

Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD

Lecturer: Dr. Zoltán Muzsnay, associate professor, PhD

Title of course: Materials and technology for microelectronics **Code**: TTFBE0201-EN	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 22 hours
- preparation for the exam: 40 hours

Total: 90 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE0106-EN

Further courses built on it: -

Topics of course

The main materials for electronics, their classification, and properties. Metals, semiconductors and dielectric material. Crystalline and amorphous materials. Band structures, optical and electrical conductivity. P-n junction. Main types of semiconductors and their technology. Si and Ge, organic semiconductors, their main properties, and parameters. Vacuum technology and basic elements. Thin layer technology, main deposition techniques: evaporation, deposition. Investigation of thin layers. The technology of single crystals, amorphous materials. The technology of Si and GaAs from bottom to the top. Diffusion, implantation and another lithography. The technology of active and passive elements, diodes, transistors, circuits. The technology of optoelectronic elements and devices: light sources and solar cells. SMT and THM technology of PCB. Quality, reliability. Some peculiar applications: sensors, memory elements, functional electronics, mechatronics. Trends in the development of micro- and nanotechnology. At the laboratory, students deal with thin film technology, thin film measurements, lithography, design, and fabrication of PCBs.

Literature

Compulsory:

1. Sze S.M. and Ng K.K. Physics of Semiconductor Devices. Wiley and Sons, 2006.
2. Sedra A.S., Smith K.C.: Microelectronic Circuits. Oxford Series in Electrical & Computer Engineering, 5th edition, Oxford University Press Inc., U.S. 2004.
3. Nalwa H.S. Nanostructured Materials and Nanotechnology. Elsevier, 2002.

Schedule:

1st week

The main materials for electronics, their classification, and properties.

2nd week

Metals, semiconductors and dielectric material. Crystalline and amorphous materials.

3rd week

Band structures, optical and electrical conductivity

4th week

P-n junction. Main types of semiconductors and their technology. Si and Ge, organic semiconductors, their main properties, and parameters.

5th week

The technology of single crystals, amorphous materials. The technology of Si and GaAs from bottom to the top.

6th week

Vacuum technology and basic elements.

7th week

Thin layer technology, main deposition techniques: evaporation, deposition.

8th week

Investigation of thin layers.

9th week

Diffusion, implantation and another lithography

10th week

Dielectric layers. The technology of SiO2 and SiN technológiája. Integrated circuits.

11th week

SMT and THM technology of PCB. Quality, reliability.

12th week

The technology of optoelectronic elements and devices: light sources and solar cells.

13th week

Some peculiar applications: sensors, memory elements, functional electronics, mechatronics.

14th week

Trends in the development of micro- and nanotechnology.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

During the semester there are two tests: the mid-term test in the 8th week and the end-term test in the 15th week. Students have to sit for the tests

- for a grade

The course ends in an **examination**. Based on the average of the grades of the designing tasks and the examination, the exam grade is calculated as an average of them:

- the average grade of the two designing tasks
- the result of the examination

The minimum requirement for the mid-term and end-term tests and the examination respectively is 60%. Based on the score of the tests separately, the grade for the tests and the examination is given according to the following table:

Score	Grade

0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

-an offered grade:
it may be offered for students if the average grade of the two designing tasks is at least satisfactory (3) and the average of the mid-term and end-term tests is at least satisfactory (3). The offered grade is the average of them.

Person responsible for course: Dr. István Csarnovics, assistant professor, PhD

Lecturer: Dr. István Csarnovics, assistant professor, PhD

Title of course: Materials and technology for microelectronics laboratory work **Code**: TTFBL0201-EN	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: -
- laboratory: 2 hours/week

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: -
- laboratory: 28 hours
- home assignment: 32 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE0106-EN

Further courses built on it: -

Topics of course

The main materials for electronics, their classification, and properties. Metals, semiconductors and dielectric material. Crystalline and amorphous materials. Band structures, optical and electrical conductivity. P-n junction. Main types of semiconductors and their technology. Si and Ge, organic semiconductors, their main properties, and parameters. Vacuum technology and basic elements. Thin layer technology, main deposition techniques: evaporation, deposition. Investigation of thin layers. The technology of single crystals, amorphous materials. The technology of Si and GaAs from bottom to the top. Diffusion, implantation and another lithography. The technology of active and passive elements, diodes, transistors, circuits. The technology of optoelectronic elements and devices: light sources and solar cells. SMT and THM technology of PCB. Quality, reliability. Some peculiar applications: sensors, memory elements, functional electronics, mechatronics. Trends in the development of micro- and nanotechnology. At the laboratory, students deal with thin film technology, thin film measurements, lithography, design, and fabrication of PCBs.

Literature

Compulsory:

1. Sze S.M. and Ng K.K. Physics of Semiconductor Devices. Wiley and Sons, 2006.
2. Sedra A.S., Smith K.C.: Microelectronic Circuits. Oxford Series in Electrical & Computer Engineering, 5th edition, Oxford University Press Inc., U.S. 2004.
3. Nalwa H.S. Nanostructured Materials and Nanotechnology. Elsevier, 2002.

Schedule:

1st week

Information about laboratory work, accident prevention.

2nd week

Design and construction of printed circuit board.

3rd week

Design and construction of printed circuit board.

4th week

Thick layer technology. Creation of thick layers.

5th week

Thick layer technology. Creation of thick layers.

6th week

Vacuum technology. Thin layer technology: vacuum evaporation.

7th week

Vacuum technology. Thin layer technology: vacuum evaporation.

8th week

Investigation of the created thin layers.

9th week

Investigation of the created thin layers.

10th week

Soldering of the elements into the created printed circuit board.

11th week

Soldering of the elements into the created printed circuit board.

12th week

Visiting the National Instruments factory.

13th week

Evaluation of the experimental results and fabrication of the report.

14th week

The presentation of the report of the experimental results.

Requirements:

- for a signature

Participation in laboratory works is compulsory. A student must attend the laboratory works and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can't make up any practice with another group. Attendance at laboratory works will be recorded by the laboratory work leader. Being late is equivalent to an absence. In case of further absences, a medical certificate needs to be presented. Missed laboratory works should be made up for at a later date, to be discussed with the tutor. Students are required to bring the reports to each laboratory works. Active participation is evaluated by the teacher in every class. If a student's behavior or conduct doesn't meet the requirements of active participation, the teacher may evaluate his/her participation as an absence because of the lack of active participation in class.

Students have to **submit all the five designing reports** as a scheduled minimum on a sufficient level.

- for a grade

The course ends with a presentation of the report of the experimental results and with a grade for it. Based on the average of the grades of the designing tasks, the grade is calculated as an average of them:

- the average grade of the five designing tasks

The grade for the tasks is given according to the following table:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any task is below 60, students can take a retake the report in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Dr. István Csarnovics, assistant professor, PhD

Lecturer: Dr. István Csarnovics, assistant professor, PhD

Title of course: Digital Electronics **Code**: TTFBE0202	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 28 hours
- preparation for the exam: 34 hours

Total: 90 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): Introduction to Electronics TTFBE0120

Further courses built on it: -

Topics of course

Refreshing and enhancing previous knowledge of Boolean algebra, logic functions and logic networks. Representing logic states with voltage levels. Logic circuits. Internal structure and characteristics of TTL and CMOS integrated circuits. Logic family interconnections. Driving external loads. Combinational networks. Encoders, decoders, multiplexers, demultiplexers, adders. Synchronous and asynchronous sequential networks. Typical sequential networks. R-S, D, T, J-K flip-flops, counters, registers. Digital to Analog and Analog to Digital converters. Programmable logic devices: PAL, PLA, FPGA. Application examples of digital electronics circuits in computers and computer controlled devices. Basic structure of microprocessors and computers.

Literature

Thomas L. Floyd: Digital Fundamentals. 11th edition, Pearson 2015

P. Horowitz, W. Hill: The Art of Electronics. 3rd edition, Cambridge University Press 2016

Schedule:

1st week

Refreshing and enhancing previous knowledge of Boolean algebra and logic functions.

2nd week

Representing logic states with voltage levels. Internal structure and characteristics of TTL integrated circuits. Open collector and Tri-State outputs.

3rd week

Internal structure and characteristics of CMOS integrated circuits. Interconnections between different logic families.

4th week

Driving external loads from logic circuits (lamps, LEDs, relays, motors, power elements).

5th week

Refreshing and enhancing existing knowledge of combination networks.

6th week

Data selectors, encoder and decoder circuits, multiplexers and demultiplexers, adders.

7th week

Test 1.

8th week

Synchronous and asynchronous sequential networks. R-S, D, T, J-K flip-flops.

9th week

Sequential networks: master-slave flip-flops, frequency dividers, counters, registers.

10th week

Digital-to-Analog and Analog-to-Digital converters

11th week

Programmable logic devices: PAL, PLA, FPGA.

12th week

Application examples of digital electronics circuits in computers. Buses in computers.

13th week

Basic structure of microprocessors. Consultation.

14th week

Test 2.

Requirements:

- *for a signature:* Attendance at lectures is recommended, but not compulsory.
- - *for a grade:* Written or oral exam. The grades are given according to the following table:
- 0-50 % failed (1)
- 51-60 % pass (2)
- 61-70 % satisfactory (3)
- 71- 80 % good (4)
- 81-100% excellent (5)
- -*an offered grade:* There will be two written tests during the semester. If both tests are successful, the student may get an offered mark based on the average of the two grades.

Person responsible for course: Dr. Gyula Zilizi, associate professor, PhD

Lecturer: Dr. Gyula Zilizi, associate professor, PhD

Title of course: Atom and nuclear physics laboratory work 2 **Code**: TTFBL0217-EN	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: -
- laboratory: 2 hours/week

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: -
- laboratory: 28 hours
- home assignment: 32 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTFBE0106-EN, TTFBE0107-EN

Further courses built on it: -

Topics of course

The determination of Boltzmann constant. The conductivity of metals and semiconductors. The temperature dependence of conductivity. The elements of the interferometers and their possible applications.
Study of the cosmic ray and gamma-gamma correlation

Literature

Compulsory:
Ujvári Balázs – Laboratory work – Nuclear Physics.
Csarnovics István – Laboratory works - Atom physics and optics.

Schedule:

1st week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Study of the cosmic ray and gamma-gamma correlation

2nd week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Study of the cosmic ray and gamma-gamma correlation

3rd week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Kozmikus sugárzás mérése, gamma-gamma korrelációs mérések

4th week

Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Study of the cosmic ray and gamma-gamma correlation

5th week

Evaluation of the experimental results and fabrication of the report.

6th week

The presentation of the report of the experimental results.

7th week

Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Study of the cosmic ray and gamma-gamma correlation

8th week

Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Kozmikus sugárzás mérése, gamma-gamma korrelációs mérések

9th week

Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Study of the cosmic ray and gamma-gamma correlation

10th week

Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

Study of the cosmic ray and gamma-gamma correlation

11th week

Evaluation of the experimental results and fabrication of the report.

12th week

The presentation of the report of the experimental results.

13th week

Optional consultations.

14th week

Catch up laboratory work

Requirements:

- for a signature

Participation in laboratory works is compulsory. A student must attend the laboratory works and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course. A student can't make up any practice with another group. Attendance at laboratory works will be recorded by the laboratory work leader. Being late is equivalent to an absence. In case of further absences, a medical certificate needs to be presented. Missed laboratory works should be made up for at a later date, to be discussed with the tutor. Students are required to bring the reports to each laboratory works. Active participation is evaluated by the teacher in every class. If a student's behavior or conduct doesn't meet the requirements of active participation, the teacher may evaluate his/her participation as an absence because of the lack of active participation in class.

Students have to **submit all the four designing reports** as a scheduled minimum on a sufficient level.

- for a grade
The course ends in a presentation of the report of the experimental results and with a grade for it. Based on the average of the grades of the designing tasks, the grade is calculated as an average of them:

- the average grade of the four designing tasks

The grade for the tasks is given according to the following table:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any task is below 60, students can take a retake the report in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Dr. István Csarnovics, assistant professor, PhD

Lecturer: Dr. István Csarnovics, assistant professor, PhD,
Dr. Balázs Ujvári, assistant professor, PhD.

Title of course: Condensed Matter Lab.Practice II. **Code**: TTFBL0219	**ECTS Credit points:** 2

Type of teaching, contact hours

- lecture: -
- practice: -
- laboratory: 1 hours/week

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:

- lecture: -
- practice: 16 hours
- laboratory: 16 hours
- home assignment: 28 hours
- preparation for the exam: -

Total: 60 hours

Year, semester: 3st year, 1st semester

Its prerequisite(s): TTFBE0106

Further courses built on it: -

Topics of course

The students

During the 4-hour laboratory work, the students get acquainted with the measurements from the subject of condensed materials to enhance their practical knowledge in the subject.

During the course four of the following six measurements must be selected by the student: Temperature dependence of magnetic properties of ferrous magnets. Metallography. Measurements with scanning electron microscope. Measurements with transmission electron microscope. Manufacture of alloys by arc defrosting. Production and testing of multilayers

Literature

Compulsory: There are instructions of 10-20 pages produced by the Institute.

Recommended:

-

Schedule:

1st week

Information, introduction, accident, work safety education, discussion of lab-schedule

2nd week

. Temperature dependence of magnetic properties of ferromagnetic materials

3rd week

Metallography (sample preparation and investigations with light microscope).

4th week

Measurements with scanning electron microscope (SEM) (sample preparation, image formation and composition measurements). *5th week* Measurements with transmission electron microscope (TEM) (sample preparation, dark-field, bright filed imaging and electron diffraction) *6th week* Preparing different alloys using arc-melting technique
Requirements: • the basic knowledge of the laboratory practice theory, the measurement, the preparation of a measurement report in electronic form: sufficient; • accurate knowledge of the theory of exercises, carrying out the measurement, making a measurement report in electronic form: medium; • Basic knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: good; • accurate knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: excellent.
Person responsible for course: Dr. Csaba Cserháti, associate professor, PhD
Lecturer: Dr. Bence Parditka, Dr. László Tóth

Title of course: Statistical Data Analysis **Code**: TFBE0603	**ECTS Credit points:** 4
Type of teaching, contact hours - lecture: 2 hours/week - practice: 1 hours/week - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: 14 hours - laboratory: - - home assignment: 38 hours - preparation for the exam: 40 hours Total: 120 hours	
Year, semester: 2nd year, 2nd semester	
Its prerequisite(s): TTMBE0818	
Further courses built on it: -	

Topics of course

Elements of probability theory: the concept of probability, random variables, probability density functions. Distributions: binomial and multinomial, Poisson, uniform, exponential, Gaussian, lognormal, chi-square distributions. Error propagation. General concepts of parameter estimation: sample, statistics, estimator, consistency, parameter fitting, sampling distribution, bias, mean squared error, sample mean, weak law of large numbers, sample variance. The Monte Carlo method and its applications: generation of a sequence of uniformly distributed random numbers, the multiplicative linear congruential algorithm, the transformation method, the acceptance-rejection method, Monte Carlo integration, applications. Statistical tests: hypotheses, test statistics, critical region, acceptance region, significance level, errors of the first and the second kind. Example with particle selection. Constructing a test statistic, linear test statistics, the Fisher discriminant function. Goodness-of-fit tests, P-value, observed significance (confidence) level. The significance of an observed signal. Pearson's chi-square test. The method of maximum likelihood: the likelihood function, estimating the values of the parameters of a density function with the method of maximum likelihood. Examples: exponential and Gaussian distributions. Variance of ML estimators: analytic method, Monte Carlo method, the Rao-Cramer-Frechet (RCF) (or information) inequality, efficient estimator, graphical method. Example of the method of maximum likelihood with two parameters. The method of least squares: connection with maximum likelihood. Linear least-squares fit. The variance of the estimated parameters.
The method of moments. Characteristic functions and their applications.
Numerical methods. Errors, error sources. Nonlinear equations: fixed-point iteration, Newton-Raphson method,

false position method. Two-equation systems: fixed-point iteration, Newton-Raphson method, gradient method. Algebraic equations: Horner scheme, Vieta theorem, Lobacsevszkij-Graeffe method. Solution of systems of linear equations: Gauss-elimination, iteration, advantages, disadvantages. Weakly determined systems of equations, geometric demonstration. Numerical integration: general formula, trapezoid formula, Simpson-formula. Numerical integration of differential equations: the basic problem and its generalizations, Euler method, Taylor method.

Literature

Glen Cowan: Statistical data analysis (Clarendon press, Oxford, 1998)
W.H. Press et al.: Numerical Recipes (Cambridge University Press, 2007.)

Schedule:

1st week Elements of probability theory: the concept of probability, random variables, probability density functions. Distributions: binomial and multinomial, Poisson, uniform, exponential, Gaussian, lognormal, chi-square distributions.

2nd week Error propagation. General concepts of parameter estimation: sample, statistics, estimator, consistency, parameter fitting, sampling distribution, bias, mean squared error, sample mean, weak law of large numbers, sample variance.

3rd week The Monte Carlo method and its applications: generation of a sequence of uniformly distributed random numbers, the multiplicative linear congruential algorithm, the transformation method, the acceptance-rejection method, Monte Carlo integration, applications.

4th week Statistical tests: hypotheses, test statistics, critical region, acceptance region, significance level, errors of the first and the second kind. Example with particle selection. Constructing a test statistic, linear test statistics, the Fisher discriminant function. Goodness-of-fit tests, P-value, observed significance (confidence) level. The significance of an observed signal. Pearson's chi-square test.

5th week The method of maximum likelihood: the likelihood function, estimating the values of the parameters of a density function with the method of maximum likelihood. Examples: exponential and Gaussian distributions.

6th week Variance of ML estimators: analytic method, Monte Carlo method, the Rao-Cramer-Frechet (RCF) or information inequality, efficient estimator, graphical method. Example of the method of maximum likelihood with two parameters.

7th week The method of least squares: connection with maximum likelihood. Linear least-squares fit. The variance of the estimated parameters.

8th week The method of moments. Characteristic functions and their applications.

9th week Numerical methods. Errors, error sources. Nonlinear equations: fixed-point iteration, Newton-Raphson method, false position method.

10th week Two-equation systems: fixed-point iteration, Newton-Raphson method, gradient method.

11th week Algebraic equations: Horner scheme, Vieta theorem, Lobacsevszkij-Graeffe method.

12th week Solution of systems of linear equations: Gauss-elimination, iteration, advantages, disadvantages. Weakly determined systems of equations, geometric demonstration.

13th week Numerical integration: general formula, trapezoid formula, Simpson-formula.

14th week Numerical integration of differential equations: the basic problem and its generalizations, Euler method, Taylor method.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

Participation at **practice classes** is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course.

- for a grade

The course ends in an **examination**.

Person responsible for course: Dr. Darai Judit, associate professor, PhD

Lecturer: Dr. Darai Judit, associate professor, PhD

Title of course: Electron and atomic microscopy
Code: TTFBE0207

ECTS Credit points: 3

Type of teaching, contact hours
- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 34
- preparation for the exam: 28 hours

Total: 90 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s):

Further courses built on it: TTFBE0103, TTFBE0105, TTFBE0106

Topics of course

During the semester, students will learn about the theoretical and practical basics of scanning electron microscopy (SEM) and electron beam (EPMA) microanalysis, as well as transmission electron microscopy (TEM) and electron diffraction (ED). Discuss the operation of the equipment, the interaction of the electron beam and the sample material, the ways of detecting the resulting signals, the electron diffraction phenomena, and the basics of imaging. We present the principles of qualitative and quantitative x-ray analysis and the preparation of microscopic samples. The basics of image processing and image analysis essential to the interpretation of microscopic images are also part of the course. In addition, other equipments such as SPM and AFM will be discussed. The students are going to use of the equipment during the course.

Literature

Compulsory:

Recommended:

Ludwig Reimer: Scanning Electron Microscopy; Physics of Image Formation and Microanalysis, Springer 1998

Joseph I. Goldstein, Dale E. Newbury, Patrick Echlin & David C. Joy: Scanning Electron Microscopy and X-Ray Microanalysis; ISBN 0-306-47292-9

Schedule:
1st week
Introduction.
The history and place of electron microscopy in modern science
2nd week

The structure of the scanning electron microscope: The vacuum system, the electron gun
3rd week
The electron gun (thermal emission, Schottky phenomenon, field emission)
4th week
The structure of the scanning electron microscope: The electron optical column (electromagnetic lenses)
5th week
Interactions between electron beam and sample (elastic and inelastic scattering)
6th week
Imaging in the scanning electron microscope (concept of pixel, scanning, point and line resolution, depth of field).
7th week
Electron detectors: Everhart-Thornley detector, backscattered electron detectors, specimen current detector. Special modes: potential contrast, electron beam induced current, cathode luminescence mode, mapping of complex materials, crystal structure analysis by channeling effect.
8th week
Sample preparation for scanning electron microscopy
9th week
Signal and image processing .
10th week
Electron beam X-ray analysis, X-ray formation and interaction with the material. The wavelength dispersive and energy dispersive spectrometry.
11th week
Quantitative analysis: quantitative analysis based on the ZAF correction procedure and the depth distribution function of X-ray diffraction.
12th week
Transmission electron microscope (TEM) and modes. The phenomenon and description of the electron diffraction (kinetic theory). X-ray analysis in TEM, the Cliff-Lorimer method.
13th week
Other microscopes based on scanning principle: STM, AFM, etc. Field Ion Microscopy (FIM), Atom Probe Tomography (APM).
14th week
Summary, discussion of questions emerging during the semester.

Requirements:

- for a grade
• Knowledge of the operating principle of the described equipment: sufficient;
• In addition, the applications of the equipment: medium;
• In addition, knowledge of the main steps of the main theories and laws, the understanding of the relationships, the knowledge of the modes of the equipment: good;
• In addition, the derivation of the presented expressions and the ability to apply them are excellent.

-*an offered grade* is not possible.

Person responsible for course: Dr. Csaba Cserháti associate professor, PhD

Lecturer: Dr. Csaba Cserháti associate professor, PhD

Title of course: Environmental Physics 1 **Code**: TTFBE0206	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 62 hours

Total: 90 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTFBE0102

Further courses built on it: -

Topics of course

The meaning of environmental physics, the place and role of environmental physics among the sciences. The environment as part of the universe in space and time. Physical impacts of extraterrestrial origin in the environment (effects of extragalactic and galactic origin, effects of the Sun, Moon and other objects of the Solar System). Physical impacts of earthly origin in the environment (Earth's origin and evolution, effects deriving from the Earth's planetary nature, Earth's internal structure, its thermal energy, gravity and magnetic field). The basics and environmental consequences of the earth's crust physics (plate tectonics, mountain formation, volcanism, earthquakes, erosion, rock and soil physics). The basics and environmental consequences of natural water physics (physical properties of water, energy and material transport of environmental waters, the physics of oceans, seas, rivers, lakes, groundwater and ice). The basics and environmental consequences of atmospheric physics (vertical and horizontal structure of atmosphere, energy balance of the Earth-atmosphere system and the atmosphere, greenhouse effect, ozone shielding, weather phenomena, atmospheric electrification and light phenomena, atmospheric material transport and aerosols, spatial distribution of climates, global climatic system, time changes of climate).

Literature

Compulsory:

- Z. Papp (2018): pdf copies of the PowerPoint presentations with the filenames EnvPhys-1-1 to EnvPhys-1-14

Recommended:

- A. W. Brinkman, Physics of the Environment, Imperial College Press, London, 2008
- R. Meissner, The Little Book of Planet Earth, Springer Science & Business Media, 2002

- M. Dzelalija, Environmental Physics, private edition, Split, 2004

Schedule:

1st week

The place and role of physics in environmental research. The place of physics in the system of natural sciences. What features and properties of the material world do physics deal with? What is the difference between physics and other natural sciences as regards their scope of competence and the scope of their laws? Which parts of the material world are involved in chemistry, biology, earth sciences, ecology? Building on one another among the natural sciences, the basic role of physics. The meaning of the concept of environment in sciences. The meaning of the concept of environmental science, the history and today's significance of environmental science. The meaning of the concept of environmental physics. The significance of environmental physics in environmental research.

The meaning and significance of historical and universal approaches to the study of the environment. The short history of the Earth's origin. Theoretical modeling of the evolution of the universe: what would have been if the values of basic physical constants were slightly different? About the strong and the weak anthropic principles in the light of the idealistic and materialistic world view.

The environment as part of the universe. Dimensions and masses in the universe. Physical impacts from outside the Milky Way system in the environment.

2nd week

Earth in the Milky Way. Environmental consequences of physical effects from Milky Way. The mass gravity effects. The effects of electromagnetic radiation. Cosmic particle radiation and environmental impacts. Interstellar material penetration into the environment. Earth in the Solar System. Physical effects from the Sun. The basic properties of the Sun and the temporal changes in the solar radiation. The consequences of the Sun's mass attracting. The electromagnetic radiation of the Sun and its environmental impacts. The Sun's radiation is thermal radiation. Essential characteristics of thermal radiation, the Stefan-Boltzmann law and the Wien law. The Sun's radiation spectrum. The interaction of solar radiation with Earth's material: scattering and absorption. Absorption in gases and in condensed material. Emission and the transformation of absorbed radiation energy into thermal radiation. Sunlight is the determinant of Earth's surface temperature. The solar constant. Solar radiation is the energetic base of living world through photosynthesis. The role of solar radiation in animal orientation. Changes of the spectral distribution of solar radiation in the atmosphere. The destructive effect of ultraviolet radiation. Most of the energy sources that can be exploited come from solar radiation. Solar wind and its earthly, environmental impacts.

3rd week

About the Moon's environmental effects. The basic properties of the Moon. Physical explanation and environmental consequences of the tidal effect on Earth. Description, cycles and environmental impacts on the seas. The deformation of the whole planet, the extension of the Earth's day, the Moon's departure and the decrease of the tidal effect. The environmental effects of the Moon's electromagnetic radiation. The Moon's formation. How would the environment develop without the Moon?

Environmental consequences of the terrestrial impacts of small cosmic bodies. Properties of the small bodies of the Solar System. Possibility of colliding with Earth. The environmental impacts of collisions depending on the size and composition of the impacting bodies. Global environmental consequences when bodies having more than 100 m diameter are impacted. Data on the impact craters on the ground. The frequency of impact as function of the body size. The possible link between impacts and massive extinctions, experimental evidence of a late cretaceous impact. The effect of regular impacts on earthly evolution.

The physical effects of planets on our environment. Space debris and its environmental impacts.

4th week

Physical effects deriving from the Earth's planetary nature in the environment. The age of Earth. The Earth's formation. Earth's development over the first 1 billion years. The main physical data of Earth. The shape of the Earth and its environmental consequences. Earth's gravitational field and its environmental impacts. Earth's circulation around the Sun, environmental consequences. Rotation of Earth around its axis, alternating between day and night. The inertia forces and their effects on the rotating Earth. The tilt of the Earth's rotational axis, alternating seasons, changing lengths of days and nights. Precession of the axis of rotation and its impact on the global climate.

5th week

The inner structure of Earth. The spread of seismic waves within the Earth. Seismic tomography. The layered structure of Earth, the extent, composition and physical properties of the layers. Earth's internal thermal energy, its origin, its outward migration. Earth's internal energy balance. Experiences on the Earth's magnetic field. The regular and irregular components of the magnetic field, the temporal change in the position of the magnetic poles. The magnetic field is the product of the "geodynamo" operating in the outer core. Slow changes in the Earth's magnetic field, polarities, paleomagnetic studies. Earth's magnetosphere. The interaction between the magnetosphere and the solar wind, the rapid changes in the magnetic field. The protective effect of the magnetosphere. The significance of the Earth's magnetic field for the wildlife.

6th week

The physics of Earth's crust and terrestrial surface. Convection flows in Earth's mantle. The plate structure of the lithosphere, the properties and the movements of the plates, the attempts to explain the plate movements. Different relative movements of the plates and their surface consequences. Migration of continents, ancient continents. The environmental consequences of continental migration.

The causes, mechanisms and forms of mountain formation. Mountain development stages. Mountain formation in the history of Earth. Environmental impacts of mountain formation. The concept, forms and causes of volcanism. The volcanicity of the rift valleys. The volcanicity of the subduction zones. The volcanicity of hot spots. The formation and mechanics of volcanic hills. The environmental impacts of volcanism.

7th week

The concept of earthquake, direct experimental experience. An explanation of earthquakes based on the known phenomena of motion in the earth's lithosphere. Properties of seismic waves, determining the location and depth of the focus. Depth distribution of earthquakes. The strength of the earthquakes and its scaling. Intensity and magnitude scales. The frequency of earthquakes in terms of strength. Surface distribution of earthquakes. Various processes that cause earthquakes. Earthquakes at the tangential slipping of plates, in subduction zones, due to volcanism. The drastic effects of earthquakes on the built artificial environment.

The basic phenomena, causes and constituents of erosion. Physical processes leading to fragmentation. Forms of gravity transport, transport effect of rivers and wind. Dependence of the fragmentation and transport on environmental factors. Geographical distribution of erosion. Processes of sediment formation.

The physics of rocks and soil. The composition and formation of rocks. Structural features of various types of rock. Some physical properties of rocks. The concept, structure and main physical properties of the soil.

8th week

The occurrence of water in the environment. The origin and history of water on Earth. The phases of water, their transitions. Composition of natural liquid waters, density according to temperature and salt content, internal friction, electrical conductivity, optical properties. Thermal properties, thermal conductivity, specific heat, freezing point. The energy balance of the surface waters, the depth distribution of the temperature. Mechanical properties. Balance in the gravitational field, hydrostatic pressure, surface energy. Convective flows induced by density differences. The properties of surface waves.

Energy and material transport of environmental waters ("water cycle"). The prominent role of the evaporation-condensation cycle in the environment's energy circulation, weather and climate.

9th week

The physics of the oceans and seas. The physical properties of the World Sea and the water contained therein. Geographical distribution of temperature and salt content. Properties of the oceanic flows and their physical explanation. The climate-influencing role of the oceans. Physics of rivers. The origin of rivers, their material balance, flow characteristics, motion energy, thermal energy. Physics of lakes. Origin of ponds, material and energy balance, depth distribution of temperature.

The physics of groundwater. Their origin and types, their material and energy balance, their mechanics and temperature.

The basic physical properties of ice. The formation and distribution of ice in the environment. Landfill icecaps, glaciers, marine ice cubes, icebergs, frozen groundwater.

10th week

The origin, history and composition of the atmosphere. The most important physical properties of air. The basics of the atmosphere mechanics. Status determinants and their relationships. Balance in the Earth's gravitational field, height dependence of density and pressure. Vertical stratification of the atmosphere according to pressure, density, composition and temperature. The kinematic characteristics of the streams starting in the absence of equilibrium, the properties of the eddies, the atmospheric boundary layer.

Energy absorption and energy release of the atmosphere. The fate of short and long wave electromagnetic radiation in the atmosphere and on the ground. Non-radiation energy transmission between the Earth's surface and the atmosphere. The physical essence of the greenhouse effect. The balance of the global energy balance of the atmosphere, the estimated magnitude of the components of energy traffic. Local and temporal energy balances, such as weather and climate determinants.

11th week

Physical basics of weather phenomena. The concept and the root causes of the weather. Horizontal structure of the atmosphere, air masses and their properties, atmospheric fronts. Temporal changes of air temperature and their explanation. Temporal and spatial changes in surface air pressure and their explanation. The concept, the reason and the mechanics of wind. Effects affecting wind direction. Local motion systems in moderate climates: cyclones and anti-cyclones. The global system of air movements: General Circulation of the atmosphere. Atmospheric angular momentum transport and the global circulation cells. Atmospheric humidity, physical conditions of evaporation and precipitation. The physical foundations of the formation of clouds and rainfall. Physical basics of weather forecasting. The chaotic nature of the laws describing the physical characteristics of the air. The principle and practical limitations of weather forecasting.

12th week

Atmospheric electricity. Electrical field strength and potential in the atmosphere. Processes leading to electric charge separation. Atmospheric ionisation effects. Atmospheric transport of ions in storm-free areas and in the thunderstorms. The electrical conditions of the environment of the thunderstorms, the physical explanation of the reversed current. The origin, physical properties and explanation of lightning.

Atmospheric optics. The scattering of light on molecules and aerosol particles. Consequences: the colours of the sky, the sun and the objects, the visibility of objects in the shadows, eyeshot, polarization of light. Refraction of light between superimposed air layers, at the border of air and water droplets, and at the border of air and ice crystals. Consequences: bending light, scintillation, rainbow, halo-phenomenon, mirage.

13th week

Material transport in the atmosphere, aerosols. Stay of materials in the atmosphere, sources and sinks. The correlation of residence time with the degree of spatial fluctuation of concentration. Physical features of materials delivered by the atmosphere. Origin of aerosol particles. Sources and varieties of natural aerosols. Sources and varieties of artificial aerosols. Distribution of natural and artificial aerosols by size. The fate of a locally injected dense aerosol mass in the atmosphere: orderly one-way delivery and dilution. Delivery within or above the boundary layer. Delivery of water vapor in the atmosphere, correlation with the global distribution pattern of rainfall. The climate-influencing and human-physiological effects of aerosols.

14th week

The concept of climate. Local, regional and global climates. Microclimate. Components of the material, process and quantity system that determine the local and global climates. The extraterrestrial, the Earth-related, the surface-related and the in-air components of the Earth's global climatic system. Backup subsystems within the climatic system. Geographical distribution of local and regional climates.

Climate change over time. Our knowledge about the global climate of the last one hundred and fifty years, the last millennium, the last ten thousand years and the older geological ages. Methods and results of paleoclimatology. Possible causes and outcomes of climate change in the past. Effects of human activities on the climatic system. Climatic impacts of increasing concentrations of greenhouse gases and aerosols of artificial origin. Climate models and their predictions for the future. The expected consequences of global warming and the chances of influencing this process.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

- for a grade

The course ends in a written **examination**.

The minimum requirement for the examination is 40%. The grade for the examination is given according to the following table:

Score	Grade
0-40	fail (1)
41-55	pass (2)
56-70	satisfactory (3)
71-85	good (4)
86-100	excellent (5)

If the score is below 41, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.
Person responsible for course: Dr. Zoltán Papp, associate professor, PhD
Lecturer: Dr. Zoltán Papp, associate professor, PhD

Title of course: Nuclear measurement techniques **Code**: TTFBE0213	**ECTS Credit points:** 3

Type of teaching, contact hours
- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 62 hours

Total: 90 hours

Year, semester: 3rd year, 2nd semester

Its prerequisite(s): TTFBE0107, (k) TTFBL0213

Further courses built on it: -

Topics of course

The meaning and basic function of nuclear measurement technology. The main properties of the nuclear and other ionizing radiations to be tested, their interaction with matter. Relevant concepts and quantities related to the detection of ionizing radiation and the measurement of the properties and quantities of ionizing radiation. Various types of measuring instruments that can be used to test ionizing radiation, principles and details of their operation (gas-filled detectors, scintillation detectors, semiconductor detectors, other detector types). Electronic auxiliaries serving the operation of measuring instruments (nuclear electronics). Measurement methods for the determination of the quantities of radionuclides or stable nuclides in material samples: alpha, beta and gamma spectrometry, mass spectrometry, activation analysis.

Literature

Compulsory:
- Z. Papp (2018), the PowerPoint presentations with the filenames NuclMeasTech-1 to NuclMeasTech-6

Recommended:
- K. Siegbahn, Alpha-, Beta- and Gamma Spectroscopy, North-Holland Publishing Company, Amsterdam, 1965
- G. F. Knoll, Radiation Detection and Measurement, John Wiley and Sons, New York, 1979
- A Handbook of Radioactivity Measurement Procedures, NCRP Report No. 58, NCRP, Bethesda, 1994
- W. B. Mann et al., Radioactivity Measurements. Principles and Practice, Pergamon Press, Oxford, 1988 (Appl. Radiat. Isot. Vol. 39, No. 8)

Schedule:

1st week

The basic purpose and method of nuclear measurement technology, the necessary tools and the information that can be learned from the atomic nucleus. Particles (ionized atoms, particles scattered on atoms, particles generated in nuclear reactions), nuclear radiation and atomic ionizing radiation that can be examined by nuclear measurement technics. The main features of the particles and radiation involved. Radioactive decay of the nucleus (decay law, decay types, decay schemes). The main properties of alpha and beta radiations, energies, intensities.

2nd week

Origination of gamma radiation after the radioactive decay of the nucleus. Properties, energies, intensities of gamma radiation. Lifetime of excited nuclear states, isomer transitions. Fission products, fission and late neutrons. Radiation databases. The properties of atomic radiation induced by nuclear processes. Characteristic X-ray generated by electron capture, Auger electrons. Internal conversion, conversion electrons, internal conversion coefficient.

3rd week

General characteristics of the interaction of radiation with matter. Modeling of elemental interaction mechanisms with a classic collision process. Interaction of heavy charged particles (proton, alpha, fission products) with matter. Specific energy loss and its dependence on radiation and matter properties. Charge exchange, energy variance, ionization of the matter. Range and its dependence on energy and the material quality of the matter.

4th week

Interaction of monoenergetic electron radiation and beta radiation having continuous energy distribution with matter. Specific energy loss, energy decreasing, energy variance, path. The dependence of the radiation weakening (transmission) on the thickness of the absorber, the absorption curve. The mass-absorption coefficient. Maximum range of beta radiation. The energy dependences of the mass-absorption coefficient and the range. Bremsstrahlung X-rays. Cherenkov radiation. Self-absorption and backscattering of beta radiation. Dependence of backscattering on the thickness and quality of matter.

5th week

Interaction of gamma-radiation and X-rays with matter. Exponential dependence of absorption on the thickness of absorber. Absorption coefficient, half-thickness. The photoelectric effect, the energy of the photoelectron, the role of the various electron shells. The Compton scattering. The properties of the Compton-scattered photon and the pushed Compton-electron. Pair-production. The dependences of the mass absorption coefficients of photoelectric effect, Compton scattering and pair-production, respectively, on the energy of the gamma radiation and on the quality of matter. Other forms of interaction. The energy dependence of the resulting radiation weakening in various materials. The dependence of the most likely interaction type on the energy of the gamma-radiation and on the atomic number of matter.

6th week

General principles for detecting nuclear and other ionizing radiations. Inhomogeneity of the radiation space, intensity of the radiation at the site of the detector. Physical changes caused by the radiation in the detector's material. The physical nature of the response of the detector and the dependence of this response on the type and properties of the radiation. Electrical and non-electrical detectors. Continuous and pulse-mode detectors. Electric pulses of pulse-mode detectors. The number of pulses (counts) within a time interval and the counting rate. The response function of the detector, the linearity of the response function. Sensitivity, space and time resolution, dead time, efficiency, background. Absolute and internal efficiency. Methods for determining efficiency. The goodness of the detector. Energy selective detectors. Energy resolution. Pulse height spectrum, energy calibration, energy spectrum.

7th week

Operating principle, structure and properties of gas-filled detectors. Gas ionization, ion recombination, ion migration, ion multiplication. Dependence of pulse size from electrode voltage. Ionization chamber. Continuous and pulse-mode chambers. Proportional counter. The dependence of pulse height on particle energy. The gas-multiplication factor. The Geiger-Müller counter. Ionization avalanches. Fill gas, avalanche extinction. Independence of pulse height from particle energy. Characteristics of the GM tube. Various GM tube constructions.

8th week

Operating principle, structure and properties of scintillation detectors. The basic processes of scintillation. Mechanism of interaction between the primary particle and the scintillator material. General features of scintillators. Specific features of some of the frequently used scintillator materials, the mechanism of scintillation. Organic and inorganic crystals, liquid scintillators. The connection of the photoelectron multiplier to the scintillator. Construction and operation of the photoelectron multiplier. Photocathode, electron optical system, electron multiplication. Energy spectrometry with scintillation counter, energy resolution, time resolution.

9th week

Semiconductor detectors operating principle, structure, properties. Effects influencing the number of charge carriers. Properties of p-n transitions. Diffusion and surface barrier detectors. Lithium drifted Si and Ge detectors. High purity Ge detectors. Detector shape, energy resolution, time resolution, efficiency. Fields of application of semiconductor detectors. Detection of gamma radiation, the need for cooling with liquid nitrogen.

10th week

Other detector types. Cherenkov detector. Liquid filled ionization and proportional counters. Solid state track detectors. Termoluminescence detectors. Visual Detectors: cloud chamber, photoemulsion, bubble chamber, spark chamber. Neutron detectors (counters ^{10}B, ^{6}Li and ^{3}H, fission chamber, current generating detector, etc.).

11th week

General construction and properties of nuclear measuring instruments. Power supply, detector, pulse processing electronics. Detectors as sources of electric signals. Characteristics of the pulses of various detectors. DC amplifiers and pulse amplifiers. Amplifier properties: linearity, frequency transmission, noise, load capacity. Pulse counters and their features: time resolution, storage capacity, sensitivity. Amplitude-discriminator, multi-channel amplitude analyzer, analog-to-digital converter. Coincidence-anticoincidence couplings.

12th week

Use of alpha spectrometry for radioanalytical purposes (sample preparation, detection, spectrometry, spectrum evaluation). Beta spectroscopy with liquid scintillation (sample preparation, detection, spectrometry, spectrum evaluation). Other radioanalytical applications of alpha- and beta-counting.

13th week

Use of gamma spectrometry for radioanalytical purposes. Sample preparation, detection, spectrometry. Structure of the gamma spectrum. Energy calibration, background reduction, correction factors, full energy peak efficiency. Efficiency energy dependence. Spectrum evaluation. Determination of absolute activity by beta-gamma coincidence method.

14th week

Operation principles and methods of mass spectroscopy. Principal structure of mass spectrometers. The ion source. Energy selectors and pulse selectors. Detectors. Mass spectra. Operation principles and methods of activation analysis. Activation, technical implementation of irradiation. Determination of the element concentration from the resulting activity and the activating particle flux using the reaction cross section. The sensitivity, advantages and limitations of the activation analytical method.

Requirements:

- *for a signature*

Attendance at **lectures** is recommended, but not compulsory.

- *for a grade*

The course ends in an oral **examination**.

The minimum requirement for the examination is 40%. The grade for the examination is given according to the following table:

Score	Grade
0-40	fail (1)
41-55	pass (2)
56-70	satisfactory (3)
71-85	good (4)
86-100	excellent (5)

If the score is below 41, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Dr. Zoltán Papp, associate professor, PhD

Lecturer: Dr. Zoltán Papp, associate professor, PhD

Title of course: Nuclear measurement techniques laboratory **Code**: TTFBL0213	**ECTS Credit points:** 1

Type of teaching, contact hours

- lecture: -
- practice: -
- laboratory: 16 hours/semester

Evaluation: grade for written laboratory record

Workload (estimated), divided into contact hours:

- lecture: -
- practice: -
- laboratory: 16 (4x4) hours
- home assignment: 14 hours
- preparation for the exam: -

Total: 30 hours

Year, semester: 3rd year, 2nd semester

Its prerequisite(s): (p) TTFBE0213

Further courses built on it: -

Topics of course

Determination of the range in the air and energy of alpha radiation using a variable pressure measuring chamber and a semiconductor detector. Examination of self-absorption of beta-radiation using Geiger-Müller counter. Study of the backscattering of beta-radiation from matter using Geiger-Müller counter. Determination of the range and energy of beta-radiation based on the measurement of the absorption curve using Geiger-Müller counter.

Literature

Compulsory:

- E. Bleuler and G. J. Goldsmith, Experimental Nucleonics, Rinehart & Company, Inc., New York, 1952

Recommended:

- K. Siegbahn, Alpha-, Beta- and Gamma Spectroscopy, North-Holland Publishing Company, Amsterdam, 1965
- G. F. Knoll, Radiation Detection and Measurement, John Wiley and Sons, New York, 1979
- A Handbook of Radioactivity Measurement Procedures, NCRP Report No. 58, NCRP, Bethesda, 1994
- W. B. Mann et al., Radioactivity Measurements. Principles and Practice, Pergamon Press, Oxford, 1988 (Appl. Radiat. Isot. Vol. 39, No. 8)

Schedule:

The four topics will be taught in the framework of four laboratory sessions need four hours each. Hence the course is held in four four-hour blocks on four consecutive weeks within the semester.

1st week

Determination of range in air and energy of alpha radiation based on variable pressure measuring chamber and CMOS video sensor chip. Devices to be used for the measurement: airtight cylindrical measuring chamber; alpha radiation source; source holders and collimators; video sensor chip with the required electronics; video-digitizing device; data collecting and data processing computer with the necessary software; manometer; pump. The student minimizes air pressure in the chamber and then increases in small increments while counting the alpha particles per unit time as a function of the pressure. The student shows on a graph the detected particle number as a function of the pressure. The particle number drops rapidly at a certain pressure as the particles lose their total energy. From this pressure, in the knowledge of the distance between the alpha source and the detector and the external air pressure, the student concludes the range in air of alpha radiation and from this determines the particle energy based on the relevant literature.

2nd week

Examination of self-absorption of beta-radiation using Geiger-Müller counter. Devices used: a series of variable-thickness radiation sources with low energy beta-emitting isotope; end-window GM tube inside a radiation shield and mounted with specimen holder; nuclear counting device; computer with the necessary software. The student examines the phenomenon that a fraction of the low energy beta radiation that is increasing with the thickness of the source can not get out of the source material because it is absorbed in it. The student counts the detection events occurring during unit time interval for the different thickness sources. The results are shown on a diagram. The student sees that from a certain source thickness the event number becomes steady (saturated). From this thickness value, the student concludes the maximum range and the maximum energy of beta-radiation.

3rd week

Study of the backscattering of beta radiation from matter with Geiger-Müller counter. Tools used: high-energy beta source; GM tube inside a radiation shield and equipped with a source holder and a backscattering specimen holder; nuclear counting device. The student examines the phenomenon that a significant proportion of the high-energy beta radiation is backscattered from matter (ie, it turns roughly in the opposite direction to its original direction of movement) and the ratio of the backscattered radiation depends on the elemental composition and thickness of the backscattering specimen. The student changes the quality of the backscattering substance (atomic number) and counts the detection events per time unit. The results are graphically depicted and using this graph the student can determine the atomic number of an unknown substance from the number of detection events per time unit counted with this substance. The student changes the thickness of the backscattering specimen and measures and depicts the number of detection events per unit of time as a function of thickness. The student places Al-disks of different thicknesses on a thick lead disk and measures and depicts the number of detection events per time unit as a function of Al-thickness. Based on this graph, the student determines the thickness of an Al-disc placing this disc on the thick lead disc, and counting the number of detection events per time unit using this complex backscattering specimen.

4th week

Determination of the range and energy of beta radiation by measuring the absorption curve using Geiger-Müller counter. Tools used: high-energy beta source; GM tube inside a radiation shield and equipped with a source holder and an absorber holder; Al-absorbers of different thicknesses; nuclear counting device. The student examines the phenomenon that a significant proportion of high-energy beta radiation is absorbed or scattered within the absorber layer between the source and the detector, and thus the attenuating part of radiation decreases with the thickness of the absorber. The student places Al-discs with varying thicknesses in between the source and the detector, and counts the detection events per time unit according to the thickness of the Al-layer. The results are graphically depicted and from this absorption curve the student determines the maximum range and energy of beta-radiation and the mass-absorption coefficient of Al for beta-radiation by using proper literature data.

Requirements:

- for a signature

Participation at laboratory sessions is compulsory. A student must attend all the four sessions. In case a student doesn't so, the course will not be signed and the student must repeat it. Attendance at laboratory sessions will be recorded by the session leader. Being late is equivalent with an absence. Students are required to bring drawing instruments to each sessions. Active participation is evaluated by the teacher. If a student's behavior or conduct doesn't meet the requirements of active participation, the teacher may evaluate his/her participation as an absence.

- for a grade

The student will obtain grades for all the four sessions one by one. The grades go from fail (1) to excellent (5) according to the following table:

Score	Grade
0-40	fail (1)
41-55	pass (2)
56-70	satisfactory (3)
71-85	good (4)
86-100	excellent (5)

The grade of the course will be the arithmetic mean of the grades obtained for each sessions rounded to the full, provided that the student has completed all the sessions with a grade better than fail (1). If the latter condition is not met then the grade of the course is fail (1) and the student must repeat the course in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

Person responsible for course: Dr. Zoltán Papp, associate professor, PhD

Instructor: Dr. Erdélyiné Dr. Eszter Baradács, assistant professor, PhD

Title of course: Programming
Code: TTFBE0617

ECTS Credit points: 2

Type of teaching, contact hours
- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 17 hours
- preparation for the exam: 15 hours

Total: 60 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): -

Further courses built on it:-

Topics of course

Programming languages; methodology of program development; basics of algorithmic problem solving; most important algorithms. Data structures and computer representation of data. Construction of a C program; structured programming. Data types of the C language, declaration and initialization of variables. Functions of standard input and output. Library functions of mathematics. Evaluation of expressions in the C language. Control of the program flow; conditional statements. Loop commands. Array as a derived data type; processing arrays with loop commands. File operations. High level and bit level logical operators. Definition and declaration of functions. Generic structure of C functions. Passing parameters by value and by address. Function calls.

Literature

Compulsory:
B. W. Kernigan and D. M. Ritchie, The C programming language (Prentice Hall, 2007).
J. R. Hanly and E. B. Koffmann, Problem Solving and Program Design in C (7th Edition), (Pearson, 2004).
Recommended:
P. van der Linden, Expert C Programming: Deep C Secrets, (SunSoft Press, 1994).

Schedule:
1st week
Introduction to C programming: development of programming languages, machine code, as-sembly, and high level programming languages, C as a high level programming language. Steps of program development, source code, compiler, executable code. Advantages and disad-vantages of compilers and interpreters. Types of errors, syntactical and semantical errors, de-bugging.

2nd week
Basics of algorithmic thinking, requirements of algorithms. Most important algorithms: Mini-mum and maximum search.
3rd week
Algorithms of sorting, insertion into sorted lists with linear and binary search, merging sorted lists. Characterization of the efficiency of algorithms.
4th week
Data structures and the computer representation of different data types. Signed and unsigned (positive, negative) integers, fixed point representation. Data types in C.
5th week
Floating point representation of real numbers, determination of the range and precision of da-ta. ASCII representation of characters. Data types of the C language, type modifyers.
6th week
General structure of a C program, function oriented program development. Declaration and initialization of variables. Header files and library functions. Functions of standard input and output.
7th week
Mid-term test. Symbolic constants in C. Arithmetic, incrementing, and decrementing operators. Library functions of mathematics. Evaluation of expressions in C. Command line algorithms.
8th week
Control of the program flow, branching the program execution, conditional statements. Loop commands in C with tests before and after the execution of the core of the loop.
9th week
Logical operators and their expressions. High level logical expressions. Control structures with logical expressions
10th week
Derived data types, arrays, vectors, and matrices in C. Processing arrays with loops.
11th week
Processing files, writing into a file, reading from a file. Library functions of standard input and output with files
12th week
Bit level logical operators. Operations at the level of bits, reading and setting the value of bits. Construction of mascs for bit level operations.
13th week
Functions in C. Definition and declaration of functions, function call. Boolean functions, functions without returned value, procedures
14th week
End-term test. Parameter passing to functions, passing one- and two-dimensional arrays to functions. Matrix operations with user defined functions. Bit manipulation with functions.

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory. Condition to obtain signature is the successful (grade 2 or higher) accomplishment of one of the two tests according to semester assessment timing.

During the semester two tests are written: the mid-term test in the 7th week and the end-term test in the 14th week. Students' participation at the tests is mandatory.

The minimum requirement for the mid-term and end-term tests is 60%. Based on the total score of the two tests, the grade is determined according to the following scheme:

Score	Grade
0-59	fail (1)
60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60%, students can get a retake opportunity according to the EDUCATION AND EXAMINATION RULES AND REGULATIONS of the university.

- *for a grade*

The course ends in an **examination**. Obtaining signature is a precondition for exam eligibility. Successful completion of the practical class of Programming 1 (grade 2 or higher) is also a precondition for exam eligibility. Results of two tests are counted in the final grade at a 60% weight. The remaining 40% of the grade is based on a written exam where evaluation is performed according to the above scoring scheme.

-an offered grade:

it may be offered for students if the average grade of the two theoretical tests during the semester is at least satisfactory (3) and the average of the mid-term and end-term tests is at least satisfactory (3). The offered grade is the average of the theoretical test.

Person responsible for course: Prof. Dr. Kun Ferenc, university professor, DSc

Lecturer: Prof. Dr. Kun Ferenc, university professor, DSc

Title of course: Programming **Code**: TTFBL0617	**ECTS Credit points:** 2

Type of teaching, contact hours
- lecture: -
- practice: 2 hours/week
- laboratory: -

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 20 hours
- preparation for the tests: 12 hours

Total: 60 hours

Year, semester: 2st year, 1st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Programming languages; methodology of program development; basics of algorithmic problem solving; most important algorithms. Data structures and computer representation of data. Construction of a C program; structured programming. Data types of the C language, declaration and initialization of variables. Functions of standard input and output. Library functions of mathematics. Evaluation of expressions in the C language. Control of the program flow; conditional statements. Loop commands. Array as a derived data type; processing arrays with loop commands. File operations. High level and bit level logical operators. Definition and declaration of functions. Generic structure of C functions. Passing parameters by value and by address. Function calls.

Literature

Compulsory:

B. W. Kernigan and D. M. Ritchie, The C programming language (Prentice Hall, 2007).

J. R. Hanly and E. B. Koffmann, Problem Solving and Program Design in C (7th Edition), (Pearson, 2004).

Recommended:

P. van der Linden, Expert C Programming: Deep C Secrets, (SunSoft Press, 1994).

Schedule:

1st week

First C program. Steps of program development: source code, compiler, executable code. Pro-gram developing environments under windows and linux. Header files. Functions of standard input and output.

2nd week

Functions of standard input and output. Data types of C, declaration and initialization of var-iables. Type modifyers. Operator of storage length. Simple arithmetic operations.

3rd week

Constants. Arithmetic, incrementing and decrementing operators and their expressions. Library functions of mathematics. Evaluation of expressions in C. The conditional operator.

4th week

Control of the program flow, branching the program execution into two and more directions, conditional statements.

5th week

Logical operators and complex logical expressions to control the structure of C programs.

6th week

Repeated execution of program blocks, organizing loops of execution with loop command.

7th week

Mid-term test. Array as a derived data type, declaration of arrays. Processing data arrays with loop commands.

8th week

Processing external files in a C program. Functions of standard input and output for file processing.

9th week

Command line arguments in C, control of the program with command line arguments.

10th week

Efficient programming of algorithms. Minimum and maximum search in arrays. The second largest element of a numerical array.

11th week

Efficient programming of algorithms. Sorting arrays into ascending and descending order. Insertion into sorted arrays, merging sorted arrays.

12th week

Bit level programming: Reading out and setting the value of a bit. Construction of mascs with bit level operations.

13th week

User defined functions in C. Definition and declaration of functions. Function call. Functions and procedures.

14th week

End-term test. Processing one- and two-dimensional arrays with functions. Bit level operations with functions.

Requirements:

- for a term grade

Attendance of practical classes is mandatory. Three classes can be missed during the semester.

During the semester two tests are written: the mid-term test in the 7th week and the end-term test in the 14th week. Students' participation at the tests is mandatory.

The minimum requirement for the mid-term and end-term tests is 60%. Based on the total score of the two tests, the grade is determined according to the following scheme:

Score	Grade
0-59	fail (1)

60-69	pass (2)
70-79	satisfactory (3)
80-89	good (4)
90-100	excellent (5)

If the score of any test is below 60%, students can get a retake opportunity according to the EDUCATION AND EXAMINATION RULES AND REGULATIONS of the university.

Person responsible for course: Prof. Dr. Kun Ferenc, university professor, DSc

Lecturer: Prof. Dr. Kun Ferenc, university professor, DSc

Title of course: Vacuum science and technology I **Code**: TTFBE0209	**ECTS Credit points:** 3

Type of teaching, contact hours

- lecture: 2 hours/week
- practice: -
- laboratory: -

Evaluation: exam

Workload (estimated), divided into contact hours:

- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 62 hours

Total: 90 hours

Year, semester: 2nd year, 2nd semester

Its prerequisite(s): thermodynamics, electromagnetism

Further courses built on it: -

Topics of course

The brief history of the vacuum science, the role and importance of the vacuum technology in the modern science and industry. The most important physical quantities in the vacum physics. The fundamentals of the kinetic theory of gases average mean free path, pressure, velocity and energy of particles, transport phenomena in low pressure gases: diffusion, internal friction, heat conduction. Flow in gases; viscous flow, molecular flow, flow trough diaphragms and tubes, throughput, pump speed, calculation of pumping time. Surface phenomena; adsorption, desorption, absorption, evaporation, sublimation, permeation. Vacuum gauges; mechanical gauges, thermocuple and Pirani gauges, ionization gauges, calibration of vacuummeters. Mass spectrometers; magnetic, quadropole and time of flight spectrometers. Vacuum leak detection. Vacuum pumps; mechanical pumps, diffusion pumps, ejector pumps, turbomolecular pumps, sorption pumps, getter pumps, ion-getter pumps, cryopumps. Materials of vacuum technology; structural materials, sealants, lubricants, pump fluids. Thin film deposition techniques; vacuum evaporation, sputtering, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition. Design of vacuum systems, components, accesories.

Literature

Compulsory:
N. Yoshimura: Vacuum technology: practice for scientific instruments, Springer (2008)
Umrath: Fundamentals of Vacuum Technology, 1998
Recommended
:D.J Hucknall: Vacuum Technology and Applications, Butterworth-Heinemann Ltd. 1991
R.V. Stuart: Vacuum Technology, Thin Films and Sputtering, Academic Press (1983)
R. Ekman, J. Silberring, A. Westman-Brinkmalm,A. Kraj: Mass Sspectrometry, Wiley (2009)

Schedule:

1st week
The status of the vacuum science in the physics and technology. The brief history of the vacuum science. The most important physical quantities used in the vacuum physics.
2nd week

The most important properties and equations of ideal gases. Th basics of kinetic gas theory. The concept of pressure and average mean free path. The velocity and energy distribution functions of gas particles.

3rd week

Transport phenomena in gases: diffusion, internal friction, heat conduction

4th week

Flow in gases: viscous flow, molecular flow, througput, pump speed.

5th week

Surface phenomena; adsorption, desorption, permeation, evaporation, sublimation

6th week

Vacuum gauges: mechanical gauges, transport phenomena gauges (Pirani), ionization gauges , calibration of vacuum gauges.

7th week

Vacuum pumps: mechanical pumps, diffusion pumps, ejector pumps, turbomolecular pumps, sorption and getter pumps, cryopumps.

8th week

Mass spectrometers and their applications: magnetic, quadropole, time of flight spectrometers

9th week

Vacuum leak detection, methods and detectors

10th week

Materials of vacuum technology: structural materials, sealants, pumping fluids, getters, adsorbents, lubricants.

11th week

Methods of hin film deposition: evaporation, sputtering, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition

12th week

Structure and design of vacuum systems: components, design rules, standards.

13th week

Laboratory presentation: mass spectrometers (The SNMS and it's applications)

14th week

Laboratory presentation: layer deposition techniques: evaporation and sputtering

Requirements:

- for a signature

Attendance at **lectures** is recommended, but not compulsory.

- *for a grade*
- The course ends in an **exam**.

The minimum requirement for the exam is 50%. The grade will be calculated according to the following table:

Score	Grade
0-50	fail (1)
51-62	pass (2)
63-75	satisfactory (3)
76-87	good (4)
87-100	excellent (5)

Person responsible for course: Dr. Lajos Daróczi, associate professor, PhD

Lecturer: Dr. Lajos Daróczi, associate professor, PhD

Title of course: Modern analysis **Code**: TTMBE0816	**ECTS Credit points: 3**
Type of teaching, contact hours - lecture: 2 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: - - laboratory: - - home assignment: 34 hours - preparation for the exam: 28 hours Total: 90 hours	
Year, semester: 2nd year, 2nd semester	
Its prerequisite(s): TTMBE0814	
Further courses built on it: -	

Topics of course

Differentiability of complex functions. Curve integral, Cauchy's integral theorem. Taylor series and Laurent series. The residue theorem. Metric spaces, compactness, completeness, separability. The Hahn--Banach theorem. Bounded linear maps. Banach spaces, Hilbert spaces, Gram--Schmidt ortogonalization. Complete orthonormal systems. Fourier series, Riesz representation theorem. Self-adjoint, normal, unitary and compact operators. Spectral theory for compact operators.Fredholm and Volterra type integral operators. Banach algebras, spectrum, resolvent, Gelfand—Mazur theorem. The elements and applications of the continuous functional calculus.The mathematical foundations of quantum mechanics.

Literature

Compulsory:

-

Recommended:

- Rudin, Walter Real and complex analysis. Third edition. *McGraw-Hill Book Co., New York,* 1987. xiv+416 pp. ISBN: 0-07-054234-1
- Rudin, Walter Functional analysis. Second edition. International Series in Pure and Applied Mathematics. *McGraw-Hill, Inc., New York,* 1991. xviii+424 pp. ISBN: 0-07-054236-8
- Kolmogorov, A. N.; Fomin, S. V. Elements of the theory of functions and functional analysis. Vol. 2: Measure. The Lebesgue integral. Hilbert space. Translated from the first (1960) Russian ed. by Hyman Kamel and Horace Komm *Graylock Press, Albany, N.Y.* 1961 ix+128 pp.
- Lang, Serge Complex analysis. Fourth edition. Graduate Texts in Mathematics, 103. *Springer-Verlag, New York,* 1999. xiv+485 pp. ISBN: 0-387-98592-1
- von Neumann, John Mathematical foundations of quantum mechanics. New edition of Translated from the German and with a preface by Robert T. Beyer. Edited and with a preface by Nicholas A. Wheeler. *Princeton University Press, Princeton, NJ,* 2018. xviii+304 pp. ISBN: 978-0-691-17857-8; 978-0-691-17856-1

Schedule:

1st week

Regular functions. Differentiability of complex function. The Cauchy—Riemann equations. Constructing regular functions with the help of power series. The (complex) exponential functions and its properties. The logarithm functions and power functions, their introduction. The regular branch of complex functions.

2nd week

Integral formulae. Integral along a path. The Newton—Leibniz formula. Path-independency of the integral, connection to the primitive function. Goursat lemma and its generalizations. Integral formulae of Cauchy for convex domains. Index of a curve. Sequences of regular functions.

3rd week

Power series expansion. Uniqueness theorem for the expansion. Taylor series, Taylor series of the logarithm function and of the power functions. The Maximum Modulus Principle. Schwarz lemma. Estimating the coefficients of a power series. Liouville theorem on bounded entire functions. The Fundamental Theorem of Algebra.

4th week

Isolated singularities. Convergent Laurent series, Laurent power series expansion of regular functions. Casorati—Weierstrass Theorem. The Residue Formula and its applications to calculate improper integrals. Theorem of Rouché.

5th week

Metric spaces, topology of metric spaces, examples. Compact sets in metric spaces. Theorem of Hausdorff. Dense subsets. Separable metric spaces.

6th week

The Category Theorem and its applications. The construction of an everywhere continuous, nowhere differentiable function. The first and the second Approximation Theorem of Weierstrass,

Stone's Approximation Theorem.

7th week

Norms and semi-norms in linear spaces, The Kuratowski—Zorn lemma. The Hahn—Banach Extension Theorem, the Hahn—Banach Theorem in normed spaces and its applications, the Banach limit. Theorem of Bohnenblust and Sobczyk.

8th week

Normed and Banach spaces. Absolutely convergent series. The Schauder base. The linear speces L(X, Y) and B(X, Y). Continuity and boundedness of linear operators. Completeness of B(X, Y). The Hahn—Banach Separation Theorem.

9th week

The Open Mapping Theorem, Banach's Theorem on Bounded Inverses. Equivalent norms in Banach spaces. Norms in finite dimensional spaces. The Closed Greph Theorem.

10th week

Hilbert spaces. The Orthogonal Decomposition Theorem. The Gram—Schmidt Orthogonalization Process. Orthogonal and Fourier series. Hilbert base. Separable Hilbert spaces. Riesz' Representation Theorem. The adjoint operator. Self-adjoint, normal and unitary operators.

11th week

Compact operators. Spectal theory of compact operators.

12th week

The Fredholm Alternative Theorem. Integral operators of Volterra and of Fredholm type.

13th week

Banach algebras, invertability, spectrum, resolvent. Theorem of Gelfand and Mazur. The Spectral Radius Formula. C* algebras, basic notions, examples. Commutative C* algebras. The Continuous Functional Calculus

14th week

The mathematical foundations of quantum mechanics.

Requirements:

- for a signature

Signature requires the correct solution of at least 60% of each of the two tests. - *for a grade* Knowledge of most basic definitions, laws and theorems: grade 2; In addition, knowledge of the proof of the easiest and most straightforward statements: grade 3; In addition, knowledge of the proofs of harder theorems: grade 4; In addition, knowledge of the proofs and the capability to understand the deeper connections between the learned ares: grade 5. -*an offered grade:* –
Person responsible for course: Dr. Eszter Novák-Gselmann, associate professor, PhD
Lecturer: Dr. Eszter Novák-Gselmann, associate professor, PhD

Title of course: Modern analysis **Code**: TTMBG0816	**ECTS Credit points: 2**
Type of teaching, contact hours - lecture: - - practice: 2 hours/week - laboratory: -	
Evaluation: mid-semester grade	
Workload (estimated), divided into contact hours: - lecture: - - practice: 28 hours - laboratory: - - home assignment: 32 hours - preparation for the exam: - Total: 60 hours	
Year, semester: 2nd year, 2nd semester	
Its prerequisite(s): TTMBE0814	
Further courses built on it: -	

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6th week

Mid-term test.

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14th week

End-term test.

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Lecturer: Dr. Eszter Novák-Gselmann, associate professor, PhD