University of Debrecen
Faculty of Science and Technology
Institute of Physics

PHYSICS BSC PROGRAM

2025

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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: 13

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 Science and Technology

Number of students at the University of Debrecen: 32,351

Full time teachers of the University of Debrecen: 1,649

206 full university professors and 1,305 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 2,500 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 (13 Bachelor programs and 14 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 ~ 810 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
E-mail: kozma.gabor@science.unideb.hu

Vice Dean for Scientific Affairs: Prof. Dr. Sándor Kéki, Full Professor
E-mail: keki.sandor@science.unideb.hu

Consultant on External Relationships: Prof. Dr. Attila Bérczes, Full Professor
E-mail: berczesa@science.unideb.hu

Consultant on Talent Management Programme: Prof. dr. Tibor Magura, Full Professor
E-mail: magura.tibor@science.unideb.hu

Dean's Office
Head of Dean's Office: Mrs. Katalin Kozma-Tóth
E-mail: toth.katalin@science.unideb.hu

English Program Officer: Mrs. Alexandra Csatáry
Address: Egyetem tér 1., Chemistry Building, A/101, E-mail: acsatary@science.unideb.hu

INSTITUTE OF PHYSICS

Director of the Institute: Dr. Gyula Zilizi, PhD, habil, associate professor
https://fizika.unideb.hu

All departments are located at the Physics campus (Debrecen, Bem tér 18/a-b)

Department of Experimental Physics
https://fizika.unideb.hu/kiserleti-fizikai-tanszek
Head of department: Dr. Gyula Zilizi, PhD, habil, associate professor

Department of Theoretical Physics
https://fizika.unideb.hu/elmeleti-fizikai-tanszek
Head of department: Dr. Sándor Nagy, PhD, habil, DSc, associate professor

Department of Solid State Physics
https://fizika.unideb.hu/szilardtest-fizikai-tanszek
Prof. Dr. Zoltán Erdélyi, PhD, habil, DSc, university professor

Department of Enviromental Physics
https://fizika.unideb.hu/kornyezetfizikai-tanszek
Dr. István Csige, PhD, habil, associate professor

Department of Electric Engeneering
https://fizika.unideb.hu/villamosmernoki-tanszek
Prof. Dr. Gábor Battistig, PhD, habil, DSc, university professor

ACADEMIC CALENDAR

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

Study period	1st week	Registration*	1 week
	2nd – 14th week	Teaching period	13 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 or second week of February in the spring semester.

For further information please check the following link:
https://www.edu.unideb.hu/tartalom/downloads/University_Calendars_2025_26/University_calendar_2025-2026-Faculty_of_Science_and_Technology.pdf

THE PHYSICS BACHELOR PROGRAM

Information about the Program

Name of BSc Program:	Physics BSc Program
Specialization available:	no specializations
Field, branch:	Science
Qualification:	Physicist
Mode of attendance:	Full-time
Faculty, Institute:	Faculty of Science and Technology, Institute of Physics
Program supervisor	Prof. Dr. Zoltán Erdélyi, University Professor
Program coordinator	Dr. Gábor Katona, Assistant 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 the Physics BSc program

The prerequisites listed for each subject are required to be already completed in previous semesters to take the subject (i.e. to register to a course of the subject) with the following exceptions:

- prerequisites marked with (p): the prerequisite should either be completed in previous semesters or it should be taken in the same semester
- prerequisites marked with (k): the perquisite subject (usually a connected practical) should be completed before registering to the exam of the given subject

Type of evaluation can be either **exam (e)** or **mid-semester grade (m)**. The given contact hours are for one week and given in lecture+practice form. The semesters are suggestions, if all the prerequisites are fulfilled the subject can be taken at any time when a course is offered. Please note, that the courses for the subjects are only offered in their respective semester: fall (odd numbers) or spring (even numbers).

Please note that codes of English language courses of a subject have a '_EN' ending in Neptun.

Subject codes are composed of letters and numbers throughout the university. The subject codes at the Faculty of Science and Technology can be decoded as follows:

TT – this marks the Faculty of Science and Technology

F – marks the institute the subject is offered by (B – Biology, F – Physics, K – Chemistry, M – Mathematics, T – Earth Sciences)

B – marks BSc (for MSc subjects it is M)

E or G or L – type of the subject: E – lecture, G – practical, L – laboratory work

The numbers identify the subject, closely connected subjects usually have the same number (like lecture and connected practical)

Example: TTFBE0101 – is a lecture offered at BSc level by the Institute of Physics

TTFBG0101 – is a practical offered at BSc level by the Institute of Physics. The numbers in the codes match since these courses are lecture-practical pairs.

Suggested schedule of compulsory general science subjects

Subject code	Subject title	Semester and hours/week						Evaluation	Credit	Prerequisite
		1	2	3	4	5	6			
TTFBE0119	Mathematics in Physics	1+3						m	4	
TTFBE0120	Laboratory Practicals in Electronics				2+0			e	3	TTFBE0105
TTFBL0120	Laboratory Practicals in Electronics					0+2		m	2	TTFBE0120
TTFBL0118	Basics of measurement and evaluation	0+2						m	2	
TTMBE0815	Linear algebra			2+0				e	3	(k) TTMBG0815
TTMBG0815	Linear algebra			0+2				m	2	(p) TTMBE0815
TTMBE0822	Mathematics 1.	4+0						e	6	(k) TTMBG0822
TTMBG0822	Mathematics 1. practical	0+4						m	4	(p) TTMBE0822
TTMBE0823	Mathematics 2.		4+0					e	5	TTMBE0822 (k) TTMBG0823
TTMBG0823	Mathematics 2. practical		0+2					m	2	(p) TTMBE0823
TTTBE0040	Basic environmental science					1+0		e	1	

Suggested schedule of compulsory Physics subjects

Subject code	Subject title	Semester and hours/week						Evaluation	Credit	Prerequisite
		1	2	3	4	5	6			
TTFBE0101	Classical mechanics 1	4+0						e	6	(k) TTFBE0119 (k) TTFBG0101
TTFBG0101	Classical mechanics 1 practical	0+2						m	3	(p) TTFBE0101
TTFBE0113	Basic Computer Skills in Physics		1+2					m	2	TTFBE0101 TTFBL0118
TTFBE0102	Thermodynamics		4+0					e	6	TTFBE0101 (k) TTFBG0102 TTMBE0822
TTFBG0102	Thermodynamics practical		0+2					m	3	(p) TTFBE0102
TTFBE0103	Optics		1+0					e	1	TTFBE0101 (k) TTFBG0103
TTFBG0103	Optics practical		0+1					m	1	(p) TTFBE0103
TTFBE0104	Classical mechanics 2		2+0					e	3	TTFBE0101 (k) TTFBG0104 TTMBE0822
TTFBG0104	Classical mechanics 2 practical		0+2					m	3	(p) TTFBE0104 TTMBE0822
TTFBE0105	Electromagnetism			4+0				e	6	TTFBE0102 (k) TTFBG0105 TTMBE0823
TTFBG0105	Electromagnetism practical			0+2				m	3	(p) TTFBE0105
TTFBE0106	Condensed matters 1			2+0				e	3	TTFBE0102 TTFBE0103 (k) TTFBG0106
TTFBG0106	Condensed matters 1			0+2				m	2	(p) TTFBE0106
TTMBE0824	Mathematics 3			2+0				e	3	TTMBE0823 (k) TTMBG0824
TTMBG0824	Mathematics 3. practical			0+2				m	2	(p) TTMBE0824
TTFBE0107	Atomic and quantum physics				2+0			e	3	TTFBE0105 (k) TTFBG0127
TTFBG0127	Atomic and quantum physics				0+1			m	2	(p) TTFBE0107
TTFBE0108	Electrodynamics				2+0			e	3	TTFBE0104 TTFBE0105 (k) TTFBG0108
TTFBG0108	Electrodynamics				0+2			m	3	(p) TTFBE0108
TTFBE0109	Condensed matters 2					2+0		e	3	TTFBE0106 (k) TTFBG0109 (p) TTFBE0110
TTFBG0109	Condensed matters 2					0+2		m	2	(p) TTFBE0109
TTFBE0110	Quantum Mechanics 1					3+0		e	4	TTFBE0104 TTFBE0107 (k) TTFBG0110
TTFBG0110	Quantum Mechanics 1					0+2		m	3	(p) TTFBE0110
TTFBE0112	Nuclear physics					2+1		e	4	TTFBE0107
TTFBE0111	Statistical physics						3+0	e	5	TTFBE0102 TTFBE0104 (k) TTFBG0111
TTFBG0111	Statistical physics						0+2	m	3	(p) TTFBE0111 TTMBE0823
TTFBE0131	Fundamental interactions						2+2	e	5	TTFBE0110

Subject code	Subject title	Semester and hours/week						Evaluation	Credit	Prerequisite
		1	2	3	4	5	6			
TTFBL0114	Laboratory practical: mechanics, optics, thermodynamics 1		0+2					m	2	TTFBE0101 TTFBL0118 (p) TTFBE0103
TTFBL0115	Laboratory practical: mechanics, optics, thermodynamics 2			0+2				m	2	TTFBL0114 TTFBE0102 TTFBE0103
TTFBL0116	Condensed Matter Laboratory Practices 1				0+2			m	2	TTFBE0106
TTFBL0117	Atomic and nuclear physics laboratory work 1					0+2		m	2	TTFBE0106 (p) TTFBE0112
TTFBL0190	Thesis						0+14	m	10	TTFBE0107

Elective subjects

If all the prerequisites are fulfilled the course can be taken at any time

Subject code	Subject title	Semester and hours/week						Evaluation	Credit	Prerequisite
		1	2	3	4	5	6			
TTFBE0201	Materials and technology for microelectronics					3+0		e	3	TTFBE0106 (k) TTFBL0201
TTFBL0201	Materials and technology for microelectronics					0+2		m	2	(p) TTFBE0201
TTFBE0205	Computer simulation methods					2+0		m	2	(k) TTFBL0205
TTFBL0205	Computer simulation methods					0+2		m	2	(p) TTFBE0205
TTFBE0204	Analytical spectroscopic methods					2+0		e	3	TTFBE0106
TTFBE0203	Analog and Applied Electronics						2+0	e	3	TTFBE0120
TTFBL0217	Atomic and nuclear physics laboratory work 2						0+2	m	2	TTFBL0117
TTKBE0141	Introduction to chemistry	2+0						e	2	
TTKBL0141	Introduction to chemistry		0+2					m	2	TTKBE0141
TTFBE0202	Digital Electronics					2+0		e	3	TTFBE0120
TTFBE0207	Electron and atomic microscopy				2+0			e	3	TTFBE0103 TTFBE0105 TTFBE0106
TTFBL0219	Condensed Matter Laboratory Practices 2						0+2	m	2	TTFBL0116
TTFBE0206	Environmental Physics 1			2+0				e	3	TTFBE0102
TTFBE0208	Statistical Data Analysis				2+1			e	4	TTMBE0823
TTFBL0218	Applications of microcontrollers					0+2		m	2	TTFBE0120 TTFBE0210
TTMBE0816	Modern analysis				2+0			e	3	TTMBE0824 (k) TTMBG0816
TTMBG0816	Modern analysis				0+2			m	2	(p) TTMBE0816
TTFBE0213	Nuclear measurement techniques						2+0	e	3	TTFBE0107 (k) TTFBL0213
TTFBL0213	Nuclear measurement techniques						0+1	m	1	(p) TTFBE0213
TTFBE0210	Programming			2+0				e	2	(k) TTFBG0210
TTFBG0210	Programming practical			0+2				m	2	(p) TTFBE0210

Subject code	Subject title	Semester and hours/week						Evaluation	Credit	Prerequisite
		1	2	3	4	5	6			
TTFBE0211	Computer Controlled Measurement and Process Control				2+0			e	3	(p) TTFBE0120
TTFBL0211	Computer Controlled Measurement and Process Control					0+4		m	3	TTFBE0211
TTFBE0209	Vacuum science and technology				2+0			e	3	TTFBE0102 TTFBE0105
TTMBE0818	Probability and statistics			2+0				e	3	TTMBE0823 (k) TTMBG0818
TTMBG0818	Probability and statistics			0+2				m	2	(p) TTMBE0818

Optional subjects

Subject code	Subject title	Semester and hours/week						Evaluation	Credit	Prerequisite
		1	2	3	4	5	6			
TTFBE0223	Classical mechanics 3				2+0			e	3	TTFBE0104 (k) TTFBG0223
TTFBG0223	Classical mechanics 3				0+2			m	2	(p) TTFBE0223
TTFBE0221	Modern optics					2+0		e	3	TTFBE0103 TTFBE0108 TTFBE0107
TTFBE0224	Image processing in technical and medical applications						2+0	e	3	TTFBE0107
TTFBE0222	Environmental Physics 2				2+0			e	3	TTFBE0206
GYBFIZ0K23	Biophysics*		1+1					e	3	
TTFBE0232	Basic Astronomy		2+0					e	3	TTFBE0101
TTFBE0229	Space Astronomy				2+0			e	3	TTFBE0105 or TTFBE0232

*The Biophysics course starts according to the schedule of the Faculty of Medicine, usualy one week earlier than the other courses

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. Further information is available from the Sport Centre of the University, its website: http://sportsci.unideb.hu.

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 prerequisite of the Thesis subject (TTFBL0190) is completion of the subject Atomic and quantum physics (TTFBE0107). Students can apply for a thesis topic in 5th semester (or later) and they can take the Thesis subject in the next (usually the 6th) semester if the prerequisite is fulfilled.
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 should 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 defense 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.

Rules and Regulations

The Academic and Examination Rules and Regulations of the University of Debrecen, which contain the rules to be followed by students, are available at the following link:
https://www.edu.unideb.hu/p/rules-and-regulations

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, analysis of functions, differential equations. Mass point movement in single and multiple dimensions.

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

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

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

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.

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

Person responsible for course: 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.

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

Title of course: Mathematics 1. **Code**: TTMBE0810-EN	**ECTS Credit points**: 4
Type of teaching, contact hours - lecture: 4 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 56 - practice: - - laboratory: - - home assignment: 44 - preparation for the exam: 50 Total: 150	
Year, semester: 1st year, 1st semester	
Its prerequisite(s): -	
Further courses built on it: TTMBE0811_EN, TTMBG0811_EN	
Topics of course	
Sets. Real numbers. Complex numbers. Sequences and series. Convergence, limits. Real functions. Limit, continuity and differentiation of functions. Monotonicity, convexity, inflection. Approximation with polynomials, Taylor formula. Definition and calculation of definite, indefinite and improprius integrals. Ordinary differential equations. Vector spaces. Matrices, operations with matrices. Determinants and properties; the matrix rank. Linear equation systems. Euclidean spaces and their transformations.	
Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD	

Title of course: Mathematics 1. **Code**: TTMBG0810-EN	**ECTS Credit points**: 2
Type of teaching, contact hours - lecture: - - practice: 4 hours/week - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: - - practice: 56 - laboratory: - - home assignment: 36 - preparation for the exam: - Total: 92	
Year, semester: 1st year, 1st semester	
Its prerequisite(s): -	
Further courses built on it: TTMBE0811_EN, TTMBG0811_EN	
Topics of course	
Sets. Real numbers. Complex numbers. Sequences and series. Convergence, limits. Real functions. Limit, continuity and differentiation of functions. Monotonicity, convexity, inflection. Approximation with polynomials, Taylor formula. Definition and calculation of definite, indefinite and improprius integrals. Ordinary differential equations. Vector spaces. Matrices, operations with matrices. Determinants and properties; the matrix rank. Linear equation systems. Euclidean spaces and their transformations.	
Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD	

Title of course: Mathematics 2. **Code**: TTMBE0811-EN	**ECTS Credit points**: 4
Type of teaching, contact hours - lecture: 4 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 56 - practice: - - laboratory: - - home assignment: 44 - preparation for the exam: 50 Total: 150	
Year, semester: 1st year, 2nd semester	
Its prerequisite(s): TTMBE0810-EN	
Further courses built on it: TTMBE0812_EN, TTMBG0812_EN	
Topics of course	
Functions of several variables. Limit value, continuity, differentiation. Total derivative, partial derivatives, directional derivative. Partial Differential Equations. Multiple Integral. Elements of vector analysis. Curves, surfaces. Vector Fields. Gradient, rotation, divergence. Line, surface and volume integrals. Stokes', Green's and Gauss' theorems. Probability. Conditional probability. Total probability theorem, Bayes' theorem. Independence of events. Random variables. Discrete and continuous random variables. Probability distribution, density function. Expected value, standard deviation. Elements of statistics.	
Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD	

Title of course: Mathematics 2. **Code**: TTMBG0811-EN	**ECTS Credit points**: 2
Type of teaching, contact hours - lecture: - - practice: 2 hours/week - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: - - practice: 28 - laboratory: - - home assignment: 18 - preparation for the exam: - Total: 46	
Year, semester: 1st year, 2nd semester	
Its prerequisite(s): TTMBE0810-EN	
Further courses built on it: TTMBE0812_EN, TTMBG0812_EN	
Topics of course	
Functions of several variables. Limit value, continuity, differentiation. Total derivative, partial derivatives, directional derivative. Partial Differential Equations. Multiple Integral. Elements of vector analysis. Curves, surfaces. Vector Fields. Gradient, rotation, divergence. Line, surface and volume integrals. Stokes', Green's and Gauss' theorems. Probability. Conditional probability. Total probability theorem, Bayes' theorem. Independence of events. Random variables. Discrete and continuous random variables. Probability distribution, density function. Expected value, standard deviation. Elements of statistics.	
Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD	

Title of course: Mathematics 3. **Code**: TTMBE0812-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 - practice: - - laboratory: - - home assignment: 31 - preparation for the exam: 31 Total: 90	
Year, semester: 2nd year, 1st semester	
Its prerequisite(s): TMBE0811 Mathematics 2.	
Further courses built on it: -	
Topics of course	
Solving problems of: Differentiation of complex functions. The Cauchy-Riemann equations. Contour integral. Cauchy's integral theorem. Series representations of analytic functions. Power series. Laurent series. The residue theory. Spaces of integrable functions. Fourier series and its complex form. Bases in spaces of functions. Elements of functional analysis. Hilbert spaces. Linear forms and operators. Fourier transformation and applications. Laplace transformation and applications for investigation of differential equations.	
Person responsible for course: Dr. Ágota Figula, associate professor, PhD	

Title of course: Mathematics 3. **Code**: TTMBG0812-EN	**ECTS Credit points: 2**
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: 32 hours - preparation for the exam: - Total: 60	
Year, semester: 2nd year, 1st semester	
Its prerequisite(s): TTFBE0811 Mathematics 2.	
Further courses built on it: -	
Topics of course	
Solving problems of: Differentiation of complex functions. The Cauchy-Riemann equations. Contour integral. Cauchy's integral theorem. Series representations of analytic functions. Power series. Laurent series. The residue theory. Spaces of integrable functions. Fourier series and its complex form. Bases in spaces of functions. Elements of functional analysis. Hilbert spaces. Linear forms and operators. Fourier transformation and applications. Laplace transformation and applications for investigation of differential equations.	
Person responsible for course: Dr. Ágota Figula, associate 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: 2nd 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.

Person responsible for course: 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: 2nd 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.

Person responsible for course: Prof. Dr. István Gaál, 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.

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: 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: Measurements with pendulums, Elastic moduli, Measurements with sound waves, Refractive index and dispersion, Measurements with lenses

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

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

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

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.

Person responsible for course: 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.

Person responsible for course: Dr. Lajos Daróczi, 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.

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

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.

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

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.

Person responsible for course: 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.

Person responsible for course: 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.

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

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.
Person responsible for course: Dr. Lajos Daróczi, associate 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: 2nd year, 2nd 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.

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

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..

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

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: 2st 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. 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.
Person responsible for course: Dr. Csaba Cserháti, university professor, PhD, DSc

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

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

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. Optical properties: optical properties of metals, optical properties of non-metallic materials, refraction reflection, reflection, absorption, transmission, color, insulators transparency and opacity.

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

Title of course: Condensed matter II classwork **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: 3st 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.
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. Optical properties: optical properties of metals, optical properties of non-metallic materials, refraction reflection, reflection, absorption, transmission, color, insulators transparency and opacity.

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

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

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

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.

Person responsible for course: 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: 2nd year, 2nd 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.

Person responsible for course: 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.

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

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.

Person responsible for course: 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.
Person responsible for course: 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 hidrogen atom, selection rules. Operators acting on entangled states. Calculation of expectation values for the Bell inequality.

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: 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.
Person responsible for course: Prof. Dr. Kun Ferenc, 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, χ2-test. Construction of confidence intervals.

Person responsible for course: 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: 2^{st} year, 1^{st} 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, χ2-test. Construction of confidence intervals.

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: 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

Person responsible for course: Dr. István Csarnovics, 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

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

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.

Person responsible for course: 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.

Person responsible for course: 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).

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: Dr. Zoltán Papp, associate 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.

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: 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.

Person responsible for course: 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: -	
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.	
Person responsible for course: Dr. Eszter Novák-Gselmann, associate professor, PhD	

Title of course: Introduction to chemistry I **Code**: TTKBE0141	**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): -	
Further courses built on it: TTKBL0141	

Topics of course

History and development of chemistry and its relation to other natural sciences, the development of atomic and molecular theory. The structure of atom. Basics of radioactivity. Discovery of the periodic table and periodically changing properties. Introduction to quantum chemistry. Primary and secondary chemical bonds. Description of gaseous, liquid and solid states of matter. Phase changes. Chemical equilibrium. Acid-base theories. Basics of thermochemistry, reaction kinetics and electrochemistry.

Person responsible for course: Dr. Katalin Várnagy, university professor, PhD, DSc

Title of course: Introduction to chemistry I – practice
Code: TTKBL0141

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: 1st year, 2nd semester

Its prerequisite(s): TTKBE0141

Further courses built on it: -

Topics of course

The objective of the laboratory work is to introduce first-year students of different background to laboratory work, the use of basic laboratory equipment, simple laboratory operations and measurements. In addition, students are expected to prepare certain simple chemicals and run various basic experiments to familiarize themselves with chemical laboratory work. The seminar involves solving exercises and problems.

General laboratory work will be introduced, such as: Weighing on analytical and standard laboratory balances. Introduction to the measurement of volume: pipette, burette, volumetric flask. Students will calibrate a volume measurement device (pipette/burette/volumetric flask) and calculate the percentage difference between the nominal and actual volume. General introduction to grinding and preparation of solution. Density measurement, use of the pycnometer. Preparation of a standard solution from crystalline solid and measuring its density: determination of the density of the prepared solution with pycnometer, calculation of the weight percent composition. General introduction to separation techniques: decantation, centrifuging, filtration. Students will see a demonstration regarding the proper and safe use of laboratory gas cylinders, preparation of gases under laboratory conditions, Kipp's apparatus. Students will carry out the purification of a benzoic acid sample contaminated with sodium chloride. Students will see a demonstration of an acid-base titration and will carry out the concentration determination of a NaOH solution.

Basic calculation problems will be solved considering: Determination of atomic weight, molecular weight, empirical formula, molecular formula, amount of substance. Determination of empirical formula based on weight percent composition and on elemental analysis. General introduction to the units of concentration. Interconversion of units. Calculation problems connected to solution preparation. Introduction of the SI system. Mass concentration, molarity, mass percent composition, molar percent composition. Interconversion of concentration units. Density measurements. Mixing equations. Theoretical background of crystallization. Exercises calculation problems of crystallization. Acid-base equilibria. Theory of acid-base reactions and titrations. Exercises based on acid-base titrations. Stoichiometric calculations based on chemical equations. Determination of molar weight based on titration results.

Person responsible for course: Dr. Petra Herman, assistant professor, PhD