University of Debrecen
Faculty of Science and Technology
Institute of Physics

PHYSICS BSC PROGRAM

2019
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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 our region’s demand for professionals, we offer engineering courses with a strong scientific basis, thus expanding our training spectrum in the field of technology. Recently, we successfully re-introduced dual 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 companies in our extended region. 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

Legal status of the University of Debrecen: state university

Founder of the University of Debrecen: Hungarian State Parliament

Supervisory body of the University of Debrecen: Ministry of Education

Number of Faculties at the University of Debrecen: 14

- Faculty of Agricultural and Food Sciences and Environmental Management
- Faculty of Child and Special Needs Education
- Faculty of Dentistry
- Faculty of Economics and Business
- Faculty of Engineering
- Faculty of Health
- Faculty of Humanities
- Faculty of Informatics
- Faculty of Law
- Faculty of Medicine
- Faculty of Music
- Faculty of Pharmacy
- Faculty of Public Health
- Faculty of Science and Technology

Number of students at the University of Debrecen: 26938

Full time teachers of the University of Debrecen: 1542

207 full university professors and 1159 lecturers with a PhD.
The Faculty of Science and Technology is currently one of the largest faculties of the University of Debrecen with about 3000 students and more than 200 staff members. The Faculty has got 6 institutes: Institute of Biology and Ecology, Institute of Biotechnology, Institute of Chemistry, Institute of Earth Sciences, Institute of Physics and Institute of Mathematics. The Faculty has a very wide scope of education dominated by science and technology (10 Bachelor programs and 12 Master programs), additionally it has a significant variety of teachers’ training programs. Our teaching activities are based on a strong academic and industrial background, where highly qualified teachers with a scientific degree involve student in research and development projects as part of their curriculum. We are proud of our scientific excellence and of the application-oriented teaching programs with a strong industrial support. The number of international students of our faculty is continuously growing (currently 570 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, University Professor
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Vice Dean for Educational Affairs: Prof. Dr. Gábor Kozma, University Professor
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Registrar's Office
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English Program Officer: Mr. Imre Varga
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**DEPARTMENTS OF INSTITUTE OF PHYSICS**

**Department of Experimental Physics** (home page: http://indykfi.phys.klte.hu/kisfiz/)

4026 Debrecen, Bem tér 18/a,

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>E-mail</th>
<th>room</th>
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<tbody>
<tr>
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**Department of Theoretical Physics** (home page: http://www.phys.unideb.hu/dtp/)

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<tr>
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<td>E2</td>
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<td>E1</td>
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### Department of Electric Engineering

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<td></td>
</tr>
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</table>
**Department of Environmental Physics** (home page: http://w3.atomki.hu/deat/)

4026 Debrecen, Bem tér 18/c

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<th>Name</th>
<th>Position</th>
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<th>room</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. István Csige, PhD, habil</td>
<td>Associate Professor head of department</td>
<td><a href="mailto:csige@science.unideb.hu">csige@science.unideb.hu</a></td>
<td></td>
</tr>
<tr>
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</table>
ACADEMIC CALENDAR

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

<table>
<thead>
<tr>
<th>Study period</th>
<th>1st week</th>
<th>Registration*</th>
<th>1 week</th>
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</thead>
<tbody>
<tr>
<td>2nd – 15th week</td>
<td></td>
<td>Teaching period</td>
<td>14 weeks</td>
</tr>
<tr>
<td>Exam period</td>
<td>directly after the study period</td>
<td>Exams</td>
<td>7 weeks</td>
</tr>
</tbody>
</table>

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

For further information please check the following link:
THE PHYSICS BACHELOR PROGRAM

Information about the Program

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

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

Professional competences to be acquired

A Physicist:

a) Knowledge:
- He/she has knowledge of the general and specialized principles, laws and possible applications of mathematics and informatics.
- He/she has knowledge of the physical theories and models based on scientific results.
- He/she is aware of the possible directions and limits of the development of Physics.
- He/she has knowledge of the fundamentals of the natural sciences as well as the practices based on this knowledge and has the ability to systematize them.
- He/she has knowledge regarding practical applications, laboratory works, methods, and tools, and could apply them and use them in his profession on a basic level.
- He/she has the knowledge needed to apply his field to solve practical problems related to natural processes, natural resources, living and inanimate system.
- He/she has the knowledge of the concepts and terminology of physics.
- He/she has the necessary knowledge to analyse the processes, systems, scientific problems in ways which are acceptable in current scientific practice.
b) Abilities:
- He/she has the ability to understand the physical phenomena, its data collection, processing and analysis, and the use of basic literature needed for these activities.
- He/she has the ability to apply physical theories, principles, and laws.
- He/she has the ability based on his or her knowledge of the field of physics to produce simple physical phenomena under laboratory conditions, to demonstrate and test them.
- He/she has the ability to evaluate, interpret and document of results of measurements.
- He/she has the ability to identify issues in the relevant field of expertise.
- He/she has the ability to apply the knowledge of physics to solve basic practical problems, including the ability to support this with calculations.
- He/she has the ability to plan and organize the physics-based part of development processes.
- He/she has the ability to collect and interpret relevant data based on his or her field, and based on this, can formulate a relevant opinion on social, scientific or ethical issues.
- He/she has the ability, on the basis of the physical knowledge, to use science-based argumentation.
- He/she has the ability to increase his or her knowledge and continue studies at a higher level.

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

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

The Credit System

Majors in the Hungarian Education System have generally been instituted and ruled by the Act of Parliament under the Higher Education Act. The higher education system meets the qualifications of the Bologna Process that defines the qualifications in terms of learning outcomes: statements of what students know and can do on completing their degrees. In describing the cycles, the framework uses the European Credit Transfer and Accumulation System (ECTS).

ECTS was developed as an instrument of improving academic recognition throughout the European Universities by means of effective and general mechanisms. ECTS serves as a model of academic recognition, as it provides greater transparency of study programs and student achievement. ECTS in no way regulates the content, structure and/or equivalence of study programs.

Regarding each major the Higher Education Act prescribes which professional fields define a certain training program. It contains the proportion of the subject groups: natural sciences, economics and humanities, subject-related subjects and differentiated field-specific subjects.

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

<table>
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<th>Semesters</th>
<th>ECTS credit points</th>
<th>Evaluation</th>
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<td>6.</td>
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</tbody>
</table>

- contact hours, types of teaching (l – lecture, p – practice), credit points

## Compulsory physics subject groups

### Bases of arts and sciences subject group

<table>
<thead>
<tr>
<th>Subject</th>
<th>Instructor</th>
<th>Contact hours</th>
<th>Type of teaching</th>
<th>Credit points</th>
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</thead>
<tbody>
<tr>
<td>Mathematics in physics</td>
<td>Erdélyi Zoltán</td>
<td>15 l + 45 p /4 cr</td>
<td>Lecture</td>
<td>4</td>
<td>mid-semester grade</td>
</tr>
<tr>
<td>Basics of measurement and evolution</td>
<td>Katona Gábor</td>
<td>30 p / 2 cr</td>
<td>Lecture</td>
<td>2</td>
<td>mid-semester grade</td>
</tr>
<tr>
<td>Basic environmental science</td>
<td>Nagy Sándor Alex</td>
<td>15 l/1 cr</td>
<td>Lecture</td>
<td>1</td>
<td>Exam</td>
</tr>
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</table>

### Introduction to electronics subject group

<table>
<thead>
<tr>
<th>Subject</th>
<th>Instructor</th>
<th>Contact hours</th>
<th>Type of teaching</th>
<th>Credit points</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Practicals in Electronics</td>
<td>Oláh László</td>
<td>30 l / 3 cr</td>
<td>Lecture</td>
<td>3+2</td>
<td>Exam</td>
</tr>
<tr>
<td>Linear algebra subject group</td>
<td>Gaál István</td>
<td>30 l / 3 cr</td>
<td>Lecture</td>
<td>3+2</td>
<td>Exam</td>
</tr>
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</table>

### Differential and integral calculus subject group

<table>
<thead>
<tr>
<th>Subject</th>
<th>Instructor</th>
<th>Contact hours</th>
<th>Type of teaching</th>
<th>Credit points</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential- and integral calculus</td>
<td>Bessenyei Mihály</td>
<td>45 l / 4 cr</td>
<td>Lecture</td>
<td>4+2</td>
<td>Exam</td>
</tr>
<tr>
<td>Differential- and integral calculus in several variable</td>
<td>Páles Zsolt</td>
<td>45 l / 4 cr</td>
<td>Lecture</td>
<td>4+3</td>
<td>Exam</td>
</tr>
</tbody>
</table>

### Bases of mechanics subject group

<table>
<thead>
<tr>
<th>Subject</th>
<th>Instructor</th>
<th>Contact hours</th>
<th>Type of teaching</th>
<th>Credit points</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical mechanics 1.</td>
<td>Trócsányi Zoltán</td>
<td>60 l / 6 cr</td>
<td>Lecture</td>
<td>6+3</td>
<td>Exam</td>
</tr>
<tr>
<td>Basic Computer Skills in Physics</td>
<td>Tomán János</td>
<td>15 l + 30 p / 2 cr</td>
<td>Lecture</td>
<td>2</td>
<td>Mid-semester grade</td>
</tr>
<tr>
<td>Laboratory practical: mechanics, optics, thermodynamics 1</td>
<td>Katona Gábor</td>
<td>30 p / 2 cr</td>
<td>Lecture</td>
<td>2</td>
<td>Mid-semester grade</td>
</tr>
<tr>
<td>Subject Group</td>
<td>Course</td>
<td>Credits</td>
<td>Examination</td>
<td>Grade</td>
<td></td>
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<tr>
<td><strong>Laboratory practical: mechanics, optics, thermodynamics 2</strong></td>
<td><em>Katona Gábor</em></td>
<td>30 p / 2 cr</td>
<td></td>
<td>2 mid-semester grade</td>
<td></td>
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<tr>
<td><strong>Thermodynamic subject group</strong></td>
<td><strong>Thermodynamics</strong></td>
<td>60 l / 6 cr</td>
<td>30 p / 3 cr</td>
<td>6+3 exam mid-semester grade</td>
<td></td>
</tr>
<tr>
<td><em>Trócsányi Zoltán</em></td>
<td><em>Darai Judit</em></td>
<td></td>
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<tr>
<td><strong>Advanced mechanics subject group</strong></td>
<td><strong>Classical mechanics 2.</strong></td>
<td>30 l / 3 cr</td>
<td>30 p / 3 cr</td>
<td>3+3 exam mid-semester grade</td>
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<tr>
<td><em>Nagy Sándor</em></td>
<td></td>
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<tr>
<td><strong>Electromagnetism and optics subject group</strong></td>
<td><strong>Optics</strong></td>
<td>15 l / 1 cr</td>
<td>15 p / 1 cr</td>
<td>1+1 exam mid-semester grade</td>
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<tr>
<td><em>Dr. Csarnovics István</em></td>
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<tr>
<td><strong>Electromagnetism</strong></td>
<td><strong>Trócsányi Zoltán</strong></td>
<td>60 l / 6 cr</td>
<td>30 p / 3 cr</td>
<td>6+3 exam mid-semester grade</td>
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<tr>
<td><em>Daróczi Lajos</em></td>
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<td><strong>Electrodynamics subject group</strong></td>
<td><strong>Electrodynamics</strong></td>
<td>30 l / 3 cr</td>
<td>30 p / 3 cr</td>
<td>3+3 exam mid-semester grade</td>
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<tr>
<td><em>Vibók Ágnes</em></td>
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<tr>
<td><strong>Condensed matters 1. subject group</strong></td>
<td><strong>Condensed matters 1.</strong></td>
<td>30 l / 3 cr</td>
<td>30 p / 2 cr</td>
<td>3+2 exam mid-semester grade</td>
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<tr>
<td><em>Cserháti Csaba</em></td>
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<tr>
<td><strong>Condensed matters 2.</strong></td>
<td><strong>Condensed matters 2.</strong></td>
<td>30 l / 3 cr</td>
<td>30 p / 2 cr</td>
<td>3+2 exam mid-semester grade</td>
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<tr>
<td><em>Erdélyi Zoltán</em></td>
<td></td>
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<tr>
<td><strong>Condensed Matter Lab. Practices 1</strong></td>
<td></td>
<td>30 p / 2 cr</td>
<td></td>
<td>2 mid-semester grade</td>
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</tr>
<tr>
<td><em>Cserháti Csaba</em></td>
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<tr>
<td><strong>Atomic, Nuclear and quantum physics subject group</strong></td>
<td><strong>Atomic and quantum physics</strong></td>
<td>30 l / 3 cr</td>
<td>30 p / 3 cr</td>
<td>3+3 exam mid-semester grade</td>
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<tr>
<td><em>Trócsányi Zoltán</em></td>
<td><em>Nándori István</em></td>
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<tr>
<td><strong>Nuclear physics</strong></td>
<td><strong>Nuclear physics</strong></td>
<td>30 l + 15 p / 4 cr</td>
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<td><em>Darai Judit</em></td>
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<tr>
<td><strong>Atomic and nuclear physics laboratory work 1</strong></td>
<td><strong>Atomic and nuclear physics laboratory work 1</strong></td>
<td>30 p / 2 cr</td>
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<td>2 mid-semester grade</td>
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<tr>
<td><em>Ujvári Balázs</em></td>
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<tr>
<td>Quantum Mechanics and Fundamental interactions subject group</td>
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<tr>
<td>Quantum Mechanics 1</td>
<td>Nagy Sándor</td>
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<td>Fundamental interactions</td>
<td>Nándori István</td>
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<td>45 1 / 4 cr 30 p / 3 cr</td>
<td>4+3 exam</td>
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<tr>
<td>301 + 15 p / 4 cr</td>
<td>4 exam</td>
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<tbody>
<tr>
<td>Introduction to the theory of ordinary differential equations</td>
</tr>
<tr>
<td>Probability and statistics</td>
</tr>
<tr>
<td>301 / 3 cr 30 p / 2 cr</td>
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<tr>
<td>301 / 3 cr 30 p / 2 cr</td>
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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Materials and technology for microelectronics (KV)</td>
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<tr>
<td>451 / 3 cr 30 p / 2 cr</td>
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<table>
<thead>
<tr>
<th>Electronics subject group</th>
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<tbody>
<tr>
<td>Analog and Applied Electronics (KV)</td>
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<tr>
<td>Digital Electronics (KV)</td>
</tr>
<tr>
<td>Applications of microcontrollers (KV)</td>
</tr>
<tr>
<td>301 / 3 cr</td>
</tr>
<tr>
<td>301 / 3 cr</td>
</tr>
<tr>
<td>301 / 2 cr</td>
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<table>
<thead>
<tr>
<th>Computer simulation methods subject group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer simulation methods (KV)</td>
</tr>
<tr>
<td>301 / 2 cr 30 p / 2 cr</td>
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</table>

<table>
<thead>
<tr>
<th>Special laboratory works subject group</th>
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<tbody>
<tr>
<td>Atomic and nuclear physics laboratory work 2 (KV)</td>
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<tr>
<td>Condensed Matter Lab. Practices 2 (KV)</td>
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<tr>
<td>Statistical Data Analysis (KV)</td>
</tr>
<tr>
<td>30 p / 2 cr</td>
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<tr>
<td>30 p / 2 cr</td>
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<td>301 + 15 p / 4 cr</td>
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<tr>
<td>Subject Group</td>
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<tr>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Electron and atomic microscopy subject group</strong></td>
</tr>
<tr>
<td>Cserháti Csaba</td>
</tr>
<tr>
<td>Analytical spectroscopic methods (KV)</td>
</tr>
<tr>
<td>Csarnovics István</td>
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<td><strong>Environmental Physics subject group</strong></td>
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<tr>
<td>Papp Zoltán</td>
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<tr>
<td><strong>Nuclear measurement techniques subject group</strong></td>
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<td>Papp Zoltán</td>
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<tr>
<td><strong>Programming subject group</strong></td>
</tr>
<tr>
<td>Dr. Kun Ferenc</td>
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<tr>
<td><strong>Computer Controlled Measurement and Process Control subject group</strong></td>
</tr>
<tr>
<td>Oláh László</td>
</tr>
<tr>
<td>Computer based measurement and process control (KV)</td>
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<tr>
<td>Zilizi Gyula</td>
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<tr>
<td><strong>Vacuum science and technology subject group</strong></td>
</tr>
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<td>Daróczi Lajos</td>
</tr>
<tr>
<td><strong>Modern analysis subject group</strong></td>
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<tr>
<td>Novák-Gselmann Eszter</td>
</tr>
<tr>
<td><strong>Chemistry subject group</strong></td>
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<tr>
<td>Várnagy Katalin</td>
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<tr>
<td>Tircsó Gyula</td>
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<tr>
<td><strong>Thesis</strong></td>
</tr>
<tr>
<td>Optional courses</td>
</tr>
<tr>
<td>------------------</td>
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</table>
| Classical Mechanics III.  
  *Sailer Kornél* | 30 l / 3 cr  
  30 p / 2 cr | 3 | exam | mid-semester grade |
| Modern optics  
  *Csarnovics István* | 30 l / 3 cr | 3 | exam |
| Image processing in technical and medical applications  
  *Cserháti Csaba* | 30 l / 3 cr | 3 | exam |
| Environmental Physics 2  
  *Papp Zoltán* | 30 l / 3 cr | 3 | exam |
**Work and Fire Safety Course**

According to the Rules and Regulations of University of Debrecen a student has to complete the online course for work and fire safety. Registration for the course and completion are necessary for graduation. For MSc students the course is only necessary only if BSc diploma has been awarded outside of the University of Debrecen.

Registration in the Neptun system by the subject: MUNKAVEDELEM

Students have to read an online material until the end to get the signature on Neptun for the completion of the course. The link of the online course is available on webpage of the Faculty.

**Internship**

NO internship is required for students majoring in Physics BSc.

**Physical Education**

According to the Rules and Regulations of University of Debrecen a student has to complete Physical Education courses at least in two semesters during his/her Bachelor’s training. Our University offers a wide range of facilities to complete them. Further information is available from the Sport Centre of the University, its website: [http://sportsci.unideb.hu](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 preparation of the thesis is an independent professional activity that relies partly on the student's studies and partly on additional knowledge of the literature of the field and can be done under the guidance of a consultant for a single semester. Such professional activities may include processing the literature of a field; reproduction and processing of previous results, but it is not necessary to present a separate research work. Students will be informed about the formal requirements of the thesis upon acceptance of the application.
Final Exam

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

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

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

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

In Physics Bachelor Program the diploma grade is calculated as the average grade of the results of the followings:
- Weighted average of the overall studies at the program (A)
- Average of grades of the thesis and its defense given by the Final Exam Board (B)
- Average of the grades received at the Final Exam for the two subjects (C)

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

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

- Excellent 4.81 – 5.00
- Very good 4.51 – 4.80
- Good 3.51 – 4.50
- Satisfactory 2.51 – 3.50
- Pass 2.00 – 2.50
# Course Descriptions of Physics BSc Program

<table>
<thead>
<tr>
<th>Title of course: Mathematics in Physics</th>
<th>ECTS Credit points: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code: TTFBE0119</td>
<td></td>
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</tbody>
</table>

## 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:
1\textsuperscript{st} year, 1\textsuperscript{st} semester

## Its prerequisite(s):
-

## Further courses built on it:
TTFBE0101, TTFBG0101

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

## Literature

### Compulsory:
Moodle electronic notes

### Recommended:
Bolyai-Books:
- Bárczy, Barnabás: Differential Calculus (Differenciálszámítás)
- Bárczy, Barnabás: Integral Calculus (Integrálszámítás)

## Schedule:

1\textsuperscript{st} week
Information, introduction.
Nonsense, identities, powers, rooting identities.

2\textsuperscript{nd} week

3\textsuperscript{rd} week

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22
Vectors: concept, special vectors (unit, null), vector operations graphically, vector coordinates in orthonormal base, space vector, position vector, vector operations with coordinates, scalar form, vector product.

4th week
Limit value: sequences and rows, convergence; limit values. Differential calculus: derivative function, geometric meaning; deriving rules; derivatives of elementary functions.

5th week
Differential calculus: derivatives of higher order; extreme value calculation.

6th week
Differential calculus: derivation of multivariable functions, partial derivative.

7th week
Integral calculus: indefinite integral, primitive function; integration rules; indefinite integration of elementary functions.

8th week
Integral calculus: major integration methods.

9th week
Integral calculus: definite integral, geometric meanings; the core of integral calculus; integration rules; special integrals (linear, surface, volumetric).

10th week
Physical quantities, units and prefixes. Physical dimension, dimension analysis. Significant digits.

11th week
Kinematics: one-dimensional movement, spatial coordinates, velocity, acceleration, path, displacement.

12th week
Kinematics: motion in three dimensions, position vector, displacement vector, velocity vector, acceleration vector, path.

13th week
Circular motion: learn the quantities and units to describe steady and variable circular motion, comparing them with the acquired kinematic quantities.

14th week
Summary, consultation.

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

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

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

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

Lecturer: Dr. Gábor Somogyi, PhD
<table>
<thead>
<tr>
<th>Title of course: Basics of measurement and evaluation</th>
<th>ECTS Credit points: 2</th>
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<tbody>
<tr>
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<td><strong>Type of teaching, contact hours</strong></td>
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<tr>
<td>- lecture: -</td>
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<tr>
<td>- practice: 1 hours/week</td>
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<tr>
<td>- laboratory: 1 hours/week</td>
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<tr>
<td><strong>Evaluation:</strong> mid-semester grade</td>
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<tr>
<td><strong>Workload (estimated), divided into contact hours:</strong></td>
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</tr>
<tr>
<td>- lecture: -</td>
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<tr>
<td>- practice: 14 hours</td>
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<tr>
<td>- laboratory: 14 hours</td>
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<tr>
<td>- home assignment: 20 hours</td>
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<tr>
<td>- preparation for the exam: 12 hours</td>
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<tr>
<td>Total: 60 hours</td>
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<tr>
<td><strong>Its prerequisite(s):</strong> -</td>
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<tr>
<td><strong>Further courses built on it:</strong> TTFBE0113, TTFBL0114</td>
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<tr>
<td><strong>Topics of course</strong></td>
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<tr>
<td>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</td>
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<tr>
<td><strong>Literature</strong></td>
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<tr>
<td><em>Compulsory: -</em></td>
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<tr>
<td><em>Recommended:</em> Handouts provided on the course home page</td>
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<tr>
<td><strong>Schedule:</strong></td>
<td></td>
</tr>
<tr>
<td>1\textsuperscript{st} week</td>
<td></td>
</tr>
<tr>
<td>Physical quantities; documentation of measurements; measurement errors; measurement uncertainty; examples; computer basics for documentation</td>
<td></td>
</tr>
<tr>
<td>2\textsuperscript{nd} week</td>
<td></td>
</tr>
<tr>
<td>Distribution of measurement data; estimation of true value and standard deviation; uncertainty of measurement result; examples; evaluation with computer</td>
<td></td>
</tr>
<tr>
<td>3\textsuperscript{rd} week</td>
<td></td>
</tr>
<tr>
<td>Numerical examples for standard deviation and uncertainty of measurement result; evaluation of simple measurement, documentation</td>
<td></td>
</tr>
<tr>
<td>4\textsuperscript{th} week</td>
<td></td>
</tr>
<tr>
<td>Interdependent quantities, graphical representation; linear dependence, linear fit with computer; evaluation based on fit results; least squares</td>
<td></td>
</tr>
<tr>
<td>5\textsuperscript{th} week</td>
<td></td>
</tr>
</tbody>
</table>
Examples for linear fit
6th week
Measurement task, documentation, evaluation
7th week
Written test 1;
Propagation of uncertainty
8th week
Examples for propagation of uncertainty
9th week
Measurement task, documentation, evaluation
10th week
Nonlinear dependence, linearization, evaluation with linear least squares method
11th week
Examples for nonlinear dependence
12th week
Measurement task, documentation, evaluation
13th week
Consultation
14th week
Written test 2

**Requirements:**
- *for a signature*
  Presence on 75% of the classes.
- *for a grade*
  The grade is computed from the two written tests.

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

**Lecturer:** János Tomán, assistant lecturer
### Title of course:
Basic Environmental Sciences

### Code:
TTTBE0040_EN

### ECTS Credit points:
1

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

### Evaluation:
Exam

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

Total: 30 hours

### Year, semester:
2nd year, 2nd semester

### Its prerequisite(s):
- 

### Further courses built on it:
- 

### Topics of course

### Literature

**Compulsory:**

### Schedule:

**1st week**
Main parts of Environmental Sciences, objects of Environmental Sciences

**2nd week**
Levels of living world.

**3rd week**
Basis of monitoring and biomonitoring systems

**4th week**
Levels of Ecology, ecological methods in environmental sciences

**5th week**
Ecological impacts of invasive plant and animal species in a changing world

**6th week**
Role of small habitat islands in human transformed landscapes – nature conservation, cultural and ecosystem services
7th week
Biodiversity
8th week
Indication
9th week
The world in maps
10th week
Rivers – fluival geomorfolgy
11th week
Sustainable development – World Conferences
12th week
Ecological footprint
13th week
Man and Biosphere program
14th week
Consultation or exam.

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

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

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

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

Lecturer: Dr. István Gyulai, assistant professor, PhD
**Title of course:** Introduction to Electronics  
**Code:** TTFBL0120  
**ECTS Credit points:** 2

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 2 hours/week</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation: practical grade</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: 28 hours</td>
</tr>
<tr>
<td>- home assignment: 32 hours</td>
</tr>
<tr>
<td>- preparation for the exam: -</td>
</tr>
<tr>
<td>Total: 60 hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year, semester: 3rd year, 1st semester</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Its prerequisite(s): TTFBE1120</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Further courses built on it:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Topics of course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory work of performing electronic measurements of analog and digital circuits:</td>
</tr>
<tr>
<td>- 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</td>
</tr>
<tr>
<td>- Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders; basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory:</strong></td>
</tr>
<tr>
<td>- Oláh L.: Analog and digital electronics laboratory exercises, (laboratory textbook.)</td>
</tr>
<tr>
<td><strong>Recommended:</strong></td>
</tr>
<tr>
<td>- P. Horowitz: The art of electronics, Cambridge University Press, 1989</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Schedule: (8*3.5 hour measurement program)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
</tr>
<tr>
<td>2nd week</td>
</tr>
<tr>
<td>3rd week</td>
</tr>
<tr>
<td>4th week</td>
</tr>
</tbody>
</table>
5th week
Measurements on power supply circuits.

6th week
Specification of operational amplifiers, basic op-amp circuits: inverting, non-inverting, summing and differential amplifiers, voltage-current converters

7th week
Nonlinear circuits of operational amplifiers: integrator, differentiator, oscillator circuit, active filters.

8th week
Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders

9th week
Basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.

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

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

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

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

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-49</td>
<td>fail (1)</td>
</tr>
<tr>
<td>50-59</td>
<td>pass (2)</td>
</tr>
<tr>
<td>60-69</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>70-79</td>
<td>good (4)</td>
</tr>
<tr>
<td>80-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

-an offered grade: -

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

Lecturer: Dr. László Oláh, assistant professor, PhD
**Title of course:** Introduction to Electronics  
**Code:** TTFBL0120  
**ECTS Credit points:** 2

<table>
<thead>
<tr>
<th><strong>Type of teaching, contact hours</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 2 hours/week</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation:** practical grade

<table>
<thead>
<tr>
<th><strong>Workload (estimated), divided into contact hours:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 28 hours</td>
<td></td>
</tr>
<tr>
<td>- home assignment: 32 hours</td>
<td></td>
</tr>
<tr>
<td>- preparation for the exam: -</td>
<td></td>
</tr>
</tbody>
</table>

Total: 60 hours

<table>
<thead>
<tr>
<th><strong>Year, semester:</strong></th>
<th>3rd year, 1st semester</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Its prerequisite(s):</strong></th>
<th>TTFBE1120</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th><strong>Further courses built on it:</strong></th>
<th>-</th>
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<table>
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<tr>
<th><strong>Schedule:</strong> (8*3.5 hour measurement program)</th>
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</thead>
<tbody>
<tr>
<td>1st week Informative course, scheduling lab measurements.</td>
</tr>
<tr>
<td>2nd week Determination of resistance by Wheatstone bridge;</td>
</tr>
<tr>
<td>3rd week Determination of the dependence of salt solution conductivity</td>
</tr>
<tr>
<td>4th week Frequency resonance measurements on RLC circuits</td>
</tr>
<tr>
<td>5th week</td>
</tr>
</tbody>
</table>

30
Measurements on power supply circuits.

6th week
Specification of operational amplifiers, basic op-amp circuits: inverting, non-inverting, summing and differential amplifiers, voltage-current converters

7th week
Nonlinear circuits of operational amplifiers: integrator, differentiate, oscillator circuit, active filters.

8th week
Digital electronics: Logic gates; basic combinational logic circuits: encoders, decoders, binary adders

9th week
Basic sequential logic circuits: memories, counters, shift registers, serial-parallel converter.

### Requirements:

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

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<tr>
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</table>

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

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

- **an offered grade:** -

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

**Lecturer:** Dr. László Oláh, assistant professor, PhD
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Linear algebra</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TMMBE0815</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>3</td>
</tr>
</tbody>
</table>

**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:** 1\textsuperscript{st} year, 1\textsuperscript{st} semester

**Its prerequisite(s):** -

**Further courses built on it:**

**Topics of course**

**Literature**

*Howard Anton and Chris Rorres, Elementary Linear Algebra, John Wiley & Sons, 2010*

**Schedule:**

*1\textsuperscript{st} week*
Determinants, matrix operations
SR: understand operations with matrices, determinant calculation
2\textsuperscript{nd} week
Vector spaces, linear independence, basis, dimension
SR: understand the notions of basis and dimension
3\textsuperscript{rd} week
Linear maps on vectors spaces, Transformations of bases and coordinates
SR: understand actions of linear maps
4\textsuperscript{th} week
Rank of matrices. Sum and direct sum of subspaces. Factor space
SR: get skilled in rank calculation, understand sum of subspaces
5\textsuperscript{th} week
Systems of linear equations. Cramer’s rule, Gaussian elimination
SR: understand the theory of systems of linear equations
6\textsuperscript{th} week
Invariant subspaces. Eigenvalues, eigenvectors
SR: understand eigenvalues and eigenvectors
7\textsuperscript{th} week
Transforming the matrix of linear maps to diagonal form. The existence of a basis consisting of eigenvectors
SR: get skilled in construction bases with eigenvectors
8\textsuperscript{th} week
Bilinear and quadratic forms, inner products, Euclidean spaces
SR: get acquainted with Euclidean spaces
9\textsuperscript{th} week
Basis properties of Euclidean spaces
SR: learn the basic inequalities in Euclidean spaces
10\textsuperscript{th} week
Orthogonality, Gram-Schmidt orthogonalization, orthogonal complement
SR: understand Gram-Schmidt algorithm
11\textsuperscript{th} week
Adjoint of linear maps and its properties
SR: understand the transformation of adjunction
12\textsuperscript{th} week
Self adjoint operators and their properties
SR: understand self adjoint operators
13\textsuperscript{th} week
Orthogonal transformations and their properties.
SR: understand isometric operations
14\textsuperscript{th} week
Normal transformations
SR: understand normal transformations

**Requirements:**
- *for a signature*
- *for a grade*
  - Knowledge of definitions, theorems: grade 2;
  - In addition, knowledge of the proofs of most important theorems: grade 3;
  - In addition, knowledge of the proofs of theorems: grade 4;
  - In addition, knowledge of connections of notions and statements: grade 5.
- *an offered grade:*

**Person responsible for course:** Prof. Dr. István Gaál, university professor, DSc

**Lecturer:** Prof. Dr. István Gaál, university professor, DSc
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Linear algebra class work</th>
<th><strong>ECTS Credit points:</strong></th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TMMBG0815</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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:** 1\textsuperscript{st} year, 1\textsuperscript{st} semester

**Its prerequisite(s):** -

**Further courses built on it:**

**Topics of course**

**Literature**


**Schedule:**

1\textsuperscript{st} week
Determinants
SR: get skilled in determinant calculation

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

**Requirements:**
- for a signature

Two tests are written during the semester. The joint result of the tests is calculated in percentages:

- for a grade
  - 45%: grade 2;
  - 60%: grade 3;
  - 75%: grade 4
  - 85%: grade 5
- an offered grade:

Person responsible for course: Prof. Dr. István Gaál, university professor, DSc

Lecturer: Prof. Dr. István Gaál, university professor, DSc
Title of course: Differential and integral calculus
Code: TTMBE0813

ECTS Credit points: 4

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

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 42 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 78 hours
Total: 120 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s):

Further courses built on it: TTMBE0814; TTMBE0817; TTMBE0818; TTFBE0102; TTFBG0104.

Topics of course

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

Literature

Compulsory:
Recommended:

Schedule:
1st week
Limit of functions and its computation using limit of sequences. Cauchy’s criterions; the relation between the limit and the operations, respectively the order.
2nd week
The relation between limit and uniform convergence, respectively continuity and uniform convergence; Dini’s theorem.
3rd week
Right- and left-sided limits; points of discontinuity; classification of discontinuities of the first kind; limit properties of monotone functions.
4th week
Elementary limits; the introduction of pi. Functions stemming from elementary functions.
5th week
Differentiability and approximation with linear functions. Differentiability and continuity; differentiability and operations; the chain rule and the differentiability of the inverse function.
6th week
Local extremum, Fermat principle. The mean value theorems of Rolle, Lagrange, Cauchy and Darboux. L’Hospital rules. Higher order differentiability; Taylor’s theorem.
7th week
Monotonicity and differentiability, higher order conditions for extrema. Convex functions.
8th week
The definition of antiderivatives; basic integrals, rules of integration.
9th week
Darboux integrals and their properties.
10th week
Riemann integral and its properties.
11th week
The main classes of integrable functions. Inequalities, mean value theorems for the Riemann integral. The Newton–Leibniz theorem and the properties of antiderivatives.
12th week
The relation between Riemann-integrability and uniform convergence. Applications. Improper Riemann-integral.
13th week
Lebesgue null sets. Modulus of continuity.
14th week
Lebesgue’s criterion and its applications.

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59%</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69%</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79%</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89%</td>
<td>good (4)</td>
</tr>
</tbody>
</table>
In general, the EDUCATION AND EXAMINATION RULES AND REGULATIONS have to be taken into account.

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

**Lecturer:** Dr. Mihály Bessenyei, associate professor, PhD

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>90-100%</td>
<td>excellent (5)</td>
</tr>
<tr>
<td><strong>Title of course:</strong> Differential and integral calculus class work</td>
<td><strong>ECTS Credit points:</strong> 4</td>
</tr>
<tr>
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</tr>
<tr>
<td><strong>Code:</strong> TTMBG0813</td>
<td></td>
</tr>
</tbody>
</table>

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

**Evaluation:** exam

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

Total: 120 hours

**Year, semester:** 1st year, 1st semester

**Its prerequisite(s):** TTMBE0813

**Further courses built on it:** TTMBE0814

**Topics of course**

**Literature**

**Compulsory:**

**Recommended:**

**Schedule:**
1st week

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

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

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

5th week
Monotonicity, convexity, extrema of functions.

6th week
Summary
7th week
Midterm test.
8th week
Basic integrals, rules of integration.
9th week
Integration of partial fractions.
10th week
Applications of the integration of partial fractions.
11th week
12th week
Inequalities for Riemann integral.
13th week
Summary.
14th week
Endterm test.

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59%</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69%</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79%</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89%</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100%</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

Lecturer: Dr. Mihály Bessenyei, associate professor, PhD
Title of course: Differential and integral calculus in several variables  
ECTS Credit points: 4

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

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 42 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 78 hours
Total: 120 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMBE0813

Further courses built on it:

Topics of course

Literature

Compulsory:

Recommended:

Schedule:


5th week The notion of Fréchet derivative and its uniqueness. The connection of differentiability and continuity. The Fréchet derivative of affine and bilinear maps. The Chain Rule and its consequences.

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

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

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

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

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


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


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

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


Requirements:
- for a signature
  Attendance at lectures is recommended, but not compulsory.
- for a grade
  The course ends in an examination. Before the examination students must have grade at least ‘pass’ on Differential and integral calculus in several variables practice (TTMBG0204-EN). The grade for the examination is given according to the following table:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-49</td>
<td>fail (1)</td>
</tr>
<tr>
<td>50-61</td>
<td>pass (2)</td>
</tr>
<tr>
<td>62-74</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>75-87</td>
<td>good (4)</td>
</tr>
<tr>
<td>88-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

**Lecturer:** Prof. Dr. Zsolt Páles, university professor, DSc
<table>
<thead>
<tr>
<th><strong>Title of course:</strong> Differential and integral calculus in several variables</th>
<th><strong>ECTS Credit points:</strong> 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong> TTMBG0814</td>
<td></td>
</tr>
</tbody>
</table>

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

**Evaluation:** mid-term and end-term tests

**Workload (estimated), divided into contact hours:**
- lecture: -
- practice: 42 hours
- laboratory: -
- home assignment: 24 hours
- preparation for the tests: 24 hours
Total: 90 hours

**Year, semester:** 1\textsuperscript{st} year, 2\textsuperscript{nd} semester

**Its prerequisite(s):** TTMBE0813

**Further courses built on it:**

**Topics of course**


**Literature**

*Compulsory:*
*Recommended:*

**Schedule:**

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

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

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

4\textsuperscript{th} week The Fermat principle for local minimum and maximum. Characterization of positive definite and positive semidefinite quadratic forms. The second-order necessary and sufficient conditions of optimality.
5th week Optimization problems with equality and inequality constraints and applications of the Lagrange multiplier rule.
6th week Survey of the results and methods of the first 5 weeks.
7th week Mid-term test.
8th week Computation of the Riemann-integral with the help of the Fubini theorem. The Jordan measure of bounded sets.
9th week Computation of the Riemann-integral with the help of the integral transformation theorem.
10th week Functions of bounded and of unbounded variations. The computation of total variation.
11th week The Riemann-Stieltjes integral and the curve integral.
12th week Existence and non-existence of the primitive function (potential function) of vector fields.
13th week Survey of the results and methods of the 8th-12th weeks.
14th week End-term test.

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

During the semester there are two tests: the mid-term test in the 7th week and the end-term test in the 14th week. Students have to sit for the tests.
- for a grade
The minimum requirement for the average of the mid-term and end-term tests is 50%.

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-49</td>
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<td>good (4)</td>
</tr>
<tr>
<td>88-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

Lecturer: Prof. Dr. Zsolt Páles, university professor, DSc
**Title of course:** Classical mechanics 1  
**Code:** TTFBE0101  
**ECTS Credit points:** 6

**Type of teaching, contact hours**
- lecture: 4 hours/week  
- practice: -  
- laboratory: -

**Evaluation:** exam

**Workload (estimated), divided into contact hours:**
- lecture: 56 hours  
- practice: -  
- laboratory: -  
- home assignment: 68 hours  
- preparation for the exam: 56 hours  
Total: 180 hours

**Year, semester:** 1st year, 1st semester

**Its prerequisite(s):** TTFBE0119, TTFBG0101

**Further courses built on it:** TTFBE0103, TTFBG0103

**Topics of course**


### Literature

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

**Recommended:**

### Schedule:

1st week


2nd week


3rd week


4th week


5th week
Angular momentum of a system of particles, generalization of the theorem of conservation of angular momentum. Computation and properties of rotational inertia of rigid bodies. Definition of angular momentum of rigid bodies with respect to an axis or a point. Conditions of equilibrium of rigid bodies. Equivalent substitution of weight.

**6th week**
Discussion of rotation of a rigid body around a fixed axis: torsion pendulum, physical pendulum. Motion of a rigid body in a plane. Decomposition of angular momentum into orbital and rotational components and their respective equations of motion; roll.

**7th week**
Classification and discussion of the motion of the spinning top. Classification of collisions. Solution of collision in one dimension. Definitions of kinetic energy and work, proof of work-energy theorem in the case of a particle. Definition of power. Derivation of the work-energy theorem in case of system of particles and rigid bodies in case of motion in a plane. Definition of potential energy.

**8th week**

**9th week**

**10th week**

**11th week**
Energy transport in moving elastic waves. Wave function of and energy relations in moving sinusoidal waves. Reflection of waves in one dimension from the boundary of the medium. Wave function of standing waves and energy relations in them.

**12th week**
Wave in two and three dimensions: wave functions, wave equations, interference, diffraction and refraction of waves. Principle of Huygens and Fresnel.

**13th week**

**14th week**
Summary, discussion of questions emerging during the semester.

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

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

- **An offered grade:**

| Person responsible for course: | Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS |
| Lecturer:                     | Dr. István Nándori, associate professor, PhD |
Title of course: Classical mechanics I class work  
Code: TTFBG0101  
ECTS Credit points: 4

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

Evaluation: signature + grade for written test

Workload (estimated), divided into contact hours:
- lecture:  
- practice: 28 hours  
- laboratory:  
- home assignment: 92 hours  
- preparation for the exam:  
Total: 120 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): TTFBE0101

Further courses built on it:  

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

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

Schedule:
1st week
Problems of collisions of point-like object in one and two dimensions using conservation of momentum and Newton's 3rd law.

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

3rd week
Solution of the equation of motion with constraints: mathematical pendulum, motion on inclined plane, motion in presence of friction.

4th week
Finding the center of mass of rigid bodies in simple cases. Applications of Newton's 2nd law of motion in accelerating reference frames.

5th week
Application of the angular momentum theorem; calculation of the angular momentum of rigid bodies with respect to a fixed axis and to a fixed reference point.

6th week
Calculation of the moment of inertia of rigid bodies in simple cases; Steiner's theorem. Problems for static equilibrium of rigid bodies, dynamics of rigid bodies rotating about a fixed axis, calculation of orbital and spin angular momentum. Rolling motion.

7th week
In class test.

8th week
Application of the work-energy theorem in simple cases. Calculation of the kinetic and the potential energy; problems for application of conservation of mechanical energy. Calculation of the potential energy for various force laws.

9th week
Problems related to the second cosmic velocity; calculation of the elastic stress, the equivalent spring constant and Young's modulus.

10th week
Problems of static equilibrium of gases and liquids (hydrostatics and aerostatics). Applications of Pascal's laws, hydrostatic pressure, Archimedes law, Boyle–Mariotte law, barometric formula.

11th week
Problems for fluid mechanics: continuity equation, Bernoulli equation, Newton law of viscosity.

12th week
Solution of problems of waves: wave speed, wave function, wave equation, energy types and their relations in traveling and standing waves. Doppler formula.
13\textsuperscript{th} week
Application of Lorentz’ transformation formulas and their kinematical consequences in solving problems of relativistic kinematics.

14\textsuperscript{th} week
In class test.

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

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

**Lecturer:** Dr. István Nándori, associate professor, PhD
**Title of course:** Computer basics for physics applications  
**Code:** TTFBE0113

**ECTS Credit points:** 2

<table>
<thead>
<tr>
<th><strong>Type of teaching, contact hours</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 1 hours/week</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 2 hours/week</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation:** exam

**Workload (estimated), divided into contact hours:**
- lecture: 14 hours
- practice: -
- laboratory: 28 hours
- home assignment: 8 hours
- preparation for the exam: 10 hours
Total: 60 hours

**Year, semester:** 1st year, 2nd semester

**Its prerequisite(s):** TTFBE0101, TTFBL0118

**Further courses built on it:** -

**Topics of course**

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

**Literature**

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

- **Recommended:**
  - Introduction to Scilab by Scilab Enterprises, 2010

**Schedule:**

1st week  
Introduction to the rules of the course and to the subject. Getting familiar with Excel, important keyboard shortcuts, mouse commands, relative and absolute cell-references, R1C1 view. Simple arithmetics and the use of built-in functions.

2nd week  
Function transformations using parameters, different diagrams for plotting data, plot formatting.

3rd week  
Importing and exporting data, statistical analysis on data. Activation and use of data analysis extension in Excel.

4th week  
Activating the equation solver extension of Excel and apply it for function fitting and regression.
5th week
Interpolation and extrapolation, smoothing, online and offline mathematical applications.

6th week
Numerical derivation and integration

7th week
Practicing and connecting different parts of the learned information.

8th week
In-class test

9th week
Basics of Scilab, introduction, Scilab’s working principles, variables, functions, matrices, arithmetics, the very basics of plotting

10th week
Programming in Scilab, defining functions, cycles, file management, plotting

11th week
Different plotting methods for datasets.

12th week
Solving simple physics problems numerically with Scilab

13th week
Practicing.

14th week
In-class test.

**Requirements:**
- for a signature
- During the semester solving at least 70% of the given homeworks successfully is a requirement for the signature.

- for a grade
The course mark is calculated by a weighted average based on a) the solutions uploaded at the end of the practices and b) the results of mid-semester tests. The weights are a:b = 1:4. The grade is: fail (1) if below 50%, sufficient (2) if between 50-62%, average (3) if between 63-75%, good (4) if between 76-88%, excellent (5) if above 88%.

- an offered grade:

**Person responsible for course:** János Tomán, assistant lecturer

**Lecturer:** János Tomán, assistant lecturer
<table>
<thead>
<tr>
<th><strong>Title of course:</strong> Laboratory practical: mechanics, optics, thermodynamics 1</th>
<th><strong>ECTS Credit points:</strong> 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong> TTFBL0114</td>
<td></td>
</tr>
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</table>

<table>
<thead>
<tr>
<th><strong>Type of teaching, contact hours</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice:</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 2 hours/week (aggregated as 4 hours/week)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Evaluation:</strong> mid-semester grade</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Workload (estimated), divided into contact hours:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice:</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 20 hours</td>
<td></td>
</tr>
<tr>
<td>- home assignment: 40 hours</td>
<td></td>
</tr>
<tr>
<td>- preparation for the exam: -</td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong> 60 hours</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Year, semester:</strong> 1st year, 2nd semester</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Its prerequisite(s):</strong> TTFBE0101 and TTFBL0118</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Further courses built on it:</strong> TTFBL0115</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Topics of course</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory measurements in mechanics, thermodynamics and optics</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory:</strong></td>
</tr>
<tr>
<td>Handouts provided on the course home page</td>
</tr>
<tr>
<td><strong>Recommended:</strong></td>
</tr>
<tr>
<td>Any university textbook on the topic of the upcoming measurement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Measurements:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements with pendulums</td>
</tr>
<tr>
<td>Elastic moduli</td>
</tr>
<tr>
<td>Measurements with sound waves</td>
</tr>
<tr>
<td>Refractive index and dispersion</td>
</tr>
<tr>
<td>Measurements with lenses</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Requirements:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- <em>for a signature</em></td>
</tr>
<tr>
<td>Presence on all of the measurements and submission of laboratory report.</td>
</tr>
<tr>
<td>- <em>for a grade</em></td>
</tr>
<tr>
<td>The grade is computed from the laboratory report and occasional written and oral discussion in the topic of the measurement.</td>
</tr>
<tr>
<td><strong>Person responsible for course:</strong></td>
</tr>
<tr>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>Lecturer:</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Title of course:</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Code:</td>
</tr>
<tr>
<td>ECTS Credit points:</td>
</tr>
</tbody>
</table>

**Type of teaching, contact hours**
- lecture: -
- practice: -
- laboratory: 2 hours/week (aggregated as 4 hours/week)

**Evaluation:** mid-semester grade

**Workload (estimated), divided into contact hours:**
- lecture: -
- practice: -
- laboratory: 20 hours
- home assignment: 40 hours
- preparation for the exam: -
Total: 60 hours

**Year, semester:** 2nd year, 1st semester

**Its prerequisite(s):** TTFBE0102, TTFBE0103 and TTFBL0114

**Further courses built on it:** -

**Topics of course**
Laboratory measurements in mechanics, thermodynamics and optics

**Literature**

*Compulsory:*
Handouts provided on the course home page

*Recommended:*
Any university textbook on the topic of the upcoming measurement

**Measurements:**
Microscope and Telescope
Viscosity
Measurement of basic thermodynamic parameters
Diffraction
Measurement of a selected phenomenon with given set of devices, without measurement guide

**Requirements:**
- *for a signature*
  Presence on all of the measurements and submission of laboratory report.
- *for a grade*
  The grade is computed from the laboratory report and occasional written and oral discussion in the topic of the measurement.
<table>
<thead>
<tr>
<th><strong>Person responsible for course:</strong></th>
<th>Dr Gábor Katona, assistant professor, PhD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecturer:</strong></td>
<td>Dr. Gábor Katona, assistant professor, PhD</td>
</tr>
<tr>
<td></td>
<td>Dr. László Tóth, assistant lecturer</td>
</tr>
</tbody>
</table>
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

**Literature**

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

**Recommended:**

**Schedule:**

1\(^{st}\) week
Lorentz transformations and their kinematical consequences: relativity of sections and time intervals, applications of Lorentz-transformations. Relativistic addition of velocity components.

2\(^{nd}\) week
Relativistic dynamics: relativistic generalization of momentum and equation of motion; relativistic generalization of the work-energy theorem and energy. Equivalence of mass and energy, concept of internal energy.

3\(^{rd}\) week

4\(^{th}\) week
of the molecular interaction, concept of surface tension and surface energy. Relation between surface curvature and pressure, contact angle, capillarity.

5th week

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

6th week

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

7th week


8th week

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

9th week


10th week


11th week


12th week

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

13th week


14th week

**Requirements:**

- **for a signature**

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

- **for a grade**

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

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

  *an offered grade* is not possible.

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

**Lecturer:** Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS
<table>
<thead>
<tr>
<th>Title of course:</th>
<th>Thermodynamics class work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code:</td>
<td>TTFBG0102</td>
</tr>
<tr>
<td>ECTS Credit points:</td>
<td>3</td>
</tr>
</tbody>
</table>

**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:** 1<sup>st</sup> year, 2<sup>nd</sup> 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 coefficient of performance of refrigerators. Problems for calculating macro and micro states. Problems to determine entropy change from macroscopic data. Problems to calculate free energy and free enthalpy. Applying Clausius-Clapeyron equation to solve tasks. Problems to use the mean free path and Fick's law. Applying law of heat conduction (Fourier's law) to solve tasks.

**Literature**


**Schedule:**

1<sup>st</sup> week Use of temperature scales and state equations to solve problems.
2<sup>nd</sup> week Use of curvature pressure, interface energy and contact angle to calculate equilibrium fluid level.
3<sup>rd</sup> week Problems to calculate changes in internal energy.
4<sup>th</sup> week Problems to calculate changes in internal energy.
5th week. Problems to calculate the enthalpy change, applying the quasi-static adiabatic state change equations.

6th week. Application of the probability density function to solve problems.

7th week. Application of the probability density function to solve problems.

8th week. Calculating the efficiency of the Otto- and Diesel-cycle processes, the coefficient of performance of refrigerators.

9th week. Problems for calculating macro and micro states.

10th week. Problems to determine entropy change from macroscopic data.

11th week. Problems to calculate free energy and free enthalpy.

12th week. Applying Clausius-Clapeyron equation to solve tasks.

13th week. Problems to use the mean free path and Fick's law.

14th week. Applying law of heat conduction (Fourier's law) to solve tasks.

Requirements:

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

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

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

Lecturer: Dr. Darai Judit, associate professor, PhD
## Title of course
Classical mechanics 2

## Code
TTFBE0104

## ECTS Credit points
3

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

### Evaluation
exam

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

Total: 90 hours

### Year, semester
1st year, 2nd semester

### Its prerequisite(s)
TTFBE0101, TTFBG0104, TTMBE0815

### Further courses built on it
-

### Topics of course

### Literature
**Compulsory:**
H. Goldstein, C. Poole, J. Safko, Classical Mechanics (Addison Wesley, 2001)

**Recommended:**

---

**Schedule:**

<table>
<thead>
<tr>
<th>Week</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
<td>Kinematics of system of particles and continuous systems. Waves. Generalized coordinates and constraints.</td>
</tr>
<tr>
<td>2nd week</td>
<td>Periodic waves. Linear superposition and interference.</td>
</tr>
<tr>
<td>5th week</td>
<td>Lagrange’s equation of the first kind, method of Lagrange multipliers.</td>
</tr>
<tr>
<td>6th week</td>
<td>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.</td>
</tr>
<tr>
<td>7th week</td>
<td>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.</td>
</tr>
<tr>
<td>9th week</td>
<td>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.</td>
</tr>
<tr>
<td>10th week</td>
<td>Harmonic oscillator, damped harmonic oscillator, driven harmonic oscillator, over- and undercritical damping, resonance. Pendulum.</td>
</tr>
<tr>
<td>11th week</td>
<td>Hamilton equations of motion, Legendre transform.</td>
</tr>
<tr>
<td>12th week</td>
<td>Continuous systems as a system of coupled harmonic oscillators. Infinitesimal strain theory, deformation tensor.</td>
</tr>
</tbody>
</table>
13th week
Stress tensor, Hooke’s law, static deformations of continuous systems.

14th week

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

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

Lecturer: Prof. Dr. Kornel Sailer, professor emeritus, DSc
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Classical mechanics 2 class work</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TTFBG0104</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>3</td>
</tr>
</tbody>
</table>

**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**

**Literature**

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

*Recommended:*
-

**Schedule:**

*1st week*
Problems related to circular motion, solution of the harmonic oscillator, simple problems with composition of harmonic motions.

*2nd week*
Wave motion, wave equations, and their solutions.

*3rd week*
Calculations with Lagrange functions of simple systems.
4th week
In class test.

5th week
Constraints, problems related to Lagrange’s equation of the first kind.

6th week
Derivation of momentum, angular momentum, energy from the Lagrange function, continuous symmetries and conservation laws, conservation of the center of mass.

7th week
Constraints, problems related to Lagrange’s equation of the second kind.

8th week
Problems related to potential energies and conservative forces.

9th week
In class test.

10th week
Motion of particle in a potential.

11th week
Investigation of the harmonic oscillator, damped oscillator, driven oscillator.

12th week
Usage of Hamilton equations of motion, and Legendre transform.

13th week
Problems related to deformation of bodies.

14th week
In class test.

**Requirements:**

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

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

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

**Lecturer:** Prof. Dr. Kornel Sailer, professor emeritus, DSc
<table>
<thead>
<tr>
<th>Title of course:</th>
<th>Optics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code:</td>
<td>TTFBE0103</td>
</tr>
<tr>
<td>ECTS Credit points:</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 1 hours/week</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

| Evaluation: | exam |

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 14 hours</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
<tr>
<td>- home assignment: 6 hours</td>
</tr>
<tr>
<td>- preparation for the exam: 10 hours</td>
</tr>
<tr>
<td>Total: 30 hours</td>
</tr>
</tbody>
</table>

| Year, semester: | 1st year, 2nd semester |

| Its prerequisite(s): | TTFBE0101 |

| Further courses built on it: | - |

<table>
<thead>
<tr>
<th>Topics of course</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compulsory:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Schedule:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
</tr>
<tr>
<td>Light as a wave, wave equation, and its solutions. Parameters of light. The speed of light.</td>
</tr>
</tbody>
</table>
### 2nd week
The main parameters of light: wavelength, wavenumber, and frequency. The terminology of photometry.

### 3rd week
Refraction and diffraction of light. Basic laws of geometrical optics.

### 4th week
Main elements of geometrical optics: mirrors, lenses. Main parameters and possible defects.

### 5th week
Thin and thick lenses, their laws and parameters.

### 6th week
Optical systems: eye, camera, microscope, lense.

### 7th week
Main phenomena of physical optics: interference, coherence. Interference on double slit.

### 8th week
Interference in thin layers, Newtonian rings. Interferometers: Michelson, the coherence of laser source, holography.

### 9th week
Diffraction, Huygens-Fresnel law, Fresnel diffraction.

### 10th week
The conditions of diffraction. Interference and diffraction on two slit. Fraunhofer diffraction.

### 11th week
Optical gratings, their parameters, and terminology.

### 12th week
Diffraction and reflection on particles. X-ray diffraction and their application.

### 13th week

### 14th week

### Requirements:
- *for a signature*

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

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

- *for a grade*

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

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

**Lecturer:** Dr. István Csarnovics, assistant professor, PhD
**Title of course:** Optics class work  
**Code:** TTFBG0103-EN  
**ECTS Credit points:** 1

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture:</td>
<td>-</td>
</tr>
<tr>
<td>- practice: 1 hours/week</td>
<td>-</td>
</tr>
<tr>
<td>- laboratory:</td>
<td>-</td>
</tr>
</tbody>
</table>

**Evaluation:** signature and grade for class work

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 14 hours</td>
<td>-</td>
</tr>
<tr>
<td>- practice:</td>
<td>-</td>
</tr>
<tr>
<td>- laboratory:</td>
<td>-</td>
</tr>
<tr>
<td>- home assignment: 16 hours</td>
<td>-</td>
</tr>
<tr>
<td>- preparation for the exam:</td>
<td>-</td>
</tr>
<tr>
<td>Total: 30 hours</td>
<td></td>
</tr>
</tbody>
</table>

**Year, semester:** 1\(^{st}\) year, 2\(^{nd}\) semester

**Its prerequisite(s):** TTFBE0101-EN

**Further courses built on it:** -

**Topics of course**


**Literature**

<table>
<thead>
<tr>
<th>Compulsory:</th>
<th></th>
</tr>
</thead>
</table>

**Schedule:**

1\(^{st}\) week

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

75
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>The main parameters of light: wavelength, wavenumber, and frequency. The terminology of photometry.</td>
</tr>
<tr>
<td>4th</td>
<td>Main elements of geometrical optics: mirrors, lenses. Main parameters and possible defects.</td>
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<tr>
<td>5th</td>
<td>Thin and thick lenses, their laws and parameters.</td>
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<tr>
<td>6th</td>
<td>Optical systems: eye, camera, microscope, lope.</td>
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<td>7th</td>
<td>Main phenomena of physical optics: interference, coherence. Interference on double slit.</td>
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<td>Interference in thin layers, Newtonian rings. Interferometers: Michelson, the coherence of laser source, holography.</td>
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</tr>
<tr>
<td>12th</td>
<td>Diffraction and reflection on particles. X-ray diffraction and their application.</td>
</tr>
</tbody>
</table>

**Requirements:**

- *For a signature*

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

During the semester there are two tests: the mid-term test in the 8th week and the end-term test in the 15th week. Students have to sit for the tests.
The course ends in grade for the class, practice work. Based on the average of the grades of the designing tasks and the two tests, the grade is calculated as an average of them:

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

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

<table>
<thead>
<tr>
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</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

**Lecturer:** Dr. István Csarnovics, assistant professor, PhD
| **Title of course:** Electromagnetism  |
| **Code:** TTFBE0105  |
| **ECTS Credit points:** 6  |

<table>
<thead>
<tr>
<th><strong>Type of teaching, contact hours</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 4 hours/week</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

| **Evaluation:** exam  |

<table>
<thead>
<tr>
<th><strong>Workload (estimated), divided into contact hours:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 56 hours</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
<tr>
<td>- home assignment: 28 hours</td>
</tr>
<tr>
<td>- preparation for the exam: 96 hours</td>
</tr>
<tr>
<td>Total: 180 hours</td>
</tr>
</tbody>
</table>

| **Year, semester:** 2nd year, 1st semester  |

| **Its prerequisite(s):** TTFBE0102  |

| **Further courses built on it:** TTFBE0107, TTFBE0108, TTFBE0120  |

<table>
<thead>
<tr>
<th><strong>Topics of course</strong></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory:</strong> Robert Resnick, David Halliday, Keneth S. Krane, Physics Volume 2, John Wiley &amp; Sons, Inc.</td>
</tr>
<tr>
<td><strong>Recommended:</strong></td>
</tr>
</tbody>
</table>
Schedule:

1st week

2nd week
The electric dipole moment, the electric field of a system of charges, the principle of superposition. Determination of the electric field of static charges, electric dipoles and continuous charge distributions. The motion of a point charge and a dipole in static electric field. Conductors in statics electric field. Gauss’s law. The basic characteristics of the static electric field. Applications of the Gauss’s law.

3rd week
Work done by the static electric field. Electrostatic potential, voltage. Potential of static charges, electric dipoles and continuous charge distributions. Potential energy of a system of charges. Conductors and insulators. The distribution of electric charge on an isolated conductor, corona discharge.

4th week
Capacitance and capacitors. Capacitors in series and in parallel. Energy density of the electro-static field. Dielectrics, electric polarization, Gauss’s law in dielectrics, susceptibility, displacement vector, energy density of the static electric field in dielectrics, piezoelectric effect.

5th week

6th week
Electronic circuits, the electromotive force. Kirchhoff’s rules, work and power in electronic circuits, Joule’s law, an RC circuit.

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

7th week
Magnetic dipole. The magnetic field induced by a current or a moving charge Biot–Savart’s and Amper’s law. Unit of electric current. Work done by magnetic field.

8th week
Flux of static magnetic field. Scalar and vector potentials. Motion of charged particles in electric and magnetic field. Mass spectrometers and particle accelerators. The Hall effect. Focusing charged particle beams by static electric and magnetic fields.

9th week
Magnetic properties of matter, magnetic susceptibility, Dia-, para- and ferromagnetic materials. An atomic view of the magnetism of matter, the Einstein de Haas experiment. Permanent magnets.

10th week

11th week
Electromagnetic oscillations. Free and damped oscillations in LC and RLC circuits, forced oscillations, coupled oscillations, resonance.

12th week
Alternating current circuits. RLC circuits, impedance, phase shift, complex calculations, AC power. Motors and generators, the transformer. The three phase alternating current.

**13th week**

**14th week**

**Requirements:**
- *for a signature*
  - Signature requires the correct solution of at least 50% of homework assignments.
- *for a grade*
  - Knowledge of definitions, laws and theorems: grade 2;
  - In addition, knowledge of the proofs of most important theorems: grade 3;
  - In addition, knowledge of the proofs of theorems: grade 4;
  - In addition, knowledge of applications: grade 5.
- *an offered grade:*

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

**Lecturer:** Dr. László Oláh, assistant professor, PhD
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Electromagnetism class work</th>
<th><strong>ECTS Credit points:</strong></th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TTFBG0105</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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:

Literature

Compulsory:

Recommended:

Schedule:

1st week

2nd week
The concept of electric field. The electric field of a system of charges, the principle of superposition. Determination of the electric field of static charges, and equilibrium conditions. The motion of a point charge in static electric field.

3rd week
Determination of the electric field of continuous charge distributions.

4th week
The electric dipole moment. Determination of the electric field of an electric dipole. Gauss’s law. Applications of the Gauss’s law: electric field of continuous symmetrical charge distributions.

5th week
Calculation of the work done by the static electric field. Electrostatic potential, voltage. Potential of static charges, electric dipoles and continuous charge distributions. Potential energy of a system of charges.

6th week

7th week

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

8th week
Static magnetic field. Determination of magnetic field inductance vector. Magnetic force acting on a current or a moving charge. The motion of a point charge in static magnetic field. Speed selectors. Mass spectrometers and particle accelerators.

9th week
Magnetic dipole. The magnetic field induced by a current or a moving charge. Applications of Biot–Savart’s and Amper’s laws for simple current configurations.

10th week

11th week

12th week
Alternating current circuits. RLC circuits, impedance, phase shift, complex calculations, AC power. The three phase alternating current. Electronic components connected in series and in parallel.

13th week

14th week
In class test.

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

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

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

Lecturer: Dr. Ferenc Cserpák, assistant professor, PhD,
Dr. László Oláh, assistant professor, PhD
**Title of course:** Electrodynamics  
**Code:** TTFBE0108  
**ECTS Credit points:** 3

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 2 hours/week</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

**Evaluation:** oral exam

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 28 hours</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
<tr>
<td>- home assignment: 34 hours</td>
</tr>
<tr>
<td>- preparation for the exam: 28 hours</td>
</tr>
</tbody>
</table>

Total: 90 hours

**Year, semester:** 2\(^{nd}\) year, 2\(^{nd}\) semester

**Its prerequisite(s):** TTFBE0105

**Further courses built on it:** -

**Topics of course**


**Literature**

*Compulsory:*

*Recommended:*
- -
**Schedule:**

1st week

2nd week

3rd week
- Boundary conditions. Energy of the electromagnetic field. Poynting vector.

4th week
- Momentum of the electromagnetic field. Ponderomotive forces.

5th week

6th week
- Electrostatics. Poisson and Laplace equations. Potential created by a static charge distribution.

7th week
- Boundary value problems in electrostatics. Electric field of conducting sphere. Point charge in the presence of a grounded conducting sphere.

8th week
- Dipole moments. Polarization of dielectric.

9th week

10th week

11th week
- Alternating currents (AC). RL circuit. RLC circuit.

12th week

13th week
- Solutions of the wave equation. Retarded potentials. Electromagnetic waves in homogeneous isotropic insulators.

14th week

**Requirements:**

- *for a signature*
  - Signature requires the correct solution of at least 50% of homework assignments.

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

—an offered grade:

<table>
<thead>
<tr>
<th>Person responsible for course:</th>
<th>Prof. Dr Ágnes Vibók, university professor, DSc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer:</td>
<td>Prof. Dr Ágnes Vibók, university professor, DSc</td>
</tr>
<tr>
<td></td>
<td>Peter Badanko, research assistant</td>
</tr>
</tbody>
</table>
**Title of course:** Electrodynamics class work  
**Code:** TTFBG0108  
**ECTS Credit points:** 2

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
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<tr>
<td>- lecture: -</td>
</tr>
<tr>
<td>- practice: 2 hours/week</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

**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**


**Literature**

*Compulsory:*


*Recommended:*

- -

**Schedule:**

*1st week*

Vector calculus. Vector differential operations.

*2nd week*


*3rd week*
Solving the basic equations of electrostatics. Poisson and Laplace equations.

4th week
Green's theorem. Point charge in the presence of a grounded conducting sphere.

5th week
Conducting sphere in a uniform electric field. Selected advanced boundary value problems in electrostatics I

6th week
Selected advanced boundary value problems in electrostatics.

7th week
In class test.

8th week

9th week
Direct current II. Solving some advanced DC linear circuit problems.

10th week

11th week
Alternating currents (AC). RL circuits.

12th week
RLC circuits.

13th week

14th week
In class test.

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

Person responsible for course: Prof. Dr Ágnes Vibók, university professor, DSc
Lecturer: Prof. Dr Ágnes Vibók, university professor, DSc
      Peter Badanko, research assistant
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Condensed matter I</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TTFBE0106</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>3</td>
</tr>
</tbody>
</table>

**Type of teaching, contact hours**

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

**Evaluation:** oral exam

**Workload (estimated), divided into contact hours:**

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

Total: 90 hours

**Year, semester:** 2nd year, 1st semester

**Its prerequisite(s):** TTFBE0102, TTFBE0103

**Further courses built on it:** TTFBG0106

**Topics of course**

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

**Literature**

*Compulsory:*
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>The place and role of material science, material properties, classification of substances</td>
</tr>
<tr>
<td>2nd</td>
<td>Bondings: atomic structure, binding forces and binding energy, primary bonds (ionic, covalent, metallic), secondary bonds (van der Waals, hydrogen)</td>
</tr>
<tr>
<td>3rd</td>
<td>Crystal lattices: unit cell, crystalline structure of metals, crystal systems and crystal types, basic cubic structures (primitive, bcc, fcc, hcp)</td>
</tr>
<tr>
<td>4th</td>
<td>Crystallographic points, directions, planes (Miller indices), linear and planar atomic density, close packs, single crystals, polycrystalline materials, bases of diffraction</td>
</tr>
<tr>
<td>5th</td>
<td>Crystal defects: most important crystal defects, interstitial atom, vacancy, edge and screw dislocation, alloy, solid solution, phase and grain boundary</td>
</tr>
<tr>
<td>6th</td>
<td>Diffusion: the description of the phenomenon and its basic laws, steady state diffusion equation and its solution in simple initial conditions, time-dependent diffusion equation and its solution in simple initial and boundary conditions</td>
</tr>
<tr>
<td>7th</td>
<td>Interdiffusion: Presentation of the phenomenon and its technical significance, time-dependent diffusion equation and its solution in case of mutual diffusion</td>
</tr>
<tr>
<td>8th</td>
<td>Elastic materials: elastic characteristics of the material, Hooke's law, relationship between elasticity constants, breakdown diagram, yield strength, tensile strength, hardness</td>
</tr>
<tr>
<td>9th</td>
<td>Tensor form of the Hooke law for isotropic substances</td>
</tr>
<tr>
<td>10th</td>
<td>Dislocations and deformation: characterization of dislocations, sliding planes, slip plane in single and polycrystalline material, deformation with twinning, increase of material strength, recrystallization</td>
</tr>
<tr>
<td>11th</td>
<td>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</td>
</tr>
<tr>
<td>12th</td>
<td>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</td>
</tr>
</tbody>
</table>
Modern material testing and characterization methods: optical and scanning electron microscopes (transmission and scanning electron microscopy, scanning probe microscopes) and their various modes, X-ray diffractometer.

**Requirements:**

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

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

-an offered grade is not possible.

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

**Lecturer:** Dr. Csaba Cserháti, associate professor, PhD
**Title of course:** Condensed matter I class work  
**Code:** TTFBG0106  
**ECTS Credit points:** 3

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td>-</td>
</tr>
<tr>
<td>- practice: 2 hours/week</td>
<td>-</td>
</tr>
<tr>
<td>- laboratory: -</td>
<td>-</td>
</tr>
</tbody>
</table>

**Evaluation:** mid-semester grade

**Workload (estimated), divided into contact hours:**

<table>
<thead>
<tr>
<th>Category</th>
<th>Contact Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>-</td>
</tr>
<tr>
<td>Practice</td>
<td>28 hours</td>
</tr>
<tr>
<td>Laboratory</td>
<td>-</td>
</tr>
<tr>
<td>Home assignment</td>
<td>34 hours</td>
</tr>
<tr>
<td>Preparation for the test</td>
<td>28 hours</td>
</tr>
</tbody>
</table>

Total: 90 hours

**Year, semester:** 2nd year, 1st semester

**Its prerequisite(s):** TTFBE0102, TTFBE0103

**Further courses built on it:** TTFBE0106

**Topics of course**

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

**Literature**

*Compulsory:*

*Recommended:*
**Schedule:**

1st week
Material properties, classification of substances.

2nd week
Bondings: atomic structure, binding forces and binding energy, primary bonds (ionic, covalent, metallic), secondary bonds (van der Waals, hydrogen).

3rd week
Crystal lattices: unit cell, crystalline structure of metals, crystal systems and crystalline types (primitive, bcc, fcc, hcp).

4th week
Crystallographic points, directions, planes (Miller indices), linear and planar atomic density, close packed crystals, single crystals, polycrystalline materials, bases of diffraction.

5th week
In class test.

6th week
Most important crystal defects, interstitial atom, vacancy, edge and screw dislocation, alloy, solid solution, phase and grain boundary.

7th week
Diffusion: Solving the steady state diffusion equation for simple initial conditions, solving the time-dependent diffusion equation for simple initial and boundary conditions.

8th week
Solving the time-dependent diffusion equation for interdiffusion, the Darken equation.

9th week
In class test.

10th week
The elastic characteristics of the material, the Hooke-law, the relation between the elasticity constants, stress-strain diagram, yield strength, tensile strength, hardness.

11th week
Use of the tensor form of the Hooke law for isotropic substances.

12th week
Characterization of dislocations, sliding planes, deformation with twinning, increase of the strength of the material, re-crystallization, calculations.

13th week
In class test.

14th week
Summary, discussion of questions emerging during the semester.

**Requirements:**

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

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

**Lecturer:** Dr. Gábor Katona, assistant professor, PhD  
Dr. Csaba Cserháti, associate professor, PhD
**Title of course:** Condensed matter II  
**Code:** TTFBE0109  
**ECTS Credit points:** 3

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

**Evaluation:** exam

**Workload (estimated), divided into contact hours:**
- lecture: 28 hours  
- practice: -  
- laboratory: -  
- home assignment: -  
- preparation for the exam: 62 hours  
Total: 90 hours

**Year, semester:** 1st year, 1st semester

**Its prerequisite(s):** TTFBE0106, TTFBE0110

**Further courses built on it:** TTFBL0219

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

**Literature**

*Compulsory:*
C. Kittel: Introduction to Solid State Physics  

*Recommended:*
M.A. Omar: Elementary Solid State Physics, Principles and Applications

**Schedule:**  
1st week  
Information, introduction.
Phase diagrams: introduction, solubility limit, phases, microstructure, phase equilibrium, single and isomorphic two-component phase diagrams.

2nd week
Phase diagrams: determination of phase composition, amount of microstructure in isomorphic alloys, mechanical properties of isomorphous alloys, binary eutectic systems.

3rd week
Phase diagrams: equilibrium phase diagram of intermediate and compound phases, eutectic and peritic reactions, Gibbs phase rule, status of Fe-C, change of microstructure in the state of the Fe-C state.

4th week
Lattice vibrations: description of one-dimensional elastic waves in continuous medium, vibration modes, defining the density of states; calculation of the specific heat based on the Einstein and the Debye model; introducing the concept of phonon.

5th week
Lattice vibrations: description of wave motion on a chain of the same atoms and one-dimensional crystal with two types of atoms.

6th week
Lattice vibrations: interpretation of thermal conductivity; unelastic scattering of X-ray, neutron radiation and visible light on a lattice.

7th week
Free-electron model of metals: specific electrical conductivity and Ohm-law; the temperature dependence of the electrical resistance, heat capacity of the conductive electrons

8th week
Fermi surface; thermal conductivity in metals; Hall effect; the limits of the free-electron model.

9th week
Energy bands in solids: the foundation of the energy band theory through the description of the wave functions in the periodic lattice, introduction of the Bloch theorem, the Brillouin zones.

10th week
Band theory of solid states: The origin of band theory a description of the Kronig-Penney model.

11th week
Semiconductors: intrinsic semiconductors, holes, conductivity; extrinsic semiconductors, doping.

12th week
How do the simple semiconductor devices – eg diode, transistor, solar cells – work.

13th week
Dielectrics: ferrous and piezoelectric materials.

14th week
Optical properties of solid state materials: metals, non-metallic materials, refraction reflection, reflection, absorption, transmission, color, insulators transparency and opacity, luminescence, light guidance; optical devices, photodiodes, solar cells, optical fibers.

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

- for a grade
  The course ends in an examination. And the final grade is given according to the result of the examination
    - Knowledge of definitions, laws and theorems: grade 2;
- In addition, knowledge of the proofs of most important theorems: grade 3;
- In addition, knowledge of the proofs of theorems: grade 4;
- In addition, knowledge of applications: grade 5.

*An offered grade* is not possible.

<table>
<thead>
<tr>
<th>Person responsible for course:</th>
<th>Prof. Dr. Zoltán Erdélyi, university professor, DSc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer:</td>
<td>Prof. Dr. Zoltán Erdélyi, university professor, DSc</td>
</tr>
<tr>
<td></td>
<td>Dr. Csaba Cserháti, associate professor, PhD</td>
</tr>
<tr>
<td></td>
<td>Dr. Gábor Katona, assistant professor, PhD</td>
</tr>
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</table>
**Title of course:** Condensed matter II clw  
**Code:** TTFBE0109  
**ECTS Credit points:** 3

<table>
<thead>
<tr>
<th><strong>Type of teaching, contact hours</strong></th>
<th></th>
</tr>
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<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: 2 hours/week</td>
<td></td>
</tr>
<tr>
<td>- laboratory: -</td>
<td></td>
</tr>
</tbody>
</table>

| **Evaluation:** |  |
|----------------|  |
| mid-semester grade |  |

<table>
<thead>
<tr>
<th><strong>Workload (estimated), divided into contact hours:</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: 28 hours</td>
<td></td>
</tr>
<tr>
<td>- laboratory: -</td>
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<tr>
<td>- home assignment: 62 hours</td>
<td></td>
</tr>
<tr>
<td>- preparation for the exam:</td>
<td></td>
</tr>
<tr>
<td>Total: 90 hours</td>
<td></td>
</tr>
</tbody>
</table>

| **Year, semester:** |  |
|---------------------|  |
| 3rd year, 1st semester |  |

| **Its prerequisite(s):** |  |
|--------------------------|  |
| (p) TTFBE0109            |  |

| **Further courses built on it:** |  |
|-----------------------------------|  |
|                                   |  |

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

<table>
<thead>
<tr>
<th><strong>Literature</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compulsory:</strong></td>
</tr>
<tr>
<td>C.Kittel: Introduction to Solid State Physics</td>
</tr>
<tr>
<td><strong>Recommended:</strong></td>
</tr>
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<td>M.A. Omar: Elementary Solid State Physics, Principles and Applications</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Schedule:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week</td>
</tr>
<tr>
<td>Phase diagrams: determination of solubility and phase equilibrium.</td>
</tr>
</tbody>
</table>
### Requirements:

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

- **for a grade**
  The final grade is based on the arithmetic mean of the percentages of the tests completed during the semester:
  - below 50%: grade 1;
  - 50-62%: grade 2;
  - 63-75%: grade 3;
  - 76-88%: grade 4;
  - 88-100%: grade 5.
-an offered grade is not possible.

<table>
<thead>
<tr>
<th>Person responsible for course:</th>
<th>Prof. Dr. Zoltán Erdélyi, university professor, DSc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer:</td>
<td>Prof. Dr. Zoltán Erdélyi, university professor, DSc</td>
</tr>
<tr>
<td></td>
<td>Dr. Csaba Cserháti, associate professor, PhD</td>
</tr>
<tr>
<td></td>
<td>Dr. Gábor Katona, assistant professor, PhD</td>
</tr>
<tr>
<td></td>
<td>Dr. László Tóth, assistant lecturer, PhD</td>
</tr>
</tbody>
</table>
**Title of course:** Condensed Matter Lab. Practice I.  
**Code:** TTFBL0116  
**ECTS Credit points:** 2

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 1 hours/week</td>
<td></td>
</tr>
</tbody>
</table>

**Evaluation:** mid-semester grade

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: 16 hours</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 16 hours</td>
<td></td>
</tr>
<tr>
<td>- home assignment: 28 hours</td>
<td></td>
</tr>
<tr>
<td>- preparation for the exam: -</td>
<td></td>
</tr>
<tr>
<td>Total: 60 hours</td>
<td></td>
</tr>
</tbody>
</table>

**Year, semester:** 3rd year, 1st semester

**Its prerequisite(s):** TTFBE0106

**Further courses built on it:** -

<table>
<thead>
<tr>
<th>Topics of course</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The students</td>
<td></td>
</tr>
<tr>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>During the course, four of the following eight measurements must be selected by the student:</td>
<td></td>
</tr>
<tr>
<td>Determining the temperature dependence of magnetism, measuring coercive force and hysteresis.</td>
<td></td>
</tr>
<tr>
<td>Measuring Barkhausen noise</td>
<td></td>
</tr>
</tbody>
</table>

**Literature**

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

<table>
<thead>
<tr>
<th>Schedule:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>1st week</em></td>
<td>Information, introduction, accident, work safety education, discussion of lab-schedule</td>
</tr>
<tr>
<td><em>2nd week</em></td>
<td>Investigating the temperature dependence of magnetism</td>
</tr>
<tr>
<td><em>3rd week</em></td>
<td>Measuring coercive force and hysteresis.</td>
</tr>
<tr>
<td><em>4th week</em></td>
<td></td>
</tr>
<tr>
<td>Week</td>
<td>Topic</td>
</tr>
<tr>
<td>------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>5th week</td>
<td>Measurement of hardness and tensile strength</td>
</tr>
<tr>
<td>6th week</td>
<td>The basics of differential thermal analysis</td>
</tr>
<tr>
<td>7th week</td>
<td>Measurement of the temperature dependence of electrical resistance.</td>
</tr>
<tr>
<td>8th week</td>
<td>Measurement of diffusion in liquid phase.</td>
</tr>
<tr>
<td></td>
<td>Measurement of Barkhausen-noise.</td>
</tr>
</tbody>
</table>

**Requirements:**

- the basic knowledge of the laboratory practice theory, the measurement, the preparation of a measurement report in electronic form: sufficient;
- accurate knowledge of the theory of exercises, carrying out the measurement, making a measurement report in electronic form: medium;
- Basic knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: good;
- accurate knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: excellent.

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

**Lecturer:** Dr. Bence Parditka,

Dr. László Tóth
<table>
<thead>
<tr>
<th><strong>Title of course</strong>:</th>
<th>Atomic and quantum physics</th>
<th><strong>ECTS Credit points</strong>:</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code</strong>:</td>
<td>TTFBE0107</td>
<td><strong>Type of teaching, contact hours</strong></td>
<td></td>
</tr>
<tr>
<td>- lecture:</td>
<td>2 hours/week</td>
<td>- lecture:</td>
<td>28 hours</td>
</tr>
<tr>
<td>- laboratory:</td>
<td>-</td>
<td>- laboratory:</td>
<td>-</td>
</tr>
<tr>
<td>- home assignment:</td>
<td>34 hours</td>
<td>- preparation for the exam:</td>
<td>28 hours</td>
</tr>
<tr>
<td><strong>Evaluation</strong>:</td>
<td>exam</td>
<td><strong>Workload (estimated), divided into contact hours</strong>:</td>
<td></td>
</tr>
<tr>
<td>- lecture:</td>
<td>2 hours/week</td>
<td>- lecture:</td>
<td>28 hours</td>
</tr>
<tr>
<td>- practice:</td>
<td>-</td>
<td>- practice:</td>
<td>-</td>
</tr>
<tr>
<td>- laboratory:</td>
<td>-</td>
<td>- laboratory:</td>
<td>-</td>
</tr>
<tr>
<td>- home assignment:</td>
<td>34 hours</td>
<td>- home assignment:</td>
<td>34 hours</td>
</tr>
<tr>
<td>- preparation for the exam:</td>
<td>28 hours</td>
<td>- preparation for the exam:</td>
<td>28 hours</td>
</tr>
<tr>
<td><strong>Total</strong>:</td>
<td>90 hours</td>
<td><strong>Year, semester</strong>:</td>
<td>2nd year, 2nd semester</td>
</tr>
<tr>
<td><strong>Its prerequisite(s)</strong>:</td>
<td>TTFBE0105, TTFBG0107</td>
<td><strong>Further courses built on it</strong>:</td>
<td>-</td>
</tr>
<tr>
<td><strong>Topics of course</strong></td>
<td></td>
<td><strong>Topics of course</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Compulsory</strong>:</td>
<td></td>
<td><strong>Compulsory</strong>:</td>
<td></td>
</tr>
<tr>
<td>- Zoltán Trócsányi: Atomic and quantum physics, lecture note in electronic format</td>
<td></td>
<td><strong>Recommended</strong>:</td>
<td></td>
</tr>
<tr>
<td><strong>Recommended</strong>:</td>
<td></td>
<td>- Robert Resnick, David Halliday, Keneth S. Krane, Physics II: Chapters 45-54 John Wiley &amp; Sons, Inc.</td>
<td></td>
</tr>
</tbody>
</table>
Schedule:

1st week
Wave properties of light: refraction, diffraction and interference, Young’s two-slit diffraction experiment.

2nd week
Quantum aspects of light: electromagnetic radiation (spectral radiance), Rayleigh-Jeans’ law, Planck’s law, application of Planck’s law and its consequences. Interpretation of Wien’s and Stefan-Boltzmann’s laws.

3rd week
Direct observation of the quantum properties of light: photo effect, Compton scattering.

4th week
X-ray diffraction, the Bragg’s law. De-Broglie hypothesis of matter waves. Discovery of the electron. Davisson-Germer experiment.

5th week
Rutherford’s experiment. Derivation of the differential cross section formula of Rutherford scattering on point-like target.

6th week
Cross section of Rutherford scattering on a point-like and extended target. Discovery of the atomic nucleus.

7th week

8th week
Fine structure of atomic spectra. Effects of magnetic field on the atomic spectra (Zeeman splitting, Larmor-frequency) and electric field on the atomic spectra (Stark effect). Einstein - de Haas experiment, Stern-Gerlach experiment and the spin of the electron.

9th week
Characteristic X-ray radiation, induced radiation, lasers.

10th week
The periodic table of elements.

11th week
Basics of quantum mechanics: states and measurements.

12th week
Spin - state vector representation.

13th week
Spin – density matrix representation.

14th week
Summary, discussion of questions emerging during the semester.

Requirements:

- for a signature

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

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

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

*a offered grade is not possible.*

<table>
<thead>
<tr>
<th>Person responsible for course:</th>
<th>Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturer:</td>
<td>Prof. Dr. Zoltán Trócsányi, university professor, DSc, member of HAS</td>
</tr>
<tr>
<td></td>
<td>Dr. István Nándori, associate professor, PhD</td>
</tr>
</tbody>
</table>
**Title of course:** Atomic and quantum physics class work  
**Code:** TTFBG0107  
**ECTS Credit points:** 3

<table>
<thead>
<tr>
<th><strong>Type of teaching, contact hours</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>lecture: -</td>
<td>-</td>
</tr>
<tr>
<td>practice: 2 hours/week</td>
<td>-</td>
</tr>
<tr>
<td>laboratory: -</td>
<td>-</td>
</tr>
</tbody>
</table>

**Evaluation:** mid-semester exam

**Workload (estimated), divided into contact hours:**
- lecture: -  
- practice: 28 hours  
- laboratory: -  
- home assignment: 62 hours  
- preparation for the exam: -  
Total: 90 hours

**Year, semester:** 2nd year, 2nd semester

**Its prerequisite(s):** TFBE0107

**Further courses built on it:** -

**Topics of course**

**Literature**

*Compulsory:*

*Recommended:*
- 

**Schedule:**

1st week
Problems on refraction, diffraction and interference.

2nd week
Problems on electromagnetic radiation (spectral radiance) and the application of Wien’s and Stefan-Boltzmann’s laws.
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>3rd week</td>
<td>Application of Planck’s law.</td>
</tr>
<tr>
<td>4th week</td>
<td>Problems of photo effect and Compton’s scattering.</td>
</tr>
<tr>
<td>5th week</td>
<td>Problems of photo effect and Compton’s scattering.</td>
</tr>
<tr>
<td>6th week</td>
<td>Problems of photo effect and Compton’s scattering.</td>
</tr>
<tr>
<td>7th week</td>
<td>Calculation of the differential cross section.</td>
</tr>
<tr>
<td>8th week</td>
<td>Application of the Rydberg-Balmer formula.</td>
</tr>
<tr>
<td>9th week</td>
<td>Solution of the Landau-Lifshitz-Gilbert equation for static applied magnetic field. Application of the Zeeman’s splitting formula.</td>
</tr>
<tr>
<td>10th week</td>
<td>Problems of characteristic X-ray radiation and the application of Moseley’s law. Understanding of inverse population and negative temperature.</td>
</tr>
<tr>
<td>11th week</td>
<td>Problems related to the periodic table of elements.</td>
</tr>
<tr>
<td>12th week</td>
<td>Simple quantum mechanical problems.</td>
</tr>
<tr>
<td>13th week</td>
<td>Problems related to the spin.</td>
</tr>
<tr>
<td>14th week</td>
<td>Test.</td>
</tr>
</tbody>
</table>

**Requirements:**

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

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

- **an offered grade:**

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

**Lecturer:** Dr. István Nándori, associate professor, PhD
<table>
<thead>
<tr>
<th>Title of course: Nuclear physics</th>
<th>ECTS Credit points: 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code: TTFBE0112</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 2 hours/week</td>
</tr>
<tr>
<td>- practice: 1 hours/week</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation: signature + exam</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 28 hours</td>
</tr>
<tr>
<td>- practice: 14 hours</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
<tr>
<td>- home assignment: 38 hours</td>
</tr>
<tr>
<td>- preparation for the exam: 40 hours</td>
</tr>
<tr>
<td>Total: 120 hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year, semester: 3rd year, 1st semester</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Its prerequisite(s): TTFBE0107</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Further courses built on it: TTFBL0117,</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Topics of course</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Literature</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Schedule:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st week Discovery of radioactivity. The characteristics of alpha decay, the Geiger-Nuttal rule, the fine structure of the spectrum. Interpretation with the tunnel effect.</td>
</tr>
</tbody>
</table>

| 2nd week The concept of parity, parity violation, the universal weak interaction. |
3rd week Electromagnetic transitions of the nucleus. Transitional probabilities, isomeric states, internal conversion, Mössbauer effect.

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

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

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

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

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

9th week Termonuclear reactions, fusion devices.

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

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

12th week Nuclear models: shell model.

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

14th week Summary, discussion.

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

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

- for a grade
  The course ends in an examination.

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

Lecturer: Dr. Krasznahorkay Attila, scientific advisor
**Title of course:** Atom and nuclear physics laboratory work 1  
**Code:** TTFBL0117-EN  
**ECTS Credit points:** 2

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: 2 hours/week</td>
</tr>
</tbody>
</table>

**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**

**Literature**

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

**Schedule:**

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

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

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

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

5th week
Evaluation of the experimental results and fabrication of the report.

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

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

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

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

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

11th week
Evaluation of the experimental results and fabrication of the report.

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

13th week
Optional consultations.

14th week
Catch up laboratory work

**Requirements:**

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

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

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

    - the average grade of the four designing tasks
The grade for the tasks is given according to the following table:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

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

Dr. Balázs Ujvári, assistant professor, PhD.
<table>
<thead>
<tr>
<th>Title of course:</th>
<th>Quantum mechanics</th>
<th>ECTS Credit points:</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code:</td>
<td>TTFBE0110</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**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**

**Literature**

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

*Recommended:*
-

**Schedule:**

1st week
Experiments that lead to quantum mechanics, the Stern-Gerlach experiment.

2nd week
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction of the quantum mechanical state, ket space, bar space, operators. Base kets and matrix representation.</td>
</tr>
<tr>
<td>2</td>
<td>The physical quantities as operators. Measurement, observables, and uncertainty relations.</td>
</tr>
<tr>
<td>3</td>
<td>Operators with continuous spectra, position, translation, momentum. Wave function.</td>
</tr>
<tr>
<td>4</td>
<td>Introduction of the time evolution, Schrödinger equation, stationary states.</td>
</tr>
<tr>
<td>6</td>
<td>The harmonic oscillator, and its time evolution.</td>
</tr>
<tr>
<td>7</td>
<td>Wave mechanics, continuity equation. Infinitesimal and finite rotations in quantum mechanics.</td>
</tr>
<tr>
<td>8</td>
<td>Rotation in spin 1/2 systems. Euler rotation. Density operator, ensemble averages, pure and mixed ensembles, time evolution of ensembles.</td>
</tr>
<tr>
<td>9</td>
<td>Angular momentum operator, eigenvalues, eigenvectors.</td>
</tr>
<tr>
<td>10</td>
<td>Orbital angular momentum, spherical harmonics.</td>
</tr>
<tr>
<td>11</td>
<td>The hydrogen atom.</td>
</tr>
<tr>
<td>12</td>
<td>Entangled states, EPR paradox, Bell’s inequality.</td>
</tr>
</tbody>
</table>

**Requirements:**
- for a grade

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

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

**Lecturer:** Dr. Sándor Nagy, associate professor, PhD
<table>
<thead>
<tr>
<th>Title of course: Quantum mechanics, class work</th>
<th>ECTS Credit points: 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code: TTFBG0104</td>
<td></td>
</tr>
</tbody>
</table>

**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:** 3\(^{rd}\) year, 1\(^{st}\) semester

**Its prerequisite(s):** TTFBE0110

**Further courses built on it:** -

**Topics of course**

**Literature**

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

**Recommended:**
-

**Schedule:**

1\(^{st}\) week
Properties of the Hilbert space.

2\(^{nd}\) week
The ket and the bra space, representation of operators, operators acting on states.

3\(^{rd}\) week
Observables, operators, uncertainty principle.

4th week
Properties of operators of continuous spectra, examples, position, momentum.

5th week
Solution of the Schrödinger equation for free particles and for simple potential forms.

6th week
Usage of the Heisenberg equation of motion for free particles and for position dependent potentials.

7th week
Problems related to the harmonic oscillator, eigenvalues, eigenvectors, selection rules.

8th week
In class test.

9th week
Solving problems in connection with rotations. Examples for pure and mixed states.

10th week
Properties of the angular momentum operator.

11th week
Problems related to the orbital angular momentum and the spherical harmonics.

12th week
Problems related to the hydrogen atom, selection rules.

13th week
Operators acting on entangled states. Calculation of expectation values for the Bell inequality.

14th week
In class test.

**Requirements:**

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

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

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

**Lecturer:** Dr. Sándor Nagy, associate professor, PhD
Title of course: Fundamental interactions
Code: TTFBE0121

ECTS Credit points: 5

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

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: 14 hours
- laboratory: -
- home assignment: 54 hours
- preparation for the exam: 54 hours
Total: 150 hours

Year, semester: 3rd year, 2nd semester

Its prerequisite(s): TTFBE0110

Further courses built on it: -

Topics of course

Literature
Compulsory:
- István Nándori, Zoltán Trócsányi: Fundamental Interactions, lecture note in electronic format

Recommended:

Schedule:
<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Four fundamental interactions and their force carriers. Classifications of elementary and compound particles, and their properties (lifetime, mass, charge, spin, parity).</td>
</tr>
<tr>
<td>2nd</td>
<td>Conservation laws: electric charge, lepton and barion numbers, angular momentum, conservation of energy and momenta in four-vector formalism and its use in particle scattering processes.</td>
</tr>
<tr>
<td>3rd</td>
<td>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.</td>
</tr>
<tr>
<td>4th</td>
<td>Symmetries in Classical Field Theory, the Noether-theorem.</td>
</tr>
<tr>
<td>5th</td>
<td>Internal symmetries and their relation to fundamental interactions.</td>
</tr>
<tr>
<td>7th</td>
<td>Measurement of luminosity, distance and velocity of celestial bodies of the Universe.</td>
</tr>
<tr>
<td>8th</td>
<td>The cosmologic principle, the Hubble-expansion and the critical Universe.</td>
</tr>
<tr>
<td>9th</td>
<td>Friedmann-equations and their solutions.</td>
</tr>
<tr>
<td>10th</td>
<td>Discovery of cosmic microwave background radiation, the interpretation of its origin and its properties.</td>
</tr>
<tr>
<td>11th</td>
<td>Barionic acoustic oscillations and the distances of SN1 supernovae.</td>
</tr>
<tr>
<td>12th</td>
<td>Nucleo-synthesis of light elements, cosmological standard model.</td>
</tr>
<tr>
<td>13th</td>
<td>Inflationary cosmology.</td>
</tr>
<tr>
<td>14th</td>
<td>Summary, discussion of questions emerging during the semester.</td>
</tr>
</tbody>
</table>

**Requirements:**
- *for a signature*
  - Signature requires the correct solution of at least 50% of homework assignments.
- *for a grade*
  - Knowledge of definitions, laws and theorems: grade 2;
  - In addition, knowledge of particle properties experimental methods and results: grade 3;
In addition, knowledge of the proofs of theorems: grade 4;
In addition, knowledge of applications: grade 5.

-an offered grade:

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

Lecturer: Dr. István Nándori, associate professor, PhD
Title of course: Statistical Physics

Code: TTFBE0216

ECTS Credit points: 5

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

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 42 hours
- practice: -
- laboratory: -
- home assignment: 60 hours
- preparation for the exam: 48 hours
Total: 150 hours

Year, semester: 3rd year, 2nd semester

Its prerequisite(s): -

Further courses built on it:-

Topics of course

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


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.


**Literature**

**Compulsory:**
- R. Kubo, Statistical mechanics with examples (The University of Tokyo, 1982).

**Recommended:**

**Schedule:**

1\(^{st}\) week


2\(^{nd}\) week


3\(^{rd}\) week

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

4\(^{th}\) week


5\(^{th}\) week

6th week
Micro-canonical ensemble, phase space density, partition function and entropy. Extensive and intensive quantities, thermodynamic relations

7th week
Mid-term test. Canonical ensemble. Canonical phase space density, internal energy and entropy. Canonical temperature. Relation of free energy and internal energy

8th week
Probability density of the energy of systems in thermal equilibrium, energy fluctuations and their dependence on the system size. Thermal equilibrium. Equivalence of micro-canonical and canonical ensembles. Derivation of thermodynamic relations in the canonical ensemble.

9th week
Macro-canonical ensemble. Phase density and partition function of macro-canonical ensemble. Probability distribution of the particle number, particle number fluctuations and their dependence on the system size. Chemical potential.

10th week
T-p ensembles. Equivalence of statistical ensembles in the thermodynamic limit.
Thermodynamic potentials from the energy and from the entropy.

11th week
Quasi-static processes, pressure, work, heat, first law of thermodynamics. Second and third laws of thermodynamics.

12th week
Canonical ensemble of the classical ideal gas, partition function, equation of state. Probability distribution of the velocity and energy of particles, the Maxwell-Boltzmann distribution. Quantum ideal gases, relation of classical and quantum mechanical descriptions.

13th week

14th week

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

During the semester two tests are written: the mid-term test in the 7th week and the end-term test in the 14th week. Students’ participation at the tests is mandatory.
The minimum requirement for the mid-term and end-term tests is 60%. Based on the total score of the two tests, the grade is determined according to the following scheme:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

- **for a grade**

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

- **an offered grade:**

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

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

**Lecturer:** Prof. Dr. Kun Ferenc, university professor, DSc
<table>
<thead>
<tr>
<th><strong>Title of course</strong>: Statistical Physics</th>
<th><strong>ECTS Credit points</strong>: 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code</strong>: TTFBG0216</td>
<td></td>
</tr>
</tbody>
</table>

**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**: 3\textsuperscript{rd} year, 2\textsuperscript{nd} 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.


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


**Literature**

**Compulsory:**
- R. Kubo, Statistical mechanics with examples (The University of Tokyo, 1982).

**Recommended:**

**Schedule:**

1st week

2nd week

3rd week
The measure and properties of information, the missing information, unbiased estimates. Shannon’s information entropy, the maximum entropy principle. Entropy of many particle systems of classical mechanics. Calculation of entropy of simple systems.

4th week

5th week

6th week
Micro-canonical ensemble, phase space density, partition function and entropy. Extensive and intensive quantities, determination of thermodynamic relations. Derivation of the thermodynamic relations of fundamental model systems of statistical physics, two-state system, harmonic oscillators.
**7th week**

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

**8th week**

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

**9th week**

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

**10th week**


**11th week**

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

Thermodynamic potentials from the energy and from the entropy.

**12th week**


**13th week**


**14th week**


**Requirements:**

*For a term grade*

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

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
</table>

125
<table>
<thead>
<tr>
<th>Score Range</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

**Lecturer:** Prof. Dr. Kun Ferenc, university professor, DSc
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Introduction to the theory of ordinary differential equations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TTMBE0817</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>3</td>
</tr>
</tbody>
</table>

**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):** TTMBE0814

**Further courses built on it:**

<table>
<thead>
<tr>
<th><strong>Topics of course</strong></th>
</tr>
</thead>
</table>

**Literature**

*Compulsory/Recommended:*

**Schedule:**

1st week
Ordinary explicit differential equations of first order solvable in an elementary way. Separable, linear and exact equations. The Euler multiplicator.

2nd week
The notion of the Cauchy problem with respect to ordinary explicit differential equation systems of first order. Solution, complete solution, unique solution. Sufficient condition for the existence of the complete solution, global and local solvability.

3rd week
Complete metric spaces. The parametric version of the Banach fixed-point theorem. Weighted function spaces; The Cauchy problem and its equivalent integral equation.

4th week
Lipschitz properties. Global existence and uniqueness theorem. Continuous dependence on initial value; local existence and uniqueness theorem.

5th week
Compact operators; Schauder's fixed point theorems. Compact subsets of the space of continuous functions on intervals. Equicontinuity and uniform boundedness. Arzelà–Ascoli theorem.

6th week
Peano's existence theorem.

7th week
Linear differential equation systems of first order and their existence and uniqueness. Fundamental system and fundamental matrix; Liouville's formula. The method of constant variation.

8th week
The general theory of linear differential equation systems with constant coefficients: spectral radius, expression of analytic functions of matrices, the fundamental system of linear differential equation systems of first order with constant coefficient.

9th week
The general theory of explicit differential equations of higher order: transmission principle, Global existence and uniqueness theorem. Cauchy problem for higher order linear differential equations. The concept and the existence of the fundamental system; Wronski-determinant and Liouville formula.

10th week
Equivalent characterization of the fundamental system of a higher order linear linear differential equation. The constant variation method. The fundamental system of higher order homogeneous linear differential equations with constant coefficients.

11th week

12th week

13th week

14th week
The Euler-Lagrange differential equations. Applications: the problem of minimal surface solid of revolution, the Poincaré half-circle model of Bolyai–Lobachevsky's geometry. The Lagrange discussion of classical mechanics.

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

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-49</td>
<td>fail (1)</td>
</tr>
<tr>
<td>50-61</td>
<td>pass (2)</td>
</tr>
<tr>
<td>62-74</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>75-87</td>
<td>good (4)</td>
</tr>
<tr>
<td>88-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

Lecturer: Prof. Dr. Zsolt Páles, university professor, DSc
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Introduction to the theory of ordinary differential equations class work</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TTMBG0817</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>2</td>
</tr>
</tbody>
</table>

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

**Evaluation:** mid-semester grade

**Workload (estimated), divided into contact hours:**
- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 14 hours
- preparation for the tests: 18 hours
Total: 60 hours

**Year, semester:** 2nd year, 1st semester

**Its prerequisite(s):** TTMBG0814

**Further courses built on it:**

**Topics of course**

**Literature**
*Compulsory/Recommended:*

**Schedule:**
1st week
Differential equations solvable in an elementary way. Separable equations.

2nd week
Differential equations of type that can be traced back into a separable equation (linear substitution, homogeneous equations).

3rd week
Types that can be traced back into a separable equation (linear fractional substitution).

4th week
Differential equations that can be solved in an elementary way: first order linear equations. Bernoulli and Riccati equations.

5th week
Differential equations that can be solved in an elementary way: exact equations, Euler's multipliers.

6th week
Summarize, practice and deepen the foregoing.

7th week
Test

8th week
First order homogeneous linear differential equation systems with constant coefficients. Construction of the fundamental system. Expression of analytic functions of matrices.

9th week
First order inhomogeneous linear differential equation systems with constant coefficient. The constant variation method

10th week
Higher order linear equations with constant coefficients. Transmission principle, Characteristic polynomial, reduced constant variation, test function.

11th week
Higher linear linear equations with variable coefficients. Wronski determinant, Liouville formula and D'Alembert reduction.

12th week
Elements of calculus of variation. The Euler-Lagrange differential equations.

13th week
Summarize, practice and deepen the foregoing.

14th week
Test

**Requirements:**
- for a signature

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

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-49</td>
<td>fail (1)</td>
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<tr>
<td>50-61</td>
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<tr>
<td>75-87</td>
<td>good (4)</td>
</tr>
<tr>
<td>88-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

**Lecturer:** Prof. Dr. Zsolt Páles, university professor, DSc
Title of course: Probability and statistics
Code: TTMBE0818

ECTS Credit points: 3

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

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 28
- preparation for the exam: 34 hours
Total: 90 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0813

Further courses built on it:

Topics of course

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

Schedule:
1st week
The σ-algebra of events. The mathematical concept of probability. Classical probability spaces.
2nd week
Geometric probability. Basic properties of probability.
3rd week
Conditional probability. Chain rule and Bayes’ theorem. Independence of events.
4th week
Random variables, cumulative distribution function. Discrete and continuous random variables.
5th week
Random vector variables. Independence of random variables. Sum of independent random variables and convolution.
6th week
Expected value of random variables and of functions of random variables.
7th week
Variance of random variables. Schwarz inequality. Covariance and correlation coefficient.

8th week
Notable discrete distributions: binomial distribution, hypergeometric distribution, Poisson distribution and geometric distribution.

9th week
Notable continuous distributions: uniform distribution, exponential distribution and normal distribution. Notable distributions derived from normal distribution: $\chi^2$ and Student distribution.

10th week
Markov’s and Chebyshev’s inequality, the weak law of large numbers and Borel’s strong law of large numbers. The general central limit theorem and the Moivre—Laplace theorem as a special case.

11th week
Statistical field, often used statistics. Statistical estimators: unbiasedness, efficiency, consistency.

12th week
The empirical distribution function and the fundamental theorem of mathematical statistics. Estimators for the probability density function, expected value and variance. Maximum likelihood estimation.

13th week
Statistical tests: u-test, t-test, $\chi^2$-tests.

14th week
Construction of confidence intervals for the expected value and the variance of a normal distribution.

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-49</td>
<td>fail (1)</td>
</tr>
<tr>
<td>50-62</td>
<td>pass (2)</td>
</tr>
<tr>
<td>63-74</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>75-86</td>
<td>good (4)</td>
</tr>
<tr>
<td>87-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

Person responsible for course: Dr. Zoltán Muzsnay, associate professor, PhD

Lecturer: Dr. Zoltán Muzsnay, associate professor, PhD
Title of course: Probability and statistics
Code: TTMBG0818

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: -
- homework: 32
- preparation for the exam: -
Total: 60 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0813

Further courses built on it:

Topics of course

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

Schedule:
1st week
The σ-algebra of events. The mathematical concept of probability. Classical probability spaces.
2nd week
Geometric probability. Basic properties of probability.
3rd week
Conditional probability. Chain rule and Bayes’ theorem. Independence of events.
4th week
Random variables, cumulative distribution function. Discrete and continuous random variables.
5th week
Random vector variables. Independence of random variables. Sum of independent random variables and convolution.
6th week
Expected value of random variables and of functions of random variables.
7\textsuperscript{th} week
Variance of random variables. Schwarz inequality. Covariance and correlation coefficient.

8\textsuperscript{th} week
In class test. Notable discrete distributions: binomial distribution, hypergeometric distribution, Poisson distribution and geometric distribution.

9\textsuperscript{th} week
Notable continuous distributions: uniform distribution, exponential distribution and normal distribution. Notable distributions derived from normal distribution: $\chi^2$ and Student distribution.

10\textsuperscript{th} week
Markov’s and Chebyshev’s inequality, the weak law of large numbers and Borel’s strong law of large numbers. The general central limit theorem and the Moivre—Laplace theorem as a special case.

11\textsuperscript{th} week
Statistical field, often used statistics. Statistical estimators: unbiasedness, efficiency, consistency.

12\textsuperscript{th} week
The empirical distribution function and the fundamental theorem of mathematical statistics. Estimators for the probability density function, expected value and variance. Maximum likelihood estimation.

13\textsuperscript{th} week
Statistical tests: u-test, t-test, $\chi^2$-tests.

14\textsuperscript{th} week
Construction of confidence intervals for the expected value and the variance of a normal distribution. In class test.

\textbf{Requirements:}
\begin{itemize}
  \item \textit{for a signature}
  Participation at practice classes is compulsory. A student must attend the practice classes and may not miss more than three times during the semester. In case a student does so, the subject will not be signed and the student must repeat the course.
  \item \textit{for a grade}
  During the semester one test is written. The grade is given according to the following table:
  \begin{center}
  \begin{tabular}{|c|c|}
    \hline
    Score & Grade \\
    \hline
    0-49 & fail (1) \\
    50-59 & pass (2) \\
    60-74 & satisfactory (3) \\
    75-84 & good (4) \\
    85-100 & excellent (5) \\
    \hline
  \end{tabular}
  \end{center}
\end{itemize}

\textbf{Person responsible for course:} Dr. Zoltán Muzsnay, associate professor, PhD

\textbf{Lecturer:} Dr. Zoltán Muzsnay, associate professor, PhD
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Materials and technology for microelectronics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TTFBE0201-EN</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>3</td>
</tr>
</tbody>
</table>

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

**Evaluation:** exam

**Workload (estimated), divided into contact hours:**
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: 22 hours
- preparation for the exam: 40 hours
Total: 90 hours

**Year, semester:** 3rd year, 1st semester

**Its prerequisite(s):** TTFBE0106-EN

**Further courses built on it:** -

**Topics of course**
The main materials for electronics, their classification, and properties. Metals, semiconductors and dielectric material. Crystalline and amorphous materials. Band structures, optical and electrical conductivity. P-n junction. Main types of semiconductors and their technology. Si and Ge, organic semiconductors, their main properties, and parameters. Vacuum technology and basic elements. Thin layer technology, main deposition techniques: evaporation, deposition. Investigation of thin layers. The technology of single crystals, amorphous materials. The technology of Si and GaAs from bottom to the top. Diffusion, implantation and another lithography. The technology of active and passive elements, diodes, transistors, circuits. The technology of optoelectronic elements and devices: light sources and solar cells. SMT and THM technology of PCB. Quality, reliability. Some peculiar applications: sensors, memory elements, functional electronics, mechatronics. Trends in the development of micro- and nanotechnology. At the laboratory, students deal with thin film technology, thin film measurements, lithography, design, and fabrication of PCBs.

**Literature**
*Compulsory:*

**Schedule:**
1st week
The main materials for electronics, their classification, and properties.
<table>
<thead>
<tr>
<th>Week</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd week</td>
<td>Metals, semiconductors and dielectric material. Crystalline and amorphous materials.</td>
</tr>
<tr>
<td>3rd week</td>
<td>Band structures, optical and electrical conductivity</td>
</tr>
<tr>
<td>4th week</td>
<td>P-n junction. Main types of semiconductors and their technology. Si and Ge, organic semiconductors, their main properties, and parameters.</td>
</tr>
<tr>
<td>5th week</td>
<td>The technology of single crystals, amorphous materials. The technology of Si and GaAs from bottom to the top.</td>
</tr>
<tr>
<td>6th week</td>
<td>Vacuum technology and basic elements.</td>
</tr>
<tr>
<td>7th week</td>
<td>Thin layer technology, main deposition techniques: evaporation, deposition.</td>
</tr>
<tr>
<td>8th week</td>
<td>Investigation of thin layers.</td>
</tr>
<tr>
<td>9th week</td>
<td>Diffusion, implantation and another lithography</td>
</tr>
<tr>
<td>10th week</td>
<td>Dielectric layers. The technology of SiO2 and SiN technológiaja. Integrated circuits.</td>
</tr>
<tr>
<td>11th week</td>
<td>SMT and THM technology of PCB. Quality, reliability.</td>
</tr>
<tr>
<td>12th week</td>
<td>The technology of optoelectronic elements and devices: light sources and solar cells.</td>
</tr>
<tr>
<td>13th week</td>
<td>Some peculiar applications: sensors, memory elements, functional electronics, mechatronics.</td>
</tr>
<tr>
<td>14th week</td>
<td>Trends in the development of micro- and nanotechnology.</td>
</tr>
</tbody>
</table>

**Requirements:**

*for a signature*

Attendance at lectures is recommended, but not compulsory.

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

*for a grade*

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

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Score Range</td>
<td>Grade</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

-an offered grade:

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

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

**Lecturer:** Dr. István Csarnovics, assistant professor, PhD
### Title of course: Materials and technology for microelectronics laboratory work

| Code: TTFBL0201-EN | ECTS Credit points: 2 |

### Type of teaching, contact hours

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

### Evaluation: mid-semester grade

### Workload (estimated), divided into contact hours:

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

Total: 60 hours

### Year, semester: 3rd year, 1st semester

### Its prerequisite(s): TTFBE0106-EN

### Further courses built on it: -

### Topics of course

The main materials for electronics, their classification, and properties. Metals, semiconductors and dielectric material. Crystalline and amorphous materials. Band structures, optical and electrical conductivity. P-n junction. Main types of semiconductors and their technology. Si and Ge, organic semiconductors, their main properties, and parameters. Vacuum technology and basic elements. Thin layer technology, main deposition techniques: evaporation, deposition. Investigation of thin layers. The technology of single crystals, amorphous materials. The technology of Si and GaAs from bottom to the top. Diffusion, implantation and another lithography. The technology of active and passive elements, diodes, transistors, circuits. The technology of optoelectronic elements and devices: light sources and solar cells. SMT and THM technology of PCB. Quality, reliability. Some peculiar applications: sensors, memory elements, functional electronics, mechatronics. Trends in the development of micro- and nanotechnology. At the laboratory, students deal with thin film technology, thin film measurements, lithography, design, and fabrication of PCBs.

### Literature

**Compulsory:**


### Schedule:

*1st week*
Information about laboratory work, accident prevention.

2nd week
Design and construction of printed circuit board.

3rd week
Design and construction of printed circuit board.

4th week
Thick layer technology. Creation of thick layers.

5th week
Thick layer technology. Creation of thick layers.

6th week
Vacuum technology. Thin layer technology: vacuum evaporation.

7th week
Vacuum technology. Thin layer technology: vacuum evaporation.

8th week
Investigation of the created thin layers.

9th week
Investigation of the created thin layers.

10th week
Soldering of the elements into the created printed circuit board.

11th week
Soldering of the elements into the created printed circuit board.

12th week
Visiting the National Instruments factory.

13th week
Evaluation of the experimental results and fabrication of the report.

14th week
The presentation of the report of the experimental results.

Requirements:
- for a signature

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

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

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

- the average grade of the five designing tasks

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

**Lecturer:** Dr. István Csarnovics, assistant professor, PhD
Title of course: Digital Electronics  
Code: TTFBE0202  
ECTS Credit points: 3

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

Evaluation: exam

Workload (estimated), divided into contact hours:  
- lecture: 28 hours  
- practice: -  
- laboratory: -  
- home assignment: 28 hours  
- preparation for the exam: 34 hours  
Total: 90 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): Introduction to Electronics TTFBE0120

Further courses built on it: -

Topics of course  

Literature  

Schedule:  
1st week  
Refreshing and enhancing previous knowledge of Boolean algebra and logic functions.  
2nd week  
Representing logic states with voltage levels. Internal structure and characteristics of TTL integrated circuits. Open collector and Tri-State outputs.  
3rd week  
Internal structure and characteristics of CMOS integrated circuits. Interconnections between different logic families.
Driving external loads from logic circuits (lamps, LEDs, relays, motors, power elements).

Refreshing and enhancing existing knowledge of combination networks.

Data selectors, encoder and decoder circuits, multiplexers and demultiplexers, adders.

Test 1.


Sequential networks: master-slave flip-flops, frequency dividers, counters, registers.

Digital-to-Analog and Analog-to-Digital converters

Programmable logic devices: PAL, PLA, FPGA.

Application examples of digital electronics circuits in computers. Buses in computers.

Basic structure of microprocessors. Consultation.

Test 2.

Requirements:
- for a signature: Attendance at lectures is recommended, but not compulsory.
- for a grade: Written or oral exam. The grades are given according to the following table:
  - 0-50 % failed (1)
  - 51-60 % pass (2)
  - 61-70 % satisfactory (3)
  - 71-80 % good (4)
  - 81-100% excellent (5)
- an offered grade: There will be two written tests during the semester. If both tests are successful, the student may get an offered mark based on the average of the two grades.

Person responsible for course: Dr. Gyula Zilizi, associate professor, PhD

Lecturer: Dr. Gyula Zilizi, associate professor, PhD
<table>
<thead>
<tr>
<th><strong>Title of course:</strong> Atom and nuclear physics laboratory work 2</th>
<th><strong>ECTS Credit points:</strong> 2</th>
</tr>
</thead>
</table>

**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

<table>
<thead>
<tr>
<th><strong>Year, semester:</strong> 3&lt;sup&gt;rd&lt;/sup&gt; year, 1&lt;sup&gt;st&lt;/sup&gt; semester</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th><strong>Its prerequisite(s):</strong> TTFBE0106-EN, TTFBE0107-EN</th>
</tr>
</thead>
</table>

**Further courses built on it:** -

**Topics of course**
The determination of Boltzmann constant. The conductivity of metals and semiconductors. The temperature dependence of conductivity. The elements of the interferometers and their possible applications.
Study of the cosmic ray and gamma-gamma correlation

**Literature**

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

<table>
<thead>
<tr>
<th><strong>Schedule:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1&lt;sup&gt;st&lt;/sup&gt; week</strong></td>
</tr>
</tbody>
</table>
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.
Study of the cosmic ray and gamma-gamma correlation

| **2<sup>nd</sup> week** |
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.
Study of the cosmic ray and gamma-gamma correlation

| **3<sup>rd</sup> week** |
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup. |
Kozmikus sugárzás mérése, gamma-gamma korrelációs mérések

4th week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.
Study of the cosmic ray and gamma-gamma correlation

5th week
Evaluation of the experimental results and fabrication of the report.

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

7th week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.
Study of the cosmic ray and gamma-gamma correlation

8th week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.

9th week
Kozmikus sugárzás mérése, gamma-gamma korrelációs mérések

10th week
Experimental determination of Boltzmann constant. Experimental measurement of refractive index and concentration of different liquids by Rayleigh interferometer setup.
Study of the cosmic ray and gamma-gamma correlation

11th week
Evaluation of the experimental results and fabrication of the report.

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

13th week
Optional consultations.

14th week
Catch up laboratory work

Requirements:
- for a signature

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

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

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

- the average grade of the four designing tasks

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

Lecturer: Dr. István Csarnovics, assistant professor, PhD,
          Dr. Balázs Ujvári, assistant professor, PhD.
Title of course: Condensed Matter Lab. Practice II.
Code: TTFBL0219

ECTS Credit points: 2

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

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 16 hours
- laboratory: 16 hours
- home assignment: 28 hours
- preparation for the exam: -
Total: 60 hours

Year, semester: 3rd 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:

Literature

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

Schedule:
1st week
Information, introduction, accident, work safety education, discussion of lab-schedule
2nd week
- Temperature dependence of magnetic properties of ferromagnetic materials
3rd week
Metallography (sample preparation and investigations with light microscope).
4th week
**Measurements with scanning electron microscope (SEM) (sample preparation, image formation and composition measurements).**

*5th week*

Measurements with transmission electron microscope (TEM) (sample preparation, dark-field, bright filed imaging and electron diffraction)

*6th week*

Preparing different alloys using arc-melting technique

<table>
<thead>
<tr>
<th>Requirements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• the basic knowledge of the laboratory practice theory, the measurement, the preparation of a measurement report in electronic form: sufficient;</td>
</tr>
<tr>
<td>• accurate knowledge of the theory of exercises, carrying out the measurement, making a measurement report in electronic form: medium;</td>
</tr>
<tr>
<td>• Basic knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: good;</td>
</tr>
<tr>
<td>• accurate knowledge of laboratory practice theory, accurate measurement and evaluation of measurements, preparation of measurement report in electronic form: excellent.</td>
</tr>
</tbody>
</table>

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

**Lecturer:** Dr. Bence Parditka,  
Dr. László Tóth
<table>
<thead>
<tr>
<th><strong>Title of course:</strong></th>
<th>Statistical Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong></td>
<td>TFBE0603</td>
</tr>
<tr>
<td><strong>ECTS Credit points:</strong></td>
<td>4</td>
</tr>
</tbody>
</table>

**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**


**Literature**


**Schedule:**

1st week Elements of probability theory: the concept of probability, random variables, probability density functions. Distributions: binomial and multinomial, Poisson, uniform, exponential, Gaussian, lognormal, chi-square distributions.

2nd week Error propagation. General concepts of parameter estimation: sample, statistics, estimator, consistency, parameter fitting, sampling distribution, bias, mean squared error, sample mean, weak law of large numbers, sample variance.

3rd week The Monte Carlo method and its applications: generation of a sequence of uniformly distributed random numbers, the multiplicative linear congruential algorithm, the transformation method, the acceptance-rejection method, Monte Carlo integration, applications.


5th week The method of maximum likelihood: the likelihood function, estimating the values of the parameters of a density function with the method of maximum likelihood. Examples: exponential and Gaussian distributions.

6th week Variance of ML estimators: analytic method, Monte Carlo method, the Rao-Cramer-Frechet (RCF) or information inequality, efficient estimator, graphical method. Example of the method of maximum likelihood with two parameters.

7th week The method of least squares: connection with maximum likelihood. Linear least-squares fit. The variance of the estimated parameters.

8th week The method of moments. Characteristic functions and their applications.

<table>
<thead>
<tr>
<th>Week</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>10th</td>
<td>Two-equation systems: fixed-point iteration, Newton-Raphson method, gradient method.</td>
</tr>
<tr>
<td>13th</td>
<td>Numerical integration: general formula, trapezoid formula, Simpson-formula.</td>
</tr>
</tbody>
</table>

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

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

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

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

**Lecturer:** Dr. Darai Judit, associate professor, PhD
Title of course: Electron and atomic microscopy  
Code: TTFBE0207  
ECTS Credit points: 3

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 2 hours/week</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

| Evaluation: exam |

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 28 hours</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
<tr>
<td>- home assignment: 34</td>
</tr>
<tr>
<td>- preparation for the exam: 28 hours</td>
</tr>
<tr>
<td>Total: 90 hours</td>
</tr>
</tbody>
</table>

| Year, semester: | 1st year, 1st semester |

| Its prerequisite(s): |

| Further courses built on it: |

| Topics of course |

During the semester, students will learn about the theoretical and practical basics of scanning electron microscopy (SEM) and electron beam (EPMA) microanalysis, as well as transmission electron microscopy (TEM) and electron diffraction (ED). Discuss the operation of the equipment, the interaction of the electron beam and the sample material, the ways of detecting the resulting signals, the electron diffraction phenomena, and the basics of imaging. We present the principles of qualitative and quantitative x-ray analysis and the preparation of microscopic samples. The basics of image processing and image analysis essential to the interpretation of microscopic images are also part of the course. In addition, other equipments such as SPM and AFM will be discussed. The students are going to use of the equipment during the course.

| Literature |

| Compulsory: |

| Recommended: |


| Schedule: |

| 1st week |

Introduction.
The history and place of electron microscopy in modern science

| 2nd week |


### Requirements:
- for a grade
  - Knowledge of the operating principle of the described equipment: sufficient;
  - In addition, the applications of the equipment: medium;
  - In addition, knowledge of the main steps of the main theories and laws, the understanding of the relationships, the knowledge of the modes of the equipment: good;
  - In addition, the derivation of the presented expressions and the ability to apply them are excellent.

- an offered grade is not possible.

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

**Lecturer:** Dr. Csaba Cserháti associate professor, PhD
Title of course: Environmental Physics 1
Code: TTFBE0206

ECTS Credit points: 3

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

Evaluation: exam

Workload (estimated), divided into contact hours:
- lecture: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 62 hours
Total: 90 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTFBE0102

Further courses built on it: -

Topics of course
The meaning of environmental physics, the place and role of environmental physics among the sciences. The environment as part of the universe in space and time. Physical impacts of extraterrestrial origin in the environment (effects of extragalactic and galactic origin, effects of the Sun, Moon and other objects of the Solar System). Physical impacts of earthly origin in the environment (Earth's origin and evolution, effects deriving from the Earth’s planetary nature, Earth's internal structure, its thermal energy, gravity and magnetic field). The basics and environmental consequences of the earth's crust physics (plate tectonics, mountain formation, volcanism, earthquakes, erosion, rock and soil physics). The basics and environmental consequences of natural water physics (physical properties of water, energy and material transport of environmental waters, the physics of oceans, seas, rivers, lakes, groundwater and ice). The basics and environmental consequences of atmospheric physics (vertical and horizontal structure of atmosphere, energy balance of the Earth-atmosphere system and the atmosphere, greenhouse effect, ozone shielding, weather phenomena, atmospheric electrification and light phenomena, atmospheric material transport and aerosols, spatial distribution of climates, global climatic system, time changes of climate).

Literature

Compulsory:
- Z. Papp (2018): pdf copies of the PowerPoint presentations with the filenames EnvPhys-1-1 to EnvPhys-1-14

Recommended:
Schedule:
1st week
The place and role of physics in environmental research. The place of physics in the system of natural sciences. What features and properties of the material world do physics deal with? What is the difference between physics and other natural sciences as regards their scope of competence and the scope of their laws? Which parts of the material world are involved in chemistry, biology, earth sciences, ecology? Building on one another among the natural sciences, the basic role of physics. The meaning of the concept of environment in sciences. The meaning of the concept of environmental science, the history and today's significance of environmental science. The meaning of the concept of environmental physics. The significance of environmental physics in environmental research. The meaning and significance of historical and universal approaches to the study of the environment. The short history of the Earth's origin. Theoretical modeling of the evolution of the universe: what would have been if the values of basic physical constants were slightly different? About the strong and the weak anthropic principles in the light of the idealistic and materialistic world view. The environment as part of the universe. Dimensions and masses in the universe. Physical impacts from outside the Milky Way system in the environment.

2nd week

3rd week
About the Moon's environmental effects. The basic properties of the Moon. Physical explanation and environmental consequences of the tidal effect on Earth. Description, cycles and environmental impacts on the seas. The deformation of the whole planet, the extension of the Earth's day, the Moon's departure and the decrease of the tidal effect. The environmental effects of the Moon's electromagnetic radiation. The Moon's formation. How would the environment develop without the Moon? Environmental consequences of the terrestrial impacts of small cosmic bodies. Properties of the small bodies of the Solar System. Possibility of colliding with Earth. The environmental impacts of collisions depending on the size and composition of the impacting bodies. Global environmental consequences when bodies having more than 100 m diameter are impacted. Data on the impact craters on the ground. The frequency of impact as function of the body size. The possible link
between impacts and massive extinctions, experimental evidence of a late cretaceous impact. The effect of regular impacts on earthly evolution.

The physical effects of planets on our environment. Space debris and its environmental impacts.

4th week

Physical effects deriving from the Earth’s planetary nature in the environment. The age of Earth. The Earth's formation. Earth's development over the first 1 billion years. The main physical data of Earth. The shape of the Earth and its environmental consequences. Earth's gravitational field and its environmental impacts. Earth's circulation around the Sun, environmental consequences. Rotation of Earth around its axis, alternating between day and night. The inertia forces and their effects on the rotating Earth. The tilt of the Earth’s rotational axis, alternating seasons, changing lengths of days and nights. Precession of the axis of rotation and its impact on the global climate.

5th week

The inner structure of Earth. The spread of seismic waves within the Earth. Seismic tomography. The layered structure of Earth, the extent, composition and physical properties of the layers. Earth's internal thermal energy, its origin, its outward migration. Earth's internal energy balance. Experiences on the Earth's magnetic field. The regular and irregular components of the magnetic field, the temporal change in the position of the magnetic poles. The magnetic field is the product of the "geodynamo" operating in the outer core. Slow changes in the Earth's magnetic field, polarities, paleomagnetic studies. Earth's magnetosphere. The interaction between the magnetosphere and the solar wind, the rapid changes in the magnetic field. The protective effect of the magnetosphere. The significance of the Earth's magnetic field for the wildlife.

6th week

The physics of Earth's crust and terrestrial surface. Convection flows in Earth's mantle. The plate structure of the lithosphere, the properties and the movements of the plates, the attempts to explain the plate movements. Different relative movements of the plates and their surface consequences. Migration of continents, ancient continents. The environmental consequences of continental migration.


7th week


The physics of rocks and soil. The composition and formation of rocks. Structural features of various types of rock. Some physical properties of rocks. The concept, structure and main physical properties of the soil.
8th week
The occurrence of water in the environment. The origin and history of water on Earth. The phases of water, their transitions. Composition of natural liquid waters, density according to temperature and salt content, internal friction, electrical conductivity, optical properties. Thermal properties, thermal conductivity, specific heat, freezing point. The energy balance of the surface waters, the depth distribution of the temperature. Mechanical properties. Balance in the gravitational field, hydrostatic pressure, surface energy. Convective flows induced by density differences. The properties of surface waves.
Energy and material transport of environmental waters ("water cycle"). The prominent role of the evaporation-condensation cycle in the environment's energy circulation, weather and climate.

9th week
The physics of groundwater. Their origin and types, their material and energy balance, their mechanics and temperature.
The basic physical properties of ice. The formation and distribution of ice in the environment. Landfill icecaps, glaciers, marine ice cubes, icebergs, frozen groundwater.

10th week
The origin, history and composition of the atmosphere. The most important physical properties of air. The basics of the atmosphere mechanics. Status determinants and their relationships. Balance in the Earth's gravitational field, height dependence of density and pressure. Vertical stratification of the atmosphere according to pressure, density, composition and temperature. The kinematic characteristics of the streams starting in the absence of equilibrium, the properties of the eddies, the atmospheric boundary layer.
Energy absorption and energy release of the atmosphere. The fate of short and long wave electromagnetic radiation in the atmosphere and on the ground. Non-radiation energy transmission between the Earth's surface and the atmosphere. The physical essence of the greenhouse effect. The balance of the global energy balance of the atmosphere, the estimated magnitude of the components of energy traffic. Local and temporal energy balances, such as weather and climate determinants.

11th week
Physical basics of weather phenomena. The concept and the root causes of the weather. Horizontal structure of the atmosphere, air masses and their properties, atmospheric fronts. Temporal changes of air temperature and their explanation. Temporal and spatial changes in surface air pressure and their explanation. The concept, the reason and the mechanics of wind. Effects affecting wind direction. Local motion systems in moderate climates: cyclones and anti-cyclones. The global system of air movements: General Circulation of the atmosphere. Atmospheric angular momentum transport and the global circulation cells. Atmospheric humidity, physical conditions of evaporation and precipitation. The physical foundations of the formation of clouds and rainfall. Physical basics of weather forecasting. The chaotic nature of the laws describing the physical characteristics of the air. The principle and practical limitations of weather forecasting.

12th week
Atmospheric electricity. Electrical field strength and potential in the atmosphere. Processes leading to electric charge separation. Atmospheric ionisation effects. Atmospheric transport of ions in storm-free areas and in the thunderstorms. The electrical conditions of the environment of the thunderstorms, the physical explanation of the reversed current. The origin, physical properties and explanation of lightning.

Atmospheric optics. The scattering of light on molecules and aerosol particles. Consequences: the colours of the sky, the sun and the objects, the visibility of objects in the shadows, eyeshot, polarization of light. Refraction of light between superimposed air layers, at the border of air and water droplets, and at the border of air and ice crystals. Consequences: bending light, scintillation, rainbow, halo-phenomenon, mirage.

13th week

14th week
The concept of climate. Local, regional and global climates. Microclimate. Components of the material, process and quantity system that determine the local and global climates. The extraterrestrial, the Earth-related, the surface-related and the in-air components of the Earth’s global climatic system. Backup subsystems within the climatic system. Geographical distribution of local and regional climates.

Climate change over time. Our knowledge about the global climate of the last one hundred and fifty years, the last millennium, the last ten thousand years and the older geological ages. Methods and results of paleoclimatology. Possible causes and outcomes of climate change in the past. Effects of human activities on the climatic system. Climatic impacts of increasing concentrations of greenhouse gases and aerosols of artificial origin. Climate models and their predictions for the future. The expected consequences of global warming and the chances of influencing this process.

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

- for a grade
  The course ends in a written examination.

  The minimum requirement for the examination is 40%. The grade for the examination is given according to the following table:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-40</td>
<td>fail (1)</td>
</tr>
<tr>
<td>41-55</td>
<td>pass (2)</td>
</tr>
<tr>
<td>56-70</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>71-85</td>
<td>good (4)</td>
</tr>
<tr>
<td>86-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

159
If the score is below 41, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

**Person responsible for course:** Dr. Zoltán Papp, associate professor, PhD

**Lecturer:** Dr. Zoltán Papp, associate professor, PhD
<table>
<thead>
<tr>
<th><strong>Title of course:</strong> Nuclear measurement techniques</th>
<th><strong>ECTS Credit points:</strong> 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Code:</strong> TTFBE0213</td>
<td></td>
</tr>
</tbody>
</table>

**Type of teaching, contact hours**

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

**Evaluation:** exam

**Workload (estimated), divided into contact hours:**

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

Total: 90 hours

**Year, semester:** 3rd year, 2nd semester

**Its prerequisite(s):** TTFBE0107, (k) TTFBL0213

**Further courses built on it:** -

**Topics of course**

The meaning and basic function of nuclear measurement technology. The main properties of the nuclear and other ionizing radiations to be tested, their interaction with matter. Relevant concepts and quantities related to the detection of ionizing radiation and the measurement of the properties and quantities of ionizing radiation. Various types of measuring instruments that can be used to test ionizing radiation, principles and details of their operation (gas-filled detectors, scintillation detectors, semiconductor detectors, other detector types). Electronic auxiliaries serving the operation of measuring instruments (nuclear electronics). Measurement methods for the determination of the quantities of radionuclides or stable nuclides in material samples: alpha, beta and gamma spectrometry, mass spectrometry, activation analysis.

**Literature**

**Compulsory:**
- Z. Papp (2018), the PowerPoint presentations with the filenames NuclMeasTech-1 to NuclMeasTech-6

**Recommended:**
Schedule:

1st week
The basic purpose and method of nuclear measurement technology, the necessary tools and the information that can be learned from the atomic nucleus. Particles (ionized atoms, particles scattered on atoms, particles generated in nuclear reactions), nuclear radiation and atomic ionizing radiation that can be examined by nuclear measurement technics. The main features of the particles and radiation involved. Radioactive decay of the nucleus (decay law, decay types, decay schemes). The main properties of alpha and beta radiations, energies, intensities.

2nd week

3rd week
General characteristics of the interaction of radiation with matter. Modeling of elemental interaction mechanisms with a classic collision process. Interaction of heavy charged particles (proton, alpha, fission products) with matter. Specific energy loss and its dependence on radiation and matter properties. Charge exchange, energy variance, ionization of the matter. Range and its dependence on energy and the material quality of the matter.

4th week

5th week
Interaction of gamma-radiation and X-rays with matter. Exponential dependence of absorption on the thickness of absorber. Absorption coefficient, half-thickness. The photoelectric effect, the energy of the photoelectron, the role of the various electron shells. The Compton scattering. The properties of the Compton-scattered photon and the pushed Compton-electron. Pair-production. The dependences of the mass absorption coefficients of photoelectric effect, Compton scattering and pair-production, respectively, on the energy of the gamma radiation and on the quality of matter. Other forms of interaction. The energy dependence of the resulting radiation weakening in various materials. The dependence of the most likely interaction type on the energy of the gamma-radiation and on the atomic number of matter.

6th week
General principles for detecting nuclear and other ionizing radiations. Inhomogeneity of the radiation space, intensity of the radiation at the site of the detector. Physical changes caused by the radiation in the detector's material. The physical nature of the response of the detector and the dependence of this response on the type and properties of the radiation. Electrical and non-electrical detectors. Continuous and pulse-mode detectors. Electric pulses of pulse-mode detectors. The number of pulses (counts) within a time interval and the counting rate. The response function of the detector, the linearity of the response function. Sensitivity, space and time resolution, dead time, efficiency, background. Absolute and internal efficiency. Methods for determining

7th week

8th week
Operating principle, structure and properties of scintillation detectors. The basic processes of scintillation. Mechanism of interaction between the primary particle and the scintillator material. General features of scintillators. Specific features of some of the frequently used scintillator materials, the mechanism of scintillation. Organic and inorganic crystals, liquid scintillators. The connection of the photoelectron multiplier to the scintillator. Construction and operation of the photomultiplier. Photocathode, electron optical system, electron multiplication. Energy spectrometry with scintillation counter, energy resolution, time resolution.

9th week
Semiconductor detectors operating principle, structure, properties. Effects influencing the number of charge carriers. Properties of p-n transitions. Diffusion and surface barrier detectors. Lithium drifted Si and Ge detectors. High purity Ge detectors. Detector shape, energy resolution, time resolution, efficiency. Fields of application of semiconductor detectors. Detection of gamma radiation, the need for cooling with liquid nitrogen.

10th week
Other detector types. Cherenkov detector. Liquid filled ionization and proportional counters. Solid state track detectors. Termoluminescence detectors. Visual Detectors: cloud chamber, photoemulsion, bubble chamber, spark chamber. Neutron detectors (counters \(^{10}\)B, \(^{6}\)Li and \(^{3}\)H, fission chamber, current generating detector, etc.).

11th week

12th week
Use of alpha spectrometry for radioanalytical purposes (sample preparation, detection, spectrometry, spectrum evaluation). Beta spectroscopy with liquid scintillation (sample preparation, detection, spectrometry, spectrum evaluation). Other radioanalytical applications of alpha- and beta-counting.

13th week

14th week

Requirements:
- *for a signature*
  Attendance at lectures is recommended, but not compulsory.
- *for a grade*
  The course ends in an oral examination.

The minimum requirement for the examination is 40%. The grade for the examination is given according to the following table:

<table>
<thead>
<tr>
<th>Score</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0-40</td>
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</tr>
<tr>
<td>86-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

If the score is below 41, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

**Person responsible for course:** Dr. Zoltán Papp, associate professor, PhD

**Lecturer:** Dr. Zoltán Papp, associate professor, PhD
**Title of course:** Nuclear measurement techniques laboratory  
**Code:** TTFBL0213  
**ECTS Credit points:** 1

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
<th>ECTS Credit points: 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
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<tr>
<td>- laboratory: 16 hours/semester</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation: grade for written laboratory record</th>
<th></th>
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</table>

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: -</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: 16 (4x4) hours</td>
<td></td>
</tr>
<tr>
<td>- home assignment: 14 hours</td>
<td></td>
</tr>
<tr>
<td>- preparation for the exam: -</td>
<td></td>
</tr>
<tr>
<td>Total: 30 hours</td>
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</table>

<table>
<thead>
<tr>
<th>Year, semester: 3rd year, 2nd semester</th>
<th></th>
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</table>

<table>
<thead>
<tr>
<th>Its prerequisite(s): (p) TTFBE0213</th>
<th></th>
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<thead>
<tr>
<th>Further courses built on it: -</th>
<th></th>
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</table>

<table>
<thead>
<tr>
<th>Topics of course</th>
<th></th>
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</table>

<table>
<thead>
<tr>
<th>Literature</th>
<th></th>
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</thead>
</table>

- **Compulsory:**  

- **Recommended:**  

<table>
<thead>
<tr>
<th>Schedule:</th>
<th></th>
</tr>
</thead>
</table>
The four topics will be taught in the framework of four laboratory sessions need four hours each. Hence the course is held in four four-hour blocks on four consecutive weeks within the semester.
1st week
Determination of range in air and energy of alpha radiation based on variable pressure measuring chamber and CMOS video sensor chip. Devices to be used for the measurement: airtight cylindrical measuring chamber; alpha radiation source; source holders and collimators; video sensor chip with the required electronics; video-digitizing device; data collecting and data processing computer with the necessary software; manometer; pump. The student minimizes air pressure in the chamber and then increases in small increments while counting the alpha particles per unit time as a function of the pressure. The student shows on a graph the detected particle number as a function of the pressure. The particle number drops rapidly at a certain pressure as the particles lose their total energy. From this pressure, in the knowledge of the distance between the alpha source and the detector and the external air pressure, the student concludes the range in air of alpha radiation and from this determines the particle energy based on the relevant literature.

2nd week
Examination of self-absorption of beta-radiation using Geiger-Müller counter. Devices used: a series of variable-thickness radiation sources with low energy beta-emitting isotope; end-window GM tube inside a radiation shield and mounted with specimen holder; nuclear counting device; computer with the necessary software. The student examines the phenomenon that a fraction of the low energy beta radiation that is increasing with the thickness of the source can not get out of the source material because it is absorbed in it. The student counts the detection events occurring during unit time interval for the different thickness sources. The results are shown on a diagram. The student sees that from a certain source thickness the event number becomes steady (saturated). From this thickness value, the student concludes the maximum range and the maximum energy of beta-radiation.

3rd week
Study of the backscattering of beta radiation from matter with Geiger-Müller counter. Tools used: high-energy beta source; GM tube inside a radiation shield and equipped with a source holder and a backscattering specimen holder; nuclear counting device. The student examines the phenomenon that a significant proportion of the high-energy beta radiation is backscattered from matter (ie, it turns roughly in the opposite direction to its original direction of movement) and the ratio of the backscattered radiation depends on the elemental composition and thickness of the backscattering specimen. The student changes the quality of the backscattering substance (atomic number) and counts the detection events per time unit. The results are graphically depicted and using this graph the student can determine the atomic number of an unknown substance from the number of detection events per time unit counted with this substance. The student changes the thickness of the backscattering specimen and measures and depicts the number of detection events per unit of time as a function of Al-thickness. Based on this graph, the student determines the thickness of an Al-disc placing this disc on the thick lead disc, and counting the number of detection events per time unit using this complex backscattering specimen.

4th week
Determination of the range and energy of beta radiation by measuring the absorption curve using Geiger-Müller counter. Tools used: high-energy beta source; GM tube inside a radiation shield and equipped with a source holder and an absorber holder; Al-absorbers of different thicknesses; nuclear counting device. The student examines the phenomenon that a significant proportion of high-energy beta radiation is absorbed or scattered within the absorber layer between the source
and the detector, and thus the attenuating part of radiation decreases with the thickness of the absorber. The student places Al-discs with varying thicknesses in between the source and the detector, and counts the detection events per time unit according to the thickness of the Al-layer. The results are graphically depicted and from this absorption curve the student determines the maximum range and energy of beta-radiation and the mass-absorption coefficient of Al for beta-radiation by using proper literature data.

**Requirements:**

- **for a signature**

Participation at laboratory sessions is compulsory. A student must attend all the four sessions. In case a student doesn’t so, the course will not be signed and the student must repeat it. Attendance at laboratory sessions will be recorded by the session leader. Being late is equivalent with an absence. Students are required to bring drawing instruments to each sessions. Active participation is evaluated by the teacher. If a student’s behavior or conduct doesn’t meet the requirements of active participation, the teacher may evaluate his/her participation as an absence.

- **for a grade**

The student will obtain grades for all the four sessions one by one. The grades go from fail (1) to excellent (5) according to the following table:

<table>
<thead>
<tr>
<th>Score</th>
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</tr>
</thead>
<tbody>
<tr>
<td>0-40</td>
<td>fail (1)</td>
</tr>
<tr>
<td>41-55</td>
<td>pass (2)</td>
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<tr>
<td>86-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

The grade of the course will be the arithmetic mean of the grades obtained for each session rounded to the full, provided that the student has completed all the sessions with a grade better than fail (1). If the latter condition is not met then the grade of the course is fail (1) and the student must repeat the course in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

**Person responsible for course:** Dr. Zoltán Papp, associate professor, PhD

**Instructor:** Dr. Erdélyiné Dr. Eszter Baradács, assistant professor, PhD
<table>
<thead>
<tr>
<th>Title of course: Programming</th>
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</thead>
<tbody>
<tr>
<td>Code: TTFBE0617</td>
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<tr>
<td>ECTS Credit points: 2</td>
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</table>

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 2 hours/week</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation: exam</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Workload (estimated), divided into contact hours:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 28 hours</td>
</tr>
<tr>
<td>- practice: -</td>
</tr>
<tr>
<td>- laboratory: -</td>
</tr>
<tr>
<td>- home assignment: 17 hours</td>
</tr>
<tr>
<td>- preparation for the exam: 15 hours</td>
</tr>
<tr>
<td>Total: 60 hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year, semester: 2(^{nd}) year, 1(^{st}) semester</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Its prerequisite(s): -</th>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Further courses built on it: -</th>
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</table>

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</table>

<table>
<thead>
<tr>
<th>Schedule:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(^{st}) week</td>
</tr>
<tr>
<td>Introduction to C programming: development of programming languages, machine code, assembly, and high level programming languages, C as a high level programming language. Steps of program development, source code, compiler, executable code. Advantages and disadvantages of compilers and interpreters. Types of errors, syntactical and semantical errors, de-bugging.</td>
</tr>
</tbody>
</table>
2<sup>nd</sup> week  
Basics of algorithmic thinking, requirements of algorithms. Most important algorithms: Mini-mum and maximum search.

3<sup>rd</sup> week  
Algorithms of sorting, insertion into sorted lists with linear and binary search, merging sorted lists. Characterization of the efficiency of algorithms.

4<sup>th</sup> week  
Data structures and the computer representation of different data types. Signed and unsigned (positive, negative) integers, fixed point representation. Data types in C.

5<sup>th</sup> week  
Floating point representation of real numbers, determination of the range and precision of da-ta. ASCII representation of characters. Data types of the C language, type modifiers.

6<sup>th</sup> week  
General structure of a C program, function oriented program development. Declaration and initialization of variables. Header files and library functions. Functions of standard input and output.

7<sup>th</sup> week  

8<sup>th</sup> week  
Control of the program flow, branching the program execution, conditional statements. Loop commands in C with tests before and after the execution of the core of the loop.

9<sup>th</sup> week  
Logical operators and their expressions. High level logical expressions. Control structures with logical expressions

10<sup>th</sup> week  
Derived data types, arrays, vectors, and matrices in C. Processing arrays with loops.

11<sup>th</sup> week  
Processing files, writing into a file, reading from a file. Library functions of standard input and output with files

12<sup>th</sup> week  
Bit level logical operators. Operations at the level of bits, reading and setting the value of bits. Construction of mases for bit level operations.

13<sup>th</sup> week  
Functions in C. Definition and declaration of functions, function call. Boolean functions, functions without returned value, procedures

14<sup>th</sup> week  
**End-term test.** Parameter passing to functions, passing one- and two-dimensional arrays to functions. Matrix operations with user defined functions. Bit manipulation with functions.

**Requirements:**

- *for a signature*

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

During the semester two tests are written: the mid-term test in the 7<sup>th</sup> week and the end-term test in the 14<sup>th</sup> week. Students’ participation at the tests is mandatory.
The minimum requirement for the mid-term and end-term tests is 60%. Based on the total score of the two tests, the grade is determined according to the following scheme:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

- **for a grade**
  The course ends in an examination. Obtaining signature is a precondition for exam eligibility. Successful completion of the practical class of Programming 1 (grade 2 or higher) is also a precondition for exam eligibility. Results of two tests are counted in the final grade at a 60% weight. The remaining 40% of the grade is based on a written exam where evaluation is performed according to the above scoring scheme.

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

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

**Lecturer:** Prof. Dr. Kun Ferenc, university professor, DSc
Title of course: Programming
Code: TTFBL0617

ECTS Credit points: 2

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

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 20 hours
- preparation for the tests: 12 hours
Total: 60 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Literature
Compulsory:
Recommended:

Schedule:
1st week

2nd week
Functions of standard input and output. Data types of C, declaration and initialization of variables. Type modifiers. Operator of storage length. Simple arithmetic operations.

3rd week


4th week

Control of the program flow, branching the program execution into two and more directions, conditional statements.

5th week

Logical operators and complex logical expressions to control the structure of C programs.

6th week

Repeated execution of program blocks, organizing loops of execution with loop command.

7th week

Mid-term test. Array as a derived data type, declaration of arrays. Processing data arrays with loop commands.

8th week

Processing external files in a C program. Functions of standard input and output for file processing.

9th week

Command line arguments in C, control of the program with command line arguments.

10th week

Efficient programming of algorithms. Minimum and maximum search in arrays. The second largest element of a numerical array.

11th week

Efficient programming of algorithms. Sorting arrays into ascending and descending order. Insertion into sorted arrays, merging sorted arrays.

12th week

Bit level programming: Reading out and setting the value of a bit. Construction of masks with bit level operations.

13th week

User defined functions in C. Definition and declaration of functions. Function call. Functions and procedures.

14th week

End-term test. Processing one- and two-dimensional arrays with functions. Bit level operations with functions.

Requirements:

- for a term grade

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

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

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

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-59</td>
<td>fail (1)</td>
</tr>
<tr>
<td>Score Range</td>
<td>Grade</td>
</tr>
<tr>
<td>-------------</td>
<td>--------</td>
</tr>
<tr>
<td>60-69</td>
<td>pass (2)</td>
</tr>
<tr>
<td>70-79</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>80-89</td>
<td>good (4)</td>
</tr>
<tr>
<td>90-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

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

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

**Lecturer:** Prof. Dr. Kun Ferenc, university professor, DSc
**Title of course:** Vacuum science and technology I  
**Code:** TTFBE0209  
**ECTS Credit points:** 3

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

**Evaluation:** exam

**Workload (estimated), divided into contact hours:**
- lecture: 28 hours  
- practice: -  
- laboratory: -  
- home assignment: -  
- preparation for the exam: 62 hours  
Total: 90 hours

**Year, semester:** 2nd year, 2nd semester

**Its prerequisite(s):** thermodynamics, electromagnetism

**Further courses built on it:** -

**Topics of course**
The brief history of the vacuum science, the role and importance of the vacuum technology in the modern science and industry. The most important physical quantities in the vacuum 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 through diaphragms and tubes, throughput, pump speed, calculation of pumping time. Surface phenomena; adsorption, desorption, absorption, evaporation, sublimation, permeation. Vacuum gauges; mechanical gauges, thermocouple and Pirani gauges, ionization gauges, calibration of vacuummeters. Mass spectrometers; magnetic, quadropole and time of flight spectrometers. Vacuum leak detection. Vacuum pumps; mechanical pumps, diffusion pumps, ejector pumps, turbomolecular pumps, sorption pumps, getter pumps, ion-getter pumps, cryopumps. Materials of vacuum technology; structural materials, sealants, lubricants, pump fluids. Thin film deposition techniques; vacuum evaporation, sputtering, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition. Design of vacuum systems, components, accesories.

**Literature**

**Compulsory:**

**Recommended:**

**Schedule:**

1st week
The status of the vacuum science in the physics and technology. The brief history of the vacuum science. The most important physical quantities used in the vacuum physics.

2nd week
The most important properties and equations of ideal gases. Th basics of kinetic gas theory. The concept of pressure and average mean free path. The velocity and energy distribution functions of gas particles.

3\textsuperscript{rd} week
Transport phenomena in gases: diffusion, internal friction, heat conduction

4\textsuperscript{th} week

5\textsuperscript{th} week
Surface phenomena; adsorption, desorption, permeation, evaporation, sublimation

6\textsuperscript{th} week
Vacuum gauges: mechanical gauges, transport phenomena gauges (Pirani), ionization gauges, calibration of vacuum gauges.

7\textsuperscript{th} week
Vacuum pumps: mechanical pumps, diffusion pumps, ejector pumps, turbomolecular pumps, sorption and getter pumps, cryopumps.

8\textsuperscript{th} week
Mass spectrometers and their applications: magnetic, quadrupole, time of flight spectrometers

9\textsuperscript{th} week
Vacuum leak detection, methods and detectors

10\textsuperscript{th} week
Materials of vacuum technology: structural materials, sealants, pumping fluids, getters, adsorbents, lubricants.

11\textsuperscript{th} week
Methods of thin film deposition: evaporation, sputtering, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition

12\textsuperscript{th} week
Structure and design of vacuum systems: components, design rules, standards.

13\textsuperscript{th} week
Laboratory presentation: mass spectrometers (The SNMS and it’s applications)

14\textsuperscript{th} week
Laboratory presentation: layer deposition techniques: evaporation and sputtering

\textbf{Requirements:}

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

- for a grade
- The course ends in an exam.

The minimum requirement for the exam is 50%. The grade will be calculated according to the following table:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-50</td>
<td>fail (1)</td>
</tr>
<tr>
<td>51-62</td>
<td>pass (2)</td>
</tr>
<tr>
<td>63-75</td>
<td>satisfactory (3)</td>
</tr>
<tr>
<td>76-87</td>
<td>good (4)</td>
</tr>
<tr>
<td>87-100</td>
<td>excellent (5)</td>
</tr>
</tbody>
</table>

\textbf{Person responsible for course:} Dr. Lajos Daróczi, associate professor, PhD

\textbf{Lecturer:} Dr. Lajos Daróczi, associate professor, PhD
**Title of course:** Modern analysis  
**Code:** TTMBE0816  
**ECTS Credit points:** 3

<table>
<thead>
<tr>
<th>Type of teaching, contact hours</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>- lecture: 2 hours/week</td>
<td></td>
</tr>
<tr>
<td>- practice: -</td>
<td></td>
</tr>
<tr>
<td>- laboratory: -</td>
<td></td>
</tr>
</tbody>
</table>

**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**

**Literature**

**Compulsory:**

**Recommended:**

**Schedule:**

1st week
Regular functions. Differentiability of complex function. The Cauchy—Riemann equations. Constructing regular functions with the help of power series. The (complex) exponential functions and its properties. The logarithm functions and power functions, their introduction. The regular branch of complex functions.
2nd week

3rd week

4th week

5th week

6th week
The Category Theorem and its applications. The construction of an everywhere continuous, nowhere differentiable function. The first and the second Approximation Theorem of Weierstrass, Stone's Approximation Theorem.

7th week
Norms and semi-norms in linear spaces, The Kuratowski—Zorn lemma. The Hahn—Banach Extension Theorem, the Hahn—Banach Theorem in normed spaces and its applications, the Banach limit. Theorem of Bohnenblust and Sobczyk.

8th week

9th week

10th week

11th week
Compact operators. Spectral theory of compact operators.

12th week
The Fredholm Alternative Theorem. Integral operators of Volterra and of Fredholm type.

13th week

14th week
The mathematical foundations of quantum mechanics.

Requirements:
- for a signature
Signature requires the correct solution of at least 60% of each of the two tests. 

*for a grade*

Knowledge of most basic definitions, laws and theorems: grade 2;
In addition, knowledge of the proof of the easiest and most straightforward statements: grade 3;
In addition, knowledge of the proofs of harder theorems: grade 4;
In addition, knowledge of the proofs and the capability to understand the deeper connections between the learned areas: grade 5.

*an offered grade: –*

| **Person responsible for course:** Dr. Eszter Novák-Gselmann, associate professor, PhD |
| **Lecturer:** Dr. Eszter Novák-Gselmann, associate professor, PhD |
Title of course: Modern analysis  
Code: TTMBG0816  
ECTS Credit points: 2

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

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 28 hours
- laboratory: -
- home assignment: 32 hours
- preparation for the exam: -
Total: 60 hours

Year, semester: 2nd year, 2nd semester

Its prerequisite(s): TTMBE0814

Further courses built on it: -

Topics of course

Literature

Compulsory:

Recommended:

Schedule:

1st week
Regular functions. Differentiability of complex function. The Cauchy—Riemann equations. Constructing regular functions with the help of power series. The (complex) exponential functions and its properties. The logarithm functions and power functions, their introduction. The regular branch of complex functions.
| 6th week | Mid-term test. |
| 7th week | Norms and semi-norms in linear spaces, The Kuratowski—Zorn lemma. The Hahn—Banach Extension Theorem, the Hahn—Banach Theorem in normed spaces and its applications, the Banach limit. Theorem of Bohnenblust and Sobczyk. |
| 9th week | The Open Mapping Theorem, Banach's Theorem on Bounded Inverses. Equivalent norms in Banach spaces. Norms in finite dimensional spaces. The Closed Graph Theorem. |
| 13th week | The mathematical foundations of quantum mechanics. |
| 14th week | End-term test. |

**Requirements:**

- for a signature
Signature requires the correct solution of at least 60% of each of the two tests.

*for a grade*

Knowledge of most basic definitions, laws and theorems: grade 2;
In addition, knowledge of the proof of the easiest and most straightforward statements: grade 3;
In addition, knowledge of the proofs of harder theorems: grade 4;
In addition, knowledge of the proofs and the capability to understand the deeper connections between the learned areas: grade 5.

*an offered grade: –*

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

**Lecturer:** Dr. Eszter Novák-Gselmann, associate professor, PhD