University of Debrecen
Faculty of Science and Technology
Institute of Mathematics

MATHEMATICS BSC PROGRAM

2024

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DEAN`S WELCOME

Welcome to the Faculty of Science and Technology!

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

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

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

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

Prof. Dr. Ferenc Kun
Dean

UNIVERSITY OF DEBRECEN

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

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

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: 13

Faculty of Agricultural and Food Sciences and Environmental Management

Faculty of Child and Special Needs Education

Faculty of Dentistry

Faculty of Economics and Business

Faculty of Engineering

Faculty of Health

Faculty of Humanities

Faculty of Informatics

Faculty of Law

Faculty of Medicine

Faculty of Music

Faculty of Pharmacy

Faculty of Science and Technology

Number of students at the University of Debrecen: 30,899

Full time teachers of the University of Debrecen: 1,597

210 full university professors and 1,262 lecturers with a PhD.

FACULTY OF SCIENCE AND TECHNOLOGY

The Faculty of Science and Technology is currently one of the largest faculties of the University of Debrecen with about 2,500 students and more than 200 staff members. The Faculty has got 6 institutes: Institute of Biology and Ecology, Institute of Biotechnology, Institute of Chemistry, Institute of Earth Sciences, Institute of Physics and Institute of Mathematics. The Faculty has a very wide scope of education dominated by science and technology (12 Bachelor programs and 14 Master programs), additionally it has a significant variety of teachers' training programs. Our teaching activities are based on a strong academic and industrial background, where highly qualified teachers with a scientific degree involve student in research and development projects as part of their curriculum. We are proud of our scientific excellence and of the application-oriented teaching programs with a strong industrial support. The number of international students of our faculty is continuously growing (currently ~760 students). The attractiveness of our education is indicated by the popularity of the Faculty in terms of incoming Erasmus students, as well.

THE ORGANIZATIONAL STRUCTURE OF THE FACULTY

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

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Consultant on Talent Management Programme: Prof. dr. Tibor Magura, Full Professor
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Dean's Office
Head of Dean's Office: Mrs. Katalin Kozma-Tóth
E-mail: toth.katalin@science.unideb.hu

English Program Officer: Mrs. Alexandra Csatáry
Address: 4032 Egyetem tér 1., Chemistry Building, A/101, E-mail: acsatary@science.unideb.hu

DEPARTMENTS OF INSTITUTE OF MATHEMATICS

Department of Algebra and Number Theory (home page: https://math.unideb.hu/en/introduction-department-algebra-and-number-theory)
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Mr. Péter Tóth	PhD student	toth.peter@science.unideb.hu	M322

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Ms. Gabriella Papp	PhD student	papp.gabriella@science.unideb.hu	-

ACADEMIC CALENDAR

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

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

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

For further information please check the following link:
https://www.edu.unideb.hu/tartalom/downloads/University_Calendars_2024_25/University_calendar_2024-2025-Faculty_of_Science_and_Technology.pdf

THE MATHEMATICS BACHELOR PROGRAM

Information about the Program

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

Objectives of the BSc program:

The aim of the Mathematics BSc program is to train professional mathematicians who have deep knowledge on theoretical and applied mathematics that makes them capable of using their basic mathematical knowledge on the fields of engineering, economics, statistics and informatics. They are prepared to continue to study in an MSc program.

Professional competences to be acquired

A Mathematician:

a) Knowledge:

- He/she knows the basic methods of mathematics in the fields of analysis, algebra, geometry, discrete mathematics, operations research and probability theory (statistics).
- He/she knows the basic correlations in pure mathematics, related to the fields of analysis, algebra, geometry, discrete mathematics, operations research and probability theory (statistics).
- He/she knows the basic correlations between different subdisciplines of mathematics.
- He/she is aware of the requirements of defining abstract concepts, he/she recognises general patterns and concepts inherited in the problems applied.
- He/she knows the requirements and basic methods of mathematical proofs.
- He/she is aware of the specific features of mathematical thinking.

b) Abilities:

- He/she is capable of formulating and communicating true and logical mathematical statements, as well as, how to exactly indicate their conditions and main consequences.
- He/she is capable of drawing conclusions of the qualitative type from quantitative data.
- He/she is capable of applying his/her factual knowledge acquired in the fields of analysis, algebra, geometry, discrete mathematics, operations research and probability theory (statistics).

- He/she is capable of finding and exploring new correlations in the fields of analysis, algebra, geometry, discrete mathematics, operations research and probability theory (statistics).
- He/she is capable of going beyond the concrete forms of problems, and formulating them both in abstract and general forms for the sake of analysis and finding a solution.
- He/she is capable of designing experiments for the sake of data collection, as well as, of analysing the results achieved by the means of mathematics and informatics.
- He/she is capable of making a comparative analysis of different mathematical models.
- He/she is capable of effectively communicating the results of mathematical analyses in foreign languages, and by the means of informatics.
- He/she is capable of identifying routine problems of his/her own professional field, using the scientific literature available (library and electronic sources) and adapting their methods to find theoretical and practical solutions

c) Attitude:
- He/she desires to enhance the scope of his/her mathematical knowledge by learning new concepts, as well as, for acquiring and developing new competencies.
- He/she aspires to apply his/her mathematical knowledge as widely as possible.
- Applying his/her mathematical knowledge, he/she aspires to get acquainted with the perceptible phenomena in the most thorough way possible, and to describe and explain the principles shaping them.
- Using his/her mathematical knowledge, he/she aspires to apply scientific reasoning.
- He/she is open to recognizing the specific problems in professional fields other than his/her own field and makes an effort to cooperate with experts of these fields, to the end of proposing a mathematical adaptation of field-specific problems.
- He/she is open to continuing professional training and development in the field of mathematics.

d) Autonomy and responsibility:
- Using his/her basic knowledge acquired in mathematical subdisciplines, he/she is capable of formulating and analysing mathematical questions on his/her own.
- He/she responsibly assesses mathematical results, their applicability and the limits of their applicability.
- He/she is aware of the value of mathematical-scientific statements, their applicability and the limits of their applicability.
- He/she is capable of making decisions on his/her own, based on the results of mathematical analyses.
- He/she is aware that he/she must carry out his/her own professional work in line with the highest ethical standards and ensuring a high level of quality.
- He/she carries out his/her theoretical and practical research activities related to different fields of mathematics, with the necessary guidance, on his/her own.

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 120 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 “Model Curriculum of Mathematics BSc Program”.

	semesters						ECTS credit points	evaluation
	1.	2.	3.	4.	5.	6.		
	contact hours, types of teaching (l – lecture, p – practice), credit points							
Linear algebra subject group								
Linear algebra 1. *Dr. Gaál István*	28 l/3 cr. 28 p /2 cr.						*5*	exam mid-semester grade
Linear algebra 2. *Dr. Gaál István*		28 l/3 cr. 28 p/2 cr.					*5*	exam mid-semester grade
Classical algebra subject group								
Introduction to Algebra and Number Theory *Dr. Pintér Ákos*	28 l/3 cr. 42 p/2 cr.						*6*	exam mid-semester grade
Algebra 1. *Dr. Remete László*		28 l/3 cr. 28 p/2 cr.					*5*	exam mid-semester grade
Algebra 2. *Dr. Remete László*			28 l/3 cr. 28 p/2 cr.				*5*	exam mid-semester grade
Classical finite mathematics subject group								
Number theory *Dr. Hajdu Lajos*			28 l/3 cr. 28 p/2 cr.				*5*	exam mid-semester grade
Combinatorics and graph theory *Dr. Nyul Gábor*	42 l/4 cr . 28 p/2 cr.						*6*	exam mid-semester grade
Classical analysis subject group								
Foundations of analysis *Dr. Lovas Rezső*	28 p/2 cr.						*2*	mid-semester grade
Introduction to analysis *Dr. Tibor Kiss*		42 l/5 cr. 42 p/3 cr.					*8*	exam mid-semester grade
Differential and integral calculus *Dr. Tibor Kiss*			42 l/5cr. 42 p/3 cr.				*8*	exam mid-semester grade
Sets, functions, real numbers *Dr. Lovas Rezső*			28 l/3 cr.				*3*	exam

Differential and integral calculus in several variables *Dr. Páles Zsolt*				42 l/5 cr . 42 p/3 cr.			*8*	exam mid-semester grade
Ordinary differential equations *Dr. Gát György*					28 l/4 cr. 28 p/2 cr.		*6*	exam mid-semester grade
Classical geometry subject group								
Geometry 1. *Dr. Vincze Csaba*	28 l/3 cr. 28 p/2 cr.						*5*	exam mid-semester grade
Geometry 2. *Dr. Vincze Csaba*		28 l/3 cr. 28 p/2 cr.					*5*	exam mid-semester grade
Differential geometry *Dr. Muzsnay Zoltán*					28 l/3 cr. 28 p/2 cr.		*5*	exam mid-semester grade
Vector analysis *Dr. Vincze Csaba*						28 l/3 cr. 28 p/2 cr.	*5*	exam mid-semester grade
Probability theory subject group								
Measure and integral theory *Dr. Nagy Gergő*				28 l/3 cr.			*3*	exam
Probability theory *Dr. Fazekas István*					42 l/4 cr. 28 p/2 cr.		*6*	exam mid-semester grade
Statistics *Dr. Fazekas István*						42 l/4 cr. 28 p/2 cr.	*5*	exam mid-semester grade
Informatics subject group								
Introduction to informatics *Dr. Tengely Szabolcs*	42 p/2 cr.						*2*	mid-semester grade
Progamming languages *Dr. Bazsó András*	28 p/2 cr.						*2*	mid-semester grade
Finite mathematical algorithms subject group								
Algorithms *Dr. Györkös-Varga Nóra*		28 l/3 cr. 28 p/2 cr.					*5*	exam mid-semester grade
Applied number theory *Dr. Hajdu Lajos*				42 l/3 cr.			*3*	exam
Algorithms in algebra and number theory *Dr. Tengely Szabolcs*				42 p/3 cr.			*3*	mid-semester grade
Introduction to cryptography *Dr. Bérczes Attila*					28 l/3 cr. 28 p /2 cr.		*5*	exam mid-semester grade

Applied analysis subject group								
Numerical analysis *Dr. Fazekas Borbála*				42 l/4 cr. 28 p/2 cr.			*6*	exam mid-semester grade
Economic mathematics *Dr. Mészáros Fruzsina*						28 l/3 cr. 28 p/2 cr	*5*	exam mid-semester grade
Computer mathematics subject group								
Analysis with computer *Dr. Fazekas Borbála*						42 p/3 cr	*3*	mid-semester grade
Computer statistics *Dr. Sikolya-Kertész Kinga*						28 p/2 cr	*2*	mid-semester grade
Computer geometry *Dr. Nagy Ábris*			42 p/3 cr.				*3*	mid-semester grade
Optimizing subject group								
Linear programming *Dr. Mészáros Fruzsina*			28 l/3 cr. 28 p/2 cr.				*5*	exam mid-semester grade
Basics of earth sciences and mathematics subject group								
Basics of mathematics *Dr.Györkös- Varga Nóra*	14 p/0 cr.						*0*	signature
Classical mechanics *Dr. Erdélyi Zoltán*				28 l/3 cr. 14 p/1 cr.			*4*	exam
Theoretical mechanics *Dr. Nagy Sándor*						28 l/3 cr. 14 p/1 cr	*4*	exam
European Union studies *Dr. Teperics Károly*	14 p/1 cr.						*1*	exam
Basic environmental science *Dr. Nagy Sándor Alex*	14 p/1 cr.						*1*	exam
Thesis I.					5 cr.		*5*	mid-semester grade
Thesis II.						5 cr.	**5**	mid-semester grade
optional courses								
optional courses							*9*	

Work and Fire Safety Course

According to the Rules and Regulations of the 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 obtaining the pre-degree certificate.
Students have to register for the subject MUNKAVEDELEM in the Neptun system.
They must read an online material until the end to get the signature on Neptun for the completion of the course. The number of credit points for the course is 1. The link of the online course is available on the webpage of the Faculty.

Physical Education

According to the Rules and Regulations of the University of Debrecen, a student has to complete Physical Education courses at least in two semesters during his/her Bachelor's training. The number of credit points for those courses is 1 per semester. Our University offers a wide range of facilities to complete them. Further information is available from the Sports Centre of the University, its website is: 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, internship (mandatory) – with the exception of preparing the 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

Students have to choose a topic for their thesis two semesters before the expected date of finishing their studies, i.e., usually at the end of the 4th semester. They have to write it in two semesters, and they have to register for the courses 'Thesis 1' and 'Thesis 2' in two different semesters. They write the thesis with the help of a supervisor who should be a lecturer of the Institute of Mathematics. (In exceptional cases, the supervisor can be a member of another institute.)
Students are not required to present new scientific results, but they have to do some scientific work on their own. The thesis should be about 20–40 pages long and using the LaTeX document preparation system is recommended. The cover page has to contain the name of the institute,

the title of the thesis, the name and the degree program of the student, the name and the university rank of the supervisor. Beside the detailed discussion of the topic, the thesis should contain an introduction, a table of contents and a bibliography. The thesis has to be defended in the final exam.

Final Exam

The final exam is an oral exam before a committee designated by the Director of the Institute of Mathematics and approved by the leaders of the Faculty of Science and Technology. The final exam consists of two parts: an account by the student on a certain exam question, and the defense of the thesis. The questions of the final exam comprise the compulsory courses of the Mathematics BSc Program. The student draws a random question from the list, and after a certain preparation period, gives an account on it. After this, the committee may ask questions also from other topics. The student gets three separate grades for their answers on the exam question, for the thesis and for the defense of the thesis.

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 – beside 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 Mathematics 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 Mathematics Bachelor Master 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 Mathematics BSc Program

Title of course: Linear algebra 1. **Code**: TTMBE0102	**ECTS Credit points:** 3

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

Evaluation: exam

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

Total: 90 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: TTMBE0103, TTMBE0607, TTMBE0209, TTMBG0701

Topics of course

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

Literature

Compulsory:
-

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

Schedule:

1st week

Basic concepts of algebra. Permutations and their properties.

2nd week

Determinants. Expanding determinants. Laplace expansion theorem.

3rd week

Operations on matrices. Matrix algebra. Multiplication theorem of determinants. Inverse of matrices.

4th week

Vector space, subspace, generating system, linear dependence and independence. Basis, dimension.

5th week

Linear mappings of vector spaces. Fundamental theorems on linear mappings. Transformation of bases and coordinates.

6th week

Rank of a set of vectors, rank of a matrix. Theorem on ranks. Calculating the rank of a matrix by elimination.

7th week

Sum and direct sum of subspaces. Equivalent properties. Coset of subspaces. Factor spaces of vector spaces. Dimension of the factor space.

8th week

Systems of linear equations. Criteria for solubility, for the uniqueness of solutions. Homogeneous systems of linear equations. Solutions space, the dimension of the solution space.

9th week

Inhomogeneous systems of linear equations. The structure of solutions. Cramer's rule Gaussian elimination.

10th week

Linear mappings of vector spaces. Kernel, image. Theorem on homomorphisms. The condition of injectivity.

11th week

Linear transformations. Injective and surjective linear transformations. The matrix of a linear transformation. Calculation the image vector. The matrix of the linear transformation in a new basis.

12th week

Operations on linear transformations. Algebra of linear transformations. Similar matrices. Automorphisms.

13th week

Invariant subspaces. Eigenvector, eigenvalues of a linear transformation. Eigenspace. Eigen-vectors of distinct eigenvalues. Eigenspaces of distinct eigenvalues.

14th week

Characteristic polynomial. Algebraic and geometric multiplicity of eigenvalues. Spectrum of a linear transformation. Existence of a basis consisting of eigenvectors.

Requirements:

- for a signature

If the student fail the course TTMBG0102, then the signature is automatically denied.

- for a grade

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

-an offered grade:

It is not possible to obtain an offered grade in this course.

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

Title of course: Linear algebra 1. **Code**: TTMBG0102	**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: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

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

Literature

Compulsory:

-

Recommended:

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

Schedule:

1st week

Abstract groups, permutation.

2nd week

Determinants. Expanding determinants.

3rd week

Operations on matrices.

4th week

Inverse of matrices. Vectors spaces. Basis, dimension.

5th week

Transformation of bases and coordinates.

6th week

Rank of a matrix. Calculating the rank of a matrix by elimination.
7th week
First test.
8th week
Homogeneous systems of linear equations. Solutions space.
9th week
Inhomogeneous systems of linear equations. Cramer's rule Gaussian elimination.
10th week
Linear mappings of vector spaces. Calculating the kernel and image.
11th week
The matrix of a linear transformation. The matrix of the linear transformation in a new basis.
12th week
Operations on linear transformations. Similar matrices.
13th week
Able to calculate eigenvalues, eigenvectors, basis consisting of eigenvectors.
14th week
Second test.

Requirements:
- for a signature
Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.
- for a grade
The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.
-an offered grade:
It is not possible to obtain an offered grade in this course.

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

Lecturer: Prof. Dr. István Gaál, university professor, DSc

Title of course: Linear algebra 2. **Code**: TTMBE0103	**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): TTMBE0102

Further courses built on it: -

Topics of course

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

Literature

Compulsory:

-

Recommended:

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

Schedule:

1st week

Nilpotent transformations. Canonical form of a nilpotent matrix.

2nd week

Jordan normal form, Jordan blocks, canonical basis.

3rd week

Linear forms, bilinear forms, quadratic forms.

4th week

Canonical form of bilinear and quadratic forms. Lagrange theorem. Sylvester theorem. Jacobi theorem. Positive definite quadratic forms and their characterization.

5th week

Inner product, Euclidean space, Cauchy-Bunyakovszkij-Schwarz inequality, Minkowski inequality.

6th week

Gram-Schmidt orthogonalization method, orthonormed bases, orthogonal complement of a subspace, Bessel inequality, Parseval equation.

7th week

Bilinear and quadratic forms in complex vector spaces. Inner product. Unitary spaces.

8th week

Linear, bilinear forms and inner products. Adjoint transformations. Properties of the adjoint transformation.

9th week

Self-adjoint transformations, eigenvalues, eigenvectors, canonical form.

10th week

Orthogonal transformations. Equivalent properties. Properties of orthogonal matrices.

11th week

Orthogonal transformations of Euclidean spaces. Quasi diagonal matrices. Representation of linear transformations by self-adjoint transformations.

12th week

Normal transformations in unitary spaces. Polar representation theorem.

13th week

Curves of second order, Asymptote directions. Diameters conjugated to a direction. Principal axis. Transformation to principal axis.

14th week

Application of symbolic algebra packages in linear algebra calculations.

Requirements:

- for a signature

If the student fail the course TTMBG0103, then the signature is automatically denied.

- for a grade

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	**Grade**
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

-an offered grade:

It is not possible to obtain an offered grade in this course.

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

Lecturer: Prof. Dr. István Gaál, university professor, DSc

Title of course: Linear algebra 2. **Code**: TTMBG0103	**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: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMBE0102

Further courses built on it: -

Topics of course

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

Literature

Compulsory:

-

Recommended:

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

Schedule:

1st week

Nilpotent transformations.

2nd week

Jordan normal form.

3rd week

Linear forms, bilinear forms, quadratic forms.

4th week

Canonical form of bilinear and quadratic forms. Positive definite quadratic forms and their characterization.

5th week

Inner product, Euclidean space.

6th week

Gram-Schmidt orthogonalization method, orthonormed bases.

7th week

First test.

8th week

Adjoint transformations. Properties of the adjoint transformation.

9th week

Self-adjoint transformations, eigenvalues, eigenvectors, canonical form.

10th week

Orthogonal transformations.

11th week

Orthogonal transformations of Euclidean spaces. Quasi diagonal matrices.

12th week

Normal transformations in unitary spaces. Polar representation theorem.

13th week

Curves of second order. Transformation to principal axis.

14th week

Second test.

Requirements:

- *for a signature*

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- *for a grade*

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.

-an offered grade:

It is not possible to obtain an offered grade in this course.

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

Lecturer: Prof. Dr. István Gaál, university professor, DSc

Title of course: Introduction to algebra and number theory **Code**: TTMBE0101	**ECTS Credit points:** 3

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

Evaluation: exam

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

Total: 90 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: TTMBE0104, TTMBG0701

Topics of course

Relations, algebraic structures, operations and their properties. Divisibility and division with remainder in Z. Greatest common divisor, Euclidean algorithm. Congruence relation and congruence classes in Z, rings of congruence classes. The theorem of Euler-Fermat. Linear congruences. Linear congruence systems, Chinese remainder theorem. Two-variable and multivariate linear Diophantine equations. Peano axioms, N, Z, Q. Complex numbers, operations, conjugate, absolute value. Trigonometric form of complex numbers, theorem of Moivre, nth roots of complex numbers, roots of unity. Polynomial ring over field. Euclidean division, greatest common divisor. Polynomial rings over Z, Q, R, and C, absolute value. Fundamental theorem of algebra. Partial fraction expression. Algebraic equations, discriminant, resultant, multiple roots, cubic and quartic equations. Multivariate polynomials, symmetric and elementary symmetric functions, fundamental theorem of symmetric polynomials.

Literature

Compulsory:

-

Recommended:

I. Nivan, H. S. Zuckerman, H. L. Montgomery: An introduction to the theory of numbers. John Wiley and Sons, 1991.

L. N., Childs:: A concrete introduction to higher algebra. New York, Springer, 2000.

Schedule:

1st week

Relations, algebraic structures, operations and their properties.

2nd week

Peano axioms, natural numbers.

3rd week

Integer and rational numbers.

4th week

Complex numbers, operations, conjugate, absolute value.

5th week

Trigonometric form of complex numbers, theorem of Moivre, nth roots of complex numbers, roots of unity.

6th week

Divisibility and division with remainder in Z. Greatest common divisor, Euclidean algorithm.

7th week

Congruence relation and congruence classes in Z, rings of congruence classes. Euler's phi-function, the theorem of Euler-Fermat.

8th week

Linear congruences. Condition of solvability, number of solutions. Linear congruence systems, Chinese remainder theorem.

9th week

Two-variable linear Diophantine equations, condition of solvability and their connection with linear congruences, multivariate linear Diophantine equations.

10th week

Polynomial ring over field. Euclidean division, greatest common divisor.

11th week

Ring of Z[x], Q[x], R[x], C[x], irreducible factorization.

12th week

Fundamental theorem of algebra. Partial fraction expression.

13th week

Algebraic equations, discriminant, resultant, multiple roots, cubic and quartic equations.

14th week

Multivariate polynomials, symmetric and elementary symmetric functions, fundamental theorem of symmetric polynomial.

Requirements:

- for a signature

If the student fail the course TTMBG0101, then the signature is automatically denied.

- for a grade

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Ákos Pintér, university professor, DSc

Lecturer: Prof. Dr. Ákos Pintér, university professor, DSc

Title of course: Introduction to algebra and number theory **Code**: TTMBG0101	**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: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Relations, algebraic structures, operations and their properties. Divisibility and division with remainder in Z. Greatest common divisor, Euclidean algorithm. Congruence relation and congruence classes in Z, rings of congruence classes. The theorem of Euler-Fermat. Linear congruences. Linear congruence systems, Chinese remainder theorem. Two-variable and multivariate linear Diophantine equations. Peano axioms, N, Z, Q. Complex numbers, operations, conjugate, absolute value. Trigonometric form of complex numbers, theorem of Moivre, nth roots of complex numbers, roots of unity. Polynomial ring over field. Euclidean division, greatest common divisor. Polynomial rings over Z, Q, R, and C, absolute value. Fundamental theorem of algebra. Partial fraction expression. Algebraic equations, discriminant, resultant, multiple roots, cubic and quartic equations. Multivariate polynomials, symmetric and elementary symmetric functions, fundamental theorem of symmetric polynomials.

Literature

Compulsory:

-

Recommended:

I. Nivan, H. S. Zuckerman, H. L. Montgomery: An introduction to the theory of numbers. John Wiley and Sons, 1991.

L. N., Childs:: A concrete introduction to higher algebra. New York, Springer, 2000.

Schedule:

1st week

Relations, algebraic structures, operations and their properties.

2nd week

Peano axioms, natural numbers.

3rd week

Integer and rational numbers.

4th week

Complex numbers, operations, conjugate, absolute value.

5th week

Trigonometric form of complex numbers, theorem of Moivre, n^th roots of complex numbers, roots of unity.

6th week

Divisibility and division with remainder in Z. Greatest common divisor, Euclidean algorithm.

7th week

First test.

8th week

Euler's phi-function, the theorem of Euler-Fermat. Linear congruences. Condition of solvability, number of solutions. Linear congruence systems, Chinese remainder theorem.

9th week

Two-variable linear Diophantine equations, condition of solvability and their connection with linear congruences, multivariate linear Diophantine equations.

10th week

Polynomial ring over field. Euclidean division, greatest common divisor.

11th week

Ring of Z[x], Q[x], R[x], C[x], irreducible factorization.

12th week

Fundamental theorem of algebra. Partial fraction expression. Algebraic equations, discriminant, resultant, multiple roots, cubic and quartic equations.

13th week

Multivariate polynomials, symmetric and elementary symmetric functions, fundamental theorem of symmetric polynomial.

14th week

Second test.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- for a grade

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Ákos Pintér, university professor, DSc

Lecturer: Prof. Dr. Ákos Pintér, university professor, DSc

Title of course: Algebra 1. **Code**: TTMBE0104	**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): TTMBE0101

Further courses built on it: TTMBE0105

Topics of course

Definition of groups, examples. Permutations, sign of permutations. Homomorphisms. Order, cyclic groups. Subgroups, generated subgroups, Lagrange´s theorem. Direct product, the fundamental theorem of finite Abelian groups. Permutation groups and group actions, Cayley´s theorem. Homomorphisms and normal subgroups, conjugation. Factor groups. Homomorphism theorem. Isomorphism theorems. Basic properties of p-groups, center. Definition of rings, examples. Subrings, generated subrings. Finite rings without zero divisors. Homomorphisms and ideals, factor rings. Rings of polynomials. Euclidean rings and principal ideal domains, the fundamental theorem of number theory. Fields, simple algebraic extensions. Minimal polynomial. The multiplicativity formula for degrees. Algebraic numbers. Construction of the splitting field. Characteristics, prime fields. Construction of finite fields, primitive roots, subfields of finite fields. Existence of irreducible polynomials over Zp with arbitrary degree. Geometric constructions with compass and straightedge: The impossibility of doubling a cube (a. k. a. the Delian problem), trisecting an edge and squaring a circle.

Literature

Compulsory:

-

Recommended:

John B. Fraleigh: A first course in abstract algebra, Addison-Wesley Publishing Company, 1989.
Derek J. S. Robinson: A course in the theory of groups, Sringer-Verlag, 1980.

Schedule:

1st week

Groups: definition, basic properties, examples. Permutations, sign. Homomorphisms.

2nd week

Order, cyclic groups, fundamental properties.

3rd week

Subgroups, generated subgroups, Lagrange´s theorem.

4th week
Direct product, fundamental theorem of finite Abelian groups (without proof). Permutation groups and group actions, Cayley´s theorem.
5th week
Homomorphisms and normal subgroups, conjugation. Factor group. Homomorphism theorem.
6th week
Isomorphism theorems (without proof). Fundamental properties of p-groups, non-triviality of the center.
7th week
First test.
8th week
Rings: definition, basic properties, examples. Subrings, generated subrings,. Finite rings with no zero divisors are division rings.
9th week
Homomorphisms and ideals, factor rings and their subrings. Polynomial rings.
10th week
Euclidean domains and PIDs, basic number theoretical properties. Fundamental theorem of number theory in Euclidean domains.
11th week
Fields, simple field extensions by an algebraic element. Minimal polynomial and degree of simple extensions. Field extensions by more than one elements.
12th week
The multiplicativity formula for degrees. Algebraic numbers, the field of algebraic numbers is algebraically closed. Construction of the quotient field (without the proof of uniqueness).
13th week
Characteristic of a field, prime field. Construction of finite fields, primitive roots, subfields of finite fields. Existence of irreducible polynomials of arbitrary degree over the p-element field. Geometric constructions: the Delean problem, trisection of an angle and squaring a circle are unsolvable with a compass and a straightedge.
14th week
Second test.

Requirements:
- for a signature
If the student fail the course TTMBG0104, then the signature is automatically denied.
- for a grade
The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 39	fail (1)
40 – 49	pass (2)
50 – 59	satisfactory (3)
60 – 69	good (4)
70 – 100	excellent (5)

-an offered grade:
It is not possible to obtain an offered grade in this course.

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

Lecturer: Dr. László Remete, assistant professor, PhD

Title of course: Algebra 1. **Code**: TTMBG0104	**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: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMBE0101

Further courses built on it: TTMBE0105, TTMBG0105

Topics of course

Definition of groups, examples. Permutations, sign of permutations. Homomorphisms. Order, cyclic groups. Subgroups, generated subgroups, Lagrange´s theorem. Direct product, the fundamental theorem of finite Abelian groups. Permutation groups and group actions, Cayley´s theorem. Homomorphisms and normal subgroups, conjugation. Factor groups. Homomorphism theorem. Isomorphism theorems. Basic properties of p-groups, center. Definition of rings, examples. Subrings, generated subrings. Finite rings without zero divisors. Homomorphisms and ideals, factor rings. Rings of polynomials. Euclidean rings and principal ideal domains, the fundamental theorem of number theory. Fields, simple algebraic extensions. Minimal polynomial. The multiplicativity formula for degrees. Algebraic numbers. Construction of the splitting field. Characteristics, prime fields. Construction of finite fields, primitive roots, subfields of finite fields. Existence of irreducible polynomials over Zp with arbitrary degree. Geometric constructions with compass and straightedge: The impossibility of doubling a cube (a. k. a. the Delian problem), trisecting an edge and squaring a circle.

Literature

Compulsory:

-

Recommended:

John B. Fraleigh: A first course in abstract algebra, Addison-Wesley Publishing Company, 1989.
Derek J. S. Robinson: A course in the theory of groups, Sringer-Verlag, 1980.

Schedule:

1st week

Groups: definition, basic properties, examples. Permutations, sign. Homomorphisms.

2nd week

Order, cyclic groups, fundamental properties.

3rd week

Subgroups, generated subgroups, Lagrange´s theorem.

4th week

Direct product, fundamental theorem of finite Abelian groups (without proof). Permutation groups and group actions, Cayley´s theorem.

5th week

Homomorphisms and normal subgroups, conjugation. Factor group. Homomorphism theorem.

6th week

Isomorphism theorems (without proof). Fundamental properties of p-groups, non-triviality of the center.

7th week

Students can ask questions and get an overview on the subject material in all topics prior to the first test.

8th week

Rings: definition, basic properties, examples. Subrings, generated subrings,. Finite rings with no zero divisors are division rings.

9th week

Homomorphisms and ideals, factor rings and their subrings. Polynomial rings.

10th week

Euclidean domains and PIDs, basic number theoretical properties. Fundamental theorem of number theory in Euclidean domains.

11th week

Fields, simple field extensions by an algebraic element. Minimal polynomial and degree of simple extensions. Field extensions by more than one elements.

12th week

The multiplicativity formula for degrees. Algebraic numbers, the field of algebraic numbers is algebraically closed. Construction of the quotient field (without the proof of uniqueness).

13th week

Characteristic of a field, prime field. Construction of finite fields, primitive roots, subfields of finite fields. Existence of irreducible polynomials of arbitrary degree over the p-element field. Geometric constructions: the Delean problem, trisection of an angle and squaring a circle are unsolvable with a compass and a straightedge.

14th week

Students can ask questions and get an overview on the subject material in all topics prior to the second test.

Requirements:

- *for a signature*

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- *for a grade*

The preliminary requirement to pass the course is to obtain at least 51 percent of total points from short tests written on a once a week basis with the exception of the 1st, 7th and 14th week.

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 39	fail (1)
40 – 49	pass (2)

50 – 59	satisfactory (3)
60 – 69	good (4)
70 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.
-an offered grade:
It is not possible to obtain an offered grade in this course.

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

Lecturer: Dr. László Remete, assistant professor, PhD

Title of course: Algebra 2. **Code**: TTMBE0105	**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): TTMBE0104

Further courses built on it:

Topics of course

Sylow´s theorems. Semidirect product. Maximal subgroups of p-groups are normal of index p. Characteristic subgroup, commutator. Solvable groups and their basic properties. Alternating group is simple if acting on at least 5 points. Free groups, generators, relations, Dyck´s theorem. Necessary and sufficient condition for a ring to be a unique factorization domain, ascending and descending chain conditions. Field of fractions. Artinian and Noetherian rings, Hilbert´s basis theorem. Algebras, minimal polynomial over algebras. Frobenius´ theorem. Splitting field, existence, uniqueness, algebraic closure, existence. Normal extensions, extensions of perfect fields are simple. Galois theory. Funadamental theorem of algebra. Compass and straightedge constructions. Theorem of Abel and Ruffini, Casus Irreducibilis is unavoidable for degree three polynomials.

Literature

Compulsory:

-

Recommended:

John B. Fraleigh: A first course in abstract algebra, Addison-Wesley Publishing Company, 1989.

Derek J. S. Robinson: A course in the theory of groups, Sringer-Verlag, 1980.

Schedule:

1st week

Sylow's theorems. Semidirect products.

2nd week

Maximal subgroups of p-groups are normal of index p. Characteristic subgroup, commutator. Fundamental theorem of finite Abelian groups.

3rd week

Isomorphism theorems. Solvable groups and their basic properties. Alternating group is simple if acting on at least 5 points.

4th week

Free groups, generators, relations, Dyck's theorem.
5th week
Necessary and sufficient condition for a ring to be a unique factorization domain, ascending and descending chain conditions.
6th week
Field of fractions. Artinian and Noetherian rings, Hilbert's basis theorem.
7th week
First test.
8th week
Algebras, minimal polynomial over algebras, Frobenius' theorem.
9th week
Splitting field, existence, uniqueness, algebraic closure existence, uniqueness.
10th week
Normal extensions, finite extensions of perfect fields are simple.
11th week
Fundamental theorem of Galois theory.
12th week
Fundamental theorem of algebra. Compass and straightedge constructions.
13th week
Theorem of Abel and Ruffini, Casus Irreducibilis is unavoidable for degree three polynomials.
14th week
Second test.

Requirements:
- for a signature
If the student fail the course TTMBG0105, then the signature is automatically denied.
- for a grade
The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 39	fail (1)
40 – 49	pass (2)
50 – 59	satisfactory (3)
60 – 69	good (4)
70 – 100	excellent (5)

-an offered grade:
It is not possible to obtain an offered grade in this course.

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

Lecturer: Dr. László Remete, assistant professor, PhD

Title of course: Algebra 2. **Code**: TTMBG0105	**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: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0104

Further courses built on it: -

Topics of course

Sylow´s theorems. Semidirect product. Maximal subgroups of p-groups are normal of index p. Characteristic subgroup, commutator. Solvable groups and their basic properties. Alternating group is simple if acting on at least 5 points. Free groups, generators, relations, Dyck´s theorem. Necessary and sufficient condition for a ring to be a unique factorization domain, ascending and descending chain conditions. Field of fractions. Artinian and Noetherian rings, Hilbert´s basis theorem. Algebras, minimal polynomial over algebras. Frobenius´ theorem. Splitting field, existence, uniquencess, algebraic closure, existence. Normal extensions, extensions of perfect fields are simple. Galois theory. Funadamental theorem of algebra. Compass and straightedge constructions. Theorem of Abel and Ruffini, Casus Irreducibilis is unavoidable for degree three polynomials.

Literature

Compulsory:

-

Recommended:

John B. Fraleigh: A first course in abstract algebra, Addison-Wesley Publishing Company, 1989.

Derek J. S. Robinson: A course in the theory of groups, Sringer-Verlag, 1980.

Schedule:

1st week

Sylow's theorems. Semidirect products.

2nd week

Maximal subgroups of p-groups are normal of index p. Characteristic subgroup, commutator. Fundamental theorem of finite Abelian groups.

3rd week

Isomorphism theorems. Solvable groups and their basic properties. Alternating group is simple if acting on at least 5 points.

4th week
Free groups, generators, relations, Dyck's theorem.
5th week
Necessary and sufficient condition for a ring to be a unique factorization domain, ascending and descending chain conditions.
6th week
Field of fractions. Artinian and Noetherian rings, Hilbert's basis theorem.
7th week
Students can ask questions and get an overview on the subject material in all topics prior to the first test.
8th week
Algebras, minimal polynomial over algebras, Frobenius' theorem.
9th week
Splitting field, existence, uniqueness, algebraic closure existence, uniqueness.
10th week
Normal extensions, finite extensions of perfect fields are simple.
11th week
Fundamental theorem of Galois theory.
12th week
Fundamental theorem of algebra. Compass and straightedge constructions.
13th week
Theorem of Abel and Ruffini, Casus Irreducibilis is unavoidable for degree three polynomials.
14th week
Students can ask questions and get an overview on the subject material in all topics prior to the second test.

Requirements:
- for a signature
Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.
- for a grade
The preliminary requirement to pass the course is to obtain at least 51 percent of total points from short tests written on a once a week basis with the exception of the 1st, 7th and 14th week.

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 39	fail (1)
40 – 49	pass (2)
50 – 59	satisfactory (3)
60 – 69	good (4)
70 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.
-an offered grade:
It is not possible to obtain an offered grade in this course.

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

Lecturer: Dr. László Remete, assistant professor, PhD

Title of course: Number theory **Code**: TTMBE0106	**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): TTMBG001, TTMBE0101

Further courses built on it: TTMBE0109, TTMBG0110

Topics of course

Orders of elements, generators and their description in Zp. Quadratic residues modulo p. Residues of higher degree. Arithmetic functions. Additive and multiplicative functions, some important arithmetic functions. Summatory function and Mobius-transform of arithmetic functions. The infinitude of the set of primes. Famous problems concerning primes. Primes in arithmetic progressions, the theorem of Dirichlet. The sume of the reciprocals of primes. The $\Pi(x)$ function, the prime number theorem. Lattices, the theorems of Blichfeldt and Minkowski and their applications. The Waring problem. Pythagorean triples. Algebraic numbers, algebraic integers. The field of algebraic numbers and the ring of algebraic integers. Algebraic number fields. Degree, basis, integers and units of a number fields. Quadratic number fields and their representations in the form $Q(\sqrt{d})$.

Literature

Compulsory:

-

Recommended:

I. Niven, H. S. Zuckerman, H. L. Montgomery: An Introduction to the Theory of Numbers, Wiley, 1991.

K. Ireland, M. Rosen, A classical introduction to modern number theory (Second edition), Springer-Verlag.

Tom Apostol, Introduction to Analytic Number Theory, Springer-Verlag.

Schedule:

1st week

Order of an element, generators and their description in Z_p.

2nd week

Quadratic residues modulo p. Legendre- and Jacobi-symbol and their properties. Quadratic reciprocity. Congruences of higher order.

3rd week

Number theoretical functions. Basic properties of additive and multiplicative functions.

4th week

Some important number theoretical functions, main properties and explicit formulas.

5th week

Summation and Mobius-transform of number theoretical functions. Mobius inversion theorem and its application to multiplicative functions.

6th week

The infinitude of the set of primes. Famous problems concerning primes: twin primes, Mersenne-primes, Fermat-primes, Goldbach's problems.

7th week

Primes in arithmetic progressions, Dirichlet's theorem, special cases, the Green-Tao theorem. The divergence of the sum of the reciprocals of primes.

8th week

The behavior of the $\Pi(x)$ function, estimates for $\Pi(x)$, the theorem of Chebishev. The density of the sequence of primes. The prime number theorem. Consequences, the asymptotic behavior of the n-th prime. The existence of arbitrarily long intervals containing no primes.

9th week

Lattices in R^n. Bases of a lattice, unimodular transformations and unimodular matrices. The fundamental parallelepiped and the lattice determinant. Lattices as discrete subgroups of R^n.

10th week

The theorems od Blichfeldt and Minkowski, and their applications for systems of linear Diophantine inequalities.

11th week

The Waring problem. Representing positive integers as sums of squares and higher powers. Pithagorean triples and reduced Pithagorean triples, Fermat's equation.

12th week

Algebraic numbers, algebraic integers. Degree, algebraic conjugates. The defining monic polinomial of an algebraic number and its properties. The field of the algebraic numbers, the ring of the algebraic integers. Transcendental numbers.

13th week

Algebraic number fields. Degree, basis, ring of integers, group of units.

14th week

Quadratic number fields and their representation in the form $Q(\sqrt{d})$. Norm and its properties in imaginary quadratic fields. Euklidean division in the rings of Gauss integers and Euler integers. Example for a ring having no unique factorization.

Requirements:

- for a signature

If the student fail the course TTMBG0106, then the signature is automatically denied.

- for a grade

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	**Grade**
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

-an offered grade:

It is not possible to obtain an offered grade in this course.
Person responsible for course: Prof. Dr. Lajos Hajdu, university professor, DSc
Lecturer: Prof. Dr. Lajos Hajdu, university professor, DSc

Title of course: Number theory **Code**: TTMBG0106	**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: - - preparation for the exam: 32 hours Total: 60 hours	
Year, semester: 2nd year, 1st semester	
Its prerequisite(s): TTMBG001, TTMBE0101	
Further courses built on it: -	

Topics of course

Orders of elements, generators and their description in Zp. Quadratic residues modulo p. Residues of higher degree. Arithmetic functions. Additive and multiplicative functions, some important arithmetic functions. Summatory function and Mobius-transform of arithmetic functions. The infinitude of the set of primes. Famous pronblems concerning primes. Primes in arithmetic progressions, the theorem of Dirichlet. The sume of the reciprocals of primes. The $\Pi(x)$ function, the prime number theorem. Lattices, the theorems of Blichfeldt and Minkowski and their applications. The Waring problem. Pithagorean triples. Algebraic numbers, algebraic integers. The field of algebraic numbers and the ring of algebraic integers. Algebraic number fields. Degree, basis, integers and units of a number fields. Quadratic number fields and their representations int he form $Q(\sqrt{d})$.

Literature

Compulsory:

-

Recommended:

I. Niven, H. S. Zuckerman, H. L. Montgomery: An Introduction to the Theory of Numbers, Wiley, 1991.

K. Ireland, M. Rosen, A classical introduction to modern number theory (Second edition), Springer-Verlag.

Tom Apostol, Introduction to Analytic Number Theory, Springer-Verlag.

Schedule:

1st week

Order of an element, generators and their description in Z_p.

2nd week

Quadratic residues modulo p. Legendre- and Jacobi-symbol and their properties. Quadratic reciprocity. Congruences of higher order.

3rd week

Number theoretical functions. Basic properties of additive and multiplicative functions.

4th week

Some important number theoretical functions, main properties and explicit formulas.

5th week

Summation and Mobius-transform of number theoretical functions. Mobius inversion theorem and its application to multiplicative functions.

6th week

The infinitude of the set of primes. Famous problems concerning primes: twin primes, Mersenne-primes, Fermat-primes, Goldbach's problems. Primes in arithmetic progressions, Dirichlet's theorem, special cases, the Green-Tao theorem.

7th week

First test.

8th week

The divergence of the sum of the reciprocals of primes. The behavior of the $\Pi(x)$ function, estimates for $\Pi(x)$, the theorem of Chebishev. The density of the sequence of primes. The prime number theorem. Consequences, the asymptotic behavior of the n-th prime. The existence of arbitrarily long intervals containing no primes.

9th week

Lattices in R^n. Bases of a lattice, unimodular transformations and unimodular matrices. The fundamental parallelepiped and the lattice determinant. Lattices as discrete subgroups of R^n.

10th week

Theorems of Minkowski and Blichfeldt and applications concerning system of linear inequalities.

11th week

The Waring problem. Representing positive integers as sums of squares and higher powers. Pithagorean triples and reduced Pithagorean triples, Fermat's equation.

12th week

Algebraic numbers, algebraic integers. Degree, algebraic conjugates. The defining monic polinomial of an algebraic number and its properties. The field of the algebraic numbers, the ring of the algebraic integers. Transcendental numbers.

13th week

Algebraic number fields. Degree, basis, ring of integers, group of units. Quadratic number fields and their representation in the form $Q(\sqrt{d})$. Norm and its properties in imaginary quadratic fields. Euklidean division in the rings of Gauss integers and Euler integers. Example for a ring having no unique factorization.

14th week

Second test.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- for a grade

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 60	fail (1)
61 – 70	pass (2)

71 – 80	satisfactory (3)
81 – 90	good (4)
91 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.
-an offered grade:
It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Lajos Hajdu, university professor, DSc

Lecturer: Prof. Dr. Lajos Hajdu, university professor, DSc

Title of course: Combinatorics and graph theory **Code**: TTMBE0107	**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: TTMBE0606

Topics of course

Fundamental enumeration problems: permutations, variations, combinations. Properties of binomial coefficients, binomial and multinomial theorem. Inversions, parity, product of permutations, cycles. Inclusion–exclusion principle and applications. Basic definitions of graph theory. Eulerian trail, Hamiltonian path and cycle. Trees and forests, spanning trees, Prüfer code and Cayley's formula. Bipartite graphs. Plane graphs, dual graph, Euler's formula, planar graphs and their characterization. Vertex and edge colourings of graphs, chromatic number, the five color theorem, chromatic polynomial, chromatic index. Fundamentals of Ramsey theory. Matrices of graphs.

Literature

Compulsory:

-

Recommended:

Béla Andrásfai: Introductory Graph Theory, Akadémiai Kiadó, 1977.
N. Ya. Vilenkin: Combinatorics, Academic Press, 1971.
Miklós Bóna: A Walk Through Combinatorics, World Scientific, 2017.

Schedule:

1st week

Pigeonhole principle and applications. Factorials, Stirling's formula, binomial coefficients.

2nd week

Permutations, variations, combinations with and without repetitions. Properties and sums of binomial coefficients.

3rd week

Binomial and multinomial theorem. Inversions, parity, product of permutations, cycles.

4th week

Inclusion–exclusion principle and applications. Basic definitions and theorems of graph theory.

5th week

Graphs with given degree sequences. Walk, trail, path, cycle, connected graph, distance.

6th week

Eulerian trail, Hamiltonian path, Hamiltonian cycle, and theorems on their existence.

7th week

Trees and forests, equivalent definitions of trees. Spanning trees, spanning forests, Prüfer code, Cayley's formula.

8th week

Bipartite graphs and characterization theorem. Plane graphs, dual graph, Euler's formula.

9th week

Planar graphs, Kuratowski's theorem.

10th week

Vertex colourings of graphs, chromatic number and bounds. Chromatic number of planar graphs, the five and four colour theorem.

11th week

Chromatic polynomial and properties, chromatic polynomial of trees. Edge colourings of graphs, chromatic index and bounds.

12th week

Ramsey numbers: the two-colour and the multicolour case, bounds, special values.

13th week

Adjacency and incidence matrices of graphs, characterization of fundamental graph properties using these matrices.

14th week

Fundamentals of the theory of directed graphs, directed acyclic graphs.

Requirements:

- for a signature

If the student fail the course TTMBG0107, then the signature is automatically denied.

- for a grade

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 –60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Dr. Gábor Nyul, associate professor, PhD

Lecturer: Dr. Gábor Nyul, associate professor, PhD

Title of course: Combinatorics and graph theory **Code**: TTMBG0107	**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: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Fundamental enumeration problems: permutations, variations, combinations. Properties of binomial coefficients, binomial and multinomial theorem. Inversions, parity, product of permutations, cycles. Inclusion–exclusion principle and applications. Basic definitions of graph theory. Eulerian trail, Hamiltonian path and cycle. Trees and forests, spanning trees, Prüfer code and Cayley's formula. Bipartite graphs. Plane graphs, dual graph, Euler's formula, planar graphs and their characterization. Vertex and edge colourings of graphs, chromatic number, the five color theorem, chromatic polynomial, chromatic index. Fundamentals of Ramsey theory. Matrices of graphs.

Literature

Compulsory:
-
Recommended:
Béla Andrásfai: Introductory Graph Theory, Akadémiai Kiadó, 1977.
N. Ya. Vilenkin: Combinatorics, Academic Press, 1971.
Miklós Bóna: A Walk Through Combinatorics, World Scientific, 2017.

Schedule:

1st week
Pigeonhole principle.
2nd week
Elementary combinatorial exercises.
3rd week
Elementary combinatorial exercises.
4th week
Combinatorial exercises under certain restrictions.
5th week

Parity, product of permutations, cycles.

6th week

Binomial and multinomial theorem.

7th week

First test.

8th week

Inclusion–exclusion principle.

9th week

Graphs with given degree sequences, Havel-Hakimi theorem.

10th week

Walk, trail, path, cycle, connectedness, distance.

11th week

Eulerian trail, Hamiltonian path, Hamiltonian cycle.

12th week

Trees and forests, Prüfer code.

13th week

Adjacency and incidence matrices of graphs. Chromatic polynomial of graphs.

14th week

Second test.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- for a grade

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 60	fail (1)
61 – 70	pass (2)
71 – 80	satisfactory (3)
81 – 90	good (4)
91 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Dr. Gábor Nyul, associate professor, PhD

Lecturer: Dr. Gábor Nyul, associate professor, PhD

Title of course: Foundations of analysis **Code**: TTMBG0212	**ECTS Credit points:** 2

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

Evaluation: exam

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

Total: 60 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: TTMBE0214, TTMBG0214, TTMBE0213

Topics of course

Foundations of logic and set theory. Cartesian product, relations: equivalence and order relations, functions. Properties of operations and the order on the set of real numbers. The notion of greatest lower and least upper bound; the least-upper-bound property. Exponential identities. Fractions and decimals. Mathematical induction. Inequalities. Sets of numbers of countable and continuum cardinality.

Literature

Compulsory:
- Walter Rudin: Principles of Mathematical Analysis, McGraw-Hill, New York, 1976.

Schedule:

1st week

Operations with sets, properties of the operations and De Morgan's laws.

2nd week

Ordered pairs, Cartesian product. Relations; domain, range and inverse of a relation. Composition of relations, properties of composition.

3rd week

Special types of relations: the notion of a function, injective, surjective and bijective functions. Connections between functions and set operations.

4th week

Special types of relations: equivalence relations and partitions. Ordering relations and partial orderings. Boundedness, minimum, maximum, greatest lower bound (infimum), least upper bound (supremum).

5th week
Power, exponential and logarithmic functions. Exponential identities.

6th week
Further exercises and problems.

7th week
First mid-term test.

8th week
Proofs by mathematical induction.

9th week
Inequalities containing absolute values, second order polynomials and fractions of first order polynomials.

10th week
Notable inequalities: Bernoulli's inequality, inequalities between harmonic, geometric and arithmetic means, Schwarz and Minkowski inequalities.

11th week
Fractions and decimals. Conversion between ordinary fractions and decimals.

12th week
Countable sets. Sets with the cardinality of the continuum.

13th week
Further exercises and problems.

14th week
Second mid-term test.

Requirements:
Participation in practical classes is compulsory. A student must attend the practical 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. Students write two mid-term tests during the semester. At the end of the semester one of the two tests can be repeated. The result of the repeated test will replace the original one. The mark will be determined by the sum of the points of the two mid-term tests according to the following tabular:

Score (percent)	Grade
0—50	fail (1)
51—60	pass (2)
60—80	satisfactory (3)
81—90	good (4)
91—100	excellent (5)

In all other questions the Education and Examination Rules and Regulations of the University of

Debrecen must be consulted.
Person responsible for course: Dr. Rezső L. Lovas, assistant professor, PhD
Lecturer: Dr. Zoltán Boros, associate professor, PhD., habil. Dr. Eszter Novák-Gselmann, associate professor, PhD., habil. Dr. Zsolt Páles, university professor, PhD., habil., DSc.

Title of course: Introduction to analysis **Code**: TTMBE0214	**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: -
- preparation for the exam: 78 hours

Total: 120 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMBG0212

Further courses built on it: TTMBE0215

Topics of course

Convergence of sequences of real numbers. Relations between convergence, boundedness and monotonicity. The Bolzano–Weierstrass theorem and Cauchy's criterion for convergence. Convergence and operations, the relation between the limit and the order. Elementary sequences; the Euler number. Accumulation points, lower and upper limit of sequences. Applications. Convergence of sequences of complex numbers. The Bolzano–Weierstrass-theorem and Cauchy's criterion for sequences of complex numbers. Relations between convergence and the operations. Series of complex numbers; absolute and conditional convergence. Summation of series and operations, grouping and rearranging series. Riemann's theorem. Complex geometric series; the comparison, root and ratio tests. Abel's formula; the theorems of Dirichlet, Leibniz and Abel. Cauchy product, Mertens theorem. Pointwise and uniform convergence of function sequences and series. Cauchy's criterion and the sufficient condition of Weiersrass for uniform convergence. Power series; the Cauchy–Hadamard theorem. Elementary functions and their addition formulas. Metric spaces, normed spaces, Banach spaces, Euclidean spaces. Basic notions in metric spaces. Equivalent metrics and equivalent norms. Hausdorff's criterion for compactness. Special norms of Euclidean spaces. The Bolzano–Weierstrass-theorem and the Heine–Borel theorem. Continuity and its characterization in terms of sequences in metrc spaces. Continuity and operations, the continuity of composite functions. Relations between compactness and continuity, respectively connectedness and continuity. Continuous bijections on compact sets. Uniform continuity and its characterization.

Literature

Compulsory:

1. W. Rudin: Principles of Mathematical Analysis. McGraw-Hill, 1964.
2. E. Hewitt, K. R. Stromberg: Real and Abstract Analysis. Springer-Verlag, 1965.
3. K. R. Stromberg: An introduction to classical real analysis. Wadsworth, California, 1981.

Recommended:

Schedule:

1st week

Convergence of sequences of real numbers. Relations between convergence, boundedness and monotonicity. The Bolzano–Weierstrass theorem and Cauchy's criterion for convergence.

2nd week

Convergence and operations, the relation between the limit and the order. Elementary sequences; the Euler number.

3rd week

Accumulation points, lower and upper limit of sequences. Applications.

4th week

Convergence of sequences of complex numbers. The Bolzano–Weierstrass-theorem and Cauchy's criterion for sequences of complex numbers. Relations between convergence and the operations.

5th week

Complex geometric series; the comparison, root and ratio tests.

6th week

Abel's formula; the theorems of Dirichlet, Leibniz and Abel. Cauchy product, Mertens theorem.

7th week

Pointwise and uniform convergence of function sequences and series. Cauchy's criterion and the sufficient condition of Weiersrass for uniform convergence. Power series; the Cauchy–Hadamard theorem.

8th week

Elementary functions and their addition formulas.

9th week

Metric spaces, normed spaces, Banach spaces, Euclidean spaces. Basic notions in metric spaces.

10th week

Boundedness and uniform boundedness in metric spaces. Topology in metric spaces. Equivalent metrics and equivalent norms.

11th week

Compactness in metric spaces. Hausdorff's criterion for compactness.

12th week

Special norms of Euclidean spaces. The Bolzano–Weierstrass-theorem and the Heine–Borel theorem.

13th week

Continuity and its characterization in terms of sequences in metrc spaces. Continuity and operations, the continuity of composite functions.

14th week

Relations between compactness and continuity, respectively connectedness and continuity. Continuous bijections on compact sets. Uniform continuity and its characterization.

Requirements:

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

Score	Grade
0-59%	fail (1)
60-69%	pass (2)

70-79% satisfactory (3) 80-89% good (4) 90-100% excellent (5) In general, the EDUCATION AND EXAMINATION RULES AND REGULATIONS have to be taken into account.
Person responsible for course: Dr. Tibor Kiss, assistant professor, PhD
Lecturer: Dr. Tibor Kiss, assistant professor, PhD

Title of course: Introduction to analysis **Code**: TTMBG0214	**ECTS Credit points: 3**

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

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 42 hours
- laboratory: -
- home assignment: 32 hours
- preparation for the exam: -

Total: 74 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMBG0212

Further courses built on it: TTMBE0214

Topics of course

Convergence of sequences of real numbers. Convergence and operations, the relation between the limit and the order. Elementary sequences; the Euler number. Convergence of sequences of complex numbers. Series of complex numbers; absolute and conditional convergence. Summation of series and operations, grouping and rearranging series. Complex geometric series; the comparison, root and ratio tests. Pointwise and uniform convergence of function sequences and series. Cauchy's criterion and the sufficient condition of Weiersrass for uniform convergence. Power series; the Cauchy–Hadamard theorem. Elementary functions and their addition formulas. Metric spaces, normed spaces, Banach spaces, Euclidean spaces. Basic notions in metric spaces. Special norms of Euclidean spaces. Continuity and its characterization in terms of sequences in metric spaces.

Literature

Compulsory:
1. W. Rudin: Principles of Mathematical Analysis. McGraw-Hill, 1964.
2. E. Hewitt, K. R. Stromberg: Real and Abstract Analysis. Springer-Verlag, 1965.
3. K. R. Stromberg: An introduction to classical real analysis. Wadsworth, California, 1981.

Recommended:

Schedule:

1st week

Convergence of sequences of real numbers. Cauchy's criterion for convergence.

2nd week

Convergence and operations, the relation between the limit and the order. Elementary sequences; the Euler number (ratio of polynomials and exponential polynomials, difference of roots).

3rd week

Convergence and operations, the relation between the limit and the order. Elementary sequences;

the Euler number (n-square and n-power of ratio of linear expressions).

4th week

Convergence of series via definition, via determining the closed form of partial sums.

5th week

Complex geometric series; the comparison, root and ratio tests.

6th week

Summary.

7th week

Mid-term test.

8th week

Power series and elementary functions.

9th week

Pointwise and uniform convergence of sequence and series of functions.

10th week

Metric spaces, normed spaces, Banach spaces, Euclidean spaces. Special norms of Euclidean spaces.

11th week

Topology and compactness in metric spaces.

12th week

Continuity and its characterization in terms of sequences in Euclidean spaces.

13th week

Summary.

14th week

End-term test.

Requirements:

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

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

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

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

Person responsible for course: Dr. Tibor Kiss, assistant professor, PhD

Lecturer: Dr. Tibor Kiss, assistant professor, PhD

Title of course: Differential and integral calculus **Code**: TTMBE0215	**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: -
- preparation for the exam: 78 hours

Total: 120 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0214, TTMBG0215

Further courses built on it: TTMBE0216

Topics of course

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

Literature

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

Recommended:

Schedule:

1st week

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

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

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

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

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

Person responsible for course: Dr. Tibor Kiss, assistant professor, PhD

Lecturer: Dr. Tibor Kiss, assistant professor, PhD

Title of course: Differential and integral calculus **Code**: TTMBG0215	**ECTS Credit points: 3**

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

Evaluation: mid-semester grade

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

Total: 90 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0214

Further courses built on it: TTMBE0215

Topics of course

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

Literature

Compulsory:

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

Recommended:

Schedule:

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

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

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

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

5th week
Monotonicity, convexity, extrema of functions.

6th week
Summary

7th week
Midterm test.

8th week
Basic integrals, rules of integration.

9th week

Integration of partial fractions.

10th week

Applications of the integration of partial fractions.

11th week
Riemann sums and Riemann integral. The Newton–Leibniz theorem. Improper Riemann integrals.

12th week
Inequalities for Riemann integral.

13th week

Summary.

14th week
Endterm test.

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

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

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

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

Person responsible for course: Dr. Tibor Kiss, assistant professor, PhD

Lecturer: Dr. Tibor Kiss, assistant professor, PhD

Title of course: Sets, functions, real numbers **Code**: TTMBE0213	**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): TTMBG0212

Further courses built on it: -

Topics of course

Foundations of set theory. Relations. Equivalence and order relations, functions. Basic notions in partially ordered sets and Tarski's fixed point theorem. Cardinality of sets, Cantor's theorem and the Schröder–Bernstein theorem. Axioms of the real numbers and their corollaries. Notable subsets of the reals: natural numbers, integers, rational and irrational numbers. Uniqueness of the set of real numbers. Existence and uniqueness of the nth root. The p-adic represantion of real numbers. Notable inequalities. The field of complex numbers. Cardinality of sets of numbers.

Literature

Compulsory:
- Walter Rudin: Principles of Mathematical Analysis, McGraw-Hill, New York, 1976.

Schedule:

1st week

Basic notions of set theory. Axiom of empty set, axiom of extensionality, axiom of pair, axiom of union, axiom of power set. Axiom of separation, Russel's theorem. Operations with sets, properties of the operations and De Morgan's laws.

2nd week

Ordered pairs, Cartesian product. Relations; domain, range and inverse of a relation. Composition of relations, properties of composition.

3rd week

The notion of a function, injective, surjective and bijective functions. Connections between functions and set operations. Indexed families of sets, axiom of choice.

4th week

Equivalence relations and partitions. Ordering relations and partial orderings, chains and intervals. Boundedness, minimum, maximum, infimum, supremum.

5th week

Completeness. Equivalent formulations of the axiom of choice: Zermelo's well ordering theorem, Hausdorff's maximum principal, Kuratowski—Zorn lemma.

6th week

Cardinality of sets. Comparison of cardinalities. Tarski's fixed point theorem and the Schröder—Bernstein theorem. Properties of relations of cardinalities.

7th week

Cardinality of a power set. Finite and infinite sets. Further axioms: axiom of regularity and axiom of infinity.

8th week

The axioms of real numbers. Corollaries of the field axioms and order axioms. The absolute value function. Dedekind's theorem and Cantor's theorem.

9th week

Natural numbers, Peano's axioms. The Archimedean property. Principle of induction and recursive definition. Properties of the binary operations. The binomial theorem and Bernoulli's inequality.

10th week

Integers, integer part and fractional part. Rational and irrational numbers, denseness theorems. Uniqueness of the set of real numbers.

11th week

Definition and existence of nth roots. Powers with rational exponents. p-adic fractions.

12th week

Notable inequalities. Power means. Inequality between the arithmetic, geometric and harmonic means. Schwarz and Minkowski inequalities.

13th week

The set of complex numbers and its algebraic structure. Real part, imaginary part, conjugate and absolute value of a complex number. Schwarz inequality for complex numbers.

14th week

Finite and infinite sets. Countable sets and the cardinality of the continuum. Cardinality of the set of natural numbers, integers, rational, real and complex numbers.

Requirements:

The course ends in an oral exam. In the exam students give an account on two exam questions. Students who reveal a profound lack of knowledge will fail the exam. Students who cannot prove the theorems in their exam questions can get at most a satisfactory (3) grade. Concerning all other questions, the Education and Examination Rules and Regulations of the University of Debrecen

must be consulted.
Person responsible for course: Dr. Rezső L. Lovas, assistant professor, PhD
Lecturer: Dr. Zoltán Boros, associate professor, PhD., habil. Dr. Eszter Novák-Gselmann, associate professor, PhD., habil.

Title of course: Differential and integral calculus in several variables **Code**: TTMBE0216	**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: -
- preparation for the exam: 78 hours

Total: 120 hours

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

Its prerequisite(s): TTMBE0215

Further courses built on it:

Topics of course

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

Literature

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

Schedule:

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

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

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

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

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

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

7th week Compact intervals in Euclidean spaces. Partitions of intervals. The lower and upper Riemann sums of bounded functions and their basic properties. The lower and upper Darboux integrals and their properties. The Darboux theorem. The additive interval property of the Darboux integrals.

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

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

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

11th week The Jordan measure and its properties. Characterization of Jordan measurability and Jordan null sets. The Riemann integral over Jordan measurable sets. Algebraic properties, connection of integrability and continuity. The Fubini theorem on simple regions. Change of variables.

12th week Functions of bounded variation and their structure. The additive interval property of total variation, the Jordan decomposition theorem and its corollaries. The computation of the total variation.

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

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

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 (TTMBG0216). The grade for the examination is given according to the following table:

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

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

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

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

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

Title of course: Differential and integral calculus in several variables **Code**: TTMBG0216	**ECTS Credit points: 3**

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

Evaluation: mid-semester grade

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: 2nd year, 2nd semester

Its prerequisite(s): TTMBE0215

Further courses built on it:

Topics of course

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

Literature

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

Schedule:

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

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

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

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

5th week Optimization problems with equality and inequality constraints and applications of the method of Lagrange Multipliers.

6th week Survey of the results and methods of the 1st-5th weeks.

7th week Mid-term test.

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

9th week Computation of the Riemann integral using change of variables.

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

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

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

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

14th week End-term test.

Requirements:

- for a signature

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

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

- for a grade

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

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

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

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

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

Title of course: Ordinary differential equations **Code**: TTMBE0217	**ECTS Credit points:** 4
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, 1st semester	
Its prerequisite(s): TTMBE0216	
Further courses built on it:	

Topics of course

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

Literature

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

Schedule:

1st week

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

Separable, linear and exact equations. The Euler multiplicator.

2nd week

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

3rd week

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

4th week

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

5th week

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

6th week

Peano's existence theorem.

7th week

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

8th week

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

9th week

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

10th week

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

11th week

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

12th week

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

13th week

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

14th week

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

discussion of classical mechanics.
Requirements: - *for a signature* Attendance at **lectures** is recommended, but not compulsory. - *for a grade* The course ends in an **examination**. Before the examination students must have grade at least 'pass' on ordinary differential equations practice (TTMBG0217). The grade for the examination is given according to the following table: Score — Grade 0-49 — fail (1) 50-61 — pass (2) 62-74 — satisfactory (3) 75-87 — good (4) 88-100 — excellent (5) If the average of the score of the examination is below 50, students can take a retake examination in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.
Person responsible for course: Prof. Dr. György Gát, university professor, DSc
Lecturer: Prof. Dr. György Gát, university professor, DSc

Title of course: Ordinary differential equations
Code: TTMBG0217

ECTS Credit points: 2

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

Evaluation: exam

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

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): Differential and integral calculus in several variables: TTMBE0216

Further courses built on it:

Topics of course

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

Literature

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

Schedule:

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 14^{th} week. Students have to sit for the tests.

- *for a grade*

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

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

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

Person responsible for course: Prof. Dr. György Gát, university professor, DSc

Lecturer: Prof. Dr. György Gát, university professor, DSc

Title of course: Geometry 1. **Code**: TTMBE0301	**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): TTMBG0301 (p)	
Further courses built on it: Geometry 2.	

Topics of course

Absolute Geometry: incidence axioms, ruler postulate, plane separation postulate, protractor postulate and the axiom of congruence. Some representative results in Absolute Geometry: congruence theorems, perpendicular and parallel lines, sufficient conditions for parallelism, inequalities. The Euclidean parallel postulate and some equivalent statements. Introduction to the Euclidean geometry (theorems for parallelograms, Intercept theorem and its relatives, similar triangles). Euclidean plane isometries: three mirrors suffice, the classification theorem. The classification of the Euclidean space isometries. Similarities, the fixpoint theorem and the classification of plane/space similarities. The general notion of congruence and similarity. Geometric measure theory: area of polygons, Jordan measure, the area of a circle. The axioms of measuring volumes, the volume of a sphere . The perimeter of a circle, the area of a sphere.

Literature

Compulsory/Recommended Readings:
Csaba Vincze and László Kozma: College Geometry, TÁMOP-4.1.2.A/1-11/1-2011-0098,
http://www.tankonyvtar.hu/hu/tartalom/tamop412A/2011-0098_college_geometry/index.html
John Roe: Elementary Geometry, Oxford University Press, 1993.

Schedule:

1st week

Incidence axioms.

2nd week

Ruler postulate, plane separation postulate.

3rd week

Protractor postulate and the axiom of congruence.

4th week

Some representative results in Absolute Geometry: congruence theorems.

5th week

Some representative results in Absolute Geometry: perpendicular and parallel lines, sufficient conditions for parallelism.

6th week

Inequalities.

7th week

The Euclidean parallel postulate and some equivalent statements.

8th week

Introduction to the Euclidean geometry (theorems for parallelograms, Intercept theorem and its relatives, similar triangles).

9th week

Euclidean plane isometries: three mirrors suffice, the classification theorem.

10th week

The classification of the Euclidean space isometries.

11th week

Similarities, the fixpoint theorem and the classification of plane/space similarities. The general notion of congruence and similarity.

12th week

Geometric measure theory: area of polygons, Jordan measure, the area of a circle.

13th week

The axioms of measuring volumes, the volume of a sphere.

14th week

The perimeter of a circle, the area of a sphere.

Requirements:

- for a signature

- for a grade

Attendance at **lectures** is recommended, but not compulsory. The course ends in an **examination**. A practice grade at least 2 (pass) is a prerequisite to take an exam. The minimum requirement of the exam is more than 60 %. The grade is given according to the following table:

Percent	Grade
0-60	fail (1)
61-70	pass (2)
71-80	satisfactory (3)
81-90	good (4)
91-100	excellent (5)

-an offered grade:

Person responsible for course: Prof. Dr. Csaba Vincze, university professor, PhD

Lecturer: Prof. Dr. Csaba Vincze, university professor, PhD

Title of course: Geometry 1. **Code**: TTMBG0301	**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: - - preparation for the exam: 32 hours Total: 60 hours	
Year, semester: 1st year, 1st semester	
Its prerequisite(s): -	
Further courses built on it: Geometry 2.	

Topics of course

Triangles and circles. Trigonometry and its applications (inaccessible distances, visibility angles). Coordinate geometry and its applications (triangles and circles), intersections. Ruler-and-compass constructions. Inversive geometry, Mohr-Masceroni's theorem. The problem of Apollonius. Conics and the reflective properties (tangent lines to ellipses, paraboles and hyperboles). Ruler-and-compass constructions related to conics. The geometry of the space (area, volume), revolution surfaces. Conic sections. The sphere (longitude and latitude), mappings of the sphere to the plane.

Literature

Compulsory/Recommended Readings:
Csaba Vincze and László Kozma: College Geometry, TÁMOP-4.1.2.A/1-11/1-2011-0098, http://www.tankonyvtar.hu/hu/tartalom/tamop412A/2011-0098_college_geometry/index.html
John Roe: Elementary Geometry, Oxford University Press, 1993.

Schedule:

1st week

Triangles.

2nd week

Circles.

3rd week

Trigonometry and its applications (inaccessible distances, visibility angles).

4th week

Coordinate geometry and its applications (triangles).

5th week

Coordinate geometry and its applications (circles).

6th week

Intersections.

7th week

Ruler-and-compass constructions.

8th week

Inversive geometry.

9th week

Mohr-Masceroni's theorem.

10th week

The problem of Apollonius.

11th week

Conics and the reflective properties (tangent lines to ellipses, paraboles and hyperboles). Ruler-and-compass constructions.

12th week

The geometry of the space (area, volume).

13th week

Revolution surfaces. Conic sections.

14th week

The sphere (longitude and latitude), mappings of the sphere to the plane.

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. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence.

- for a grade

During the semester there are two tests. The minimum requirement for a grade is to get more than 60% of the total score of the two tests, separately. The grade is given according to the following table:

Percent	Grade
0-60	fail (1)
61-70	pass (2)
71-80	satisfactory (3)
81-90	good (4)
91-100	excellent (5)

If the score of any test is below 60%, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS. The final grade is the average of the grades of the two tests by the usual rules of rounding.

-an offered grade: -

Person responsible for course: Prof. Dr. Csaba Vincze, university professor, PhD

Lecturer: Prof. Dr. Csaba Vincze, university professor, PhD

Title of course: Geometry 2. **Code**: TTMBE0302	**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): TTMBE0102, TTMBG0302 (p)	
Further courses built on it: Differential geometry	

Topics of course

Euclidean-Affin Geometry: vectors. Affine transformations, translations and central similarities. The ratio of three collinear points. Some representative results in Affine Geometry: Ceva's theorem, Menelaus' theorem. Analytic Euclidean-Affine geometry. Linear transformations, the general linear group. The analytic description of affine transformations. The fundamental theorem. Dot and cross product, vector triple product: the geometric characterization and the analytic formulas. Higher dimensional analytic geometry: reflections and isometries of the n-dimensional Euclidean space. The orthogonal group. Lower dimensional cases: two- and three-dimesnional spaces. Coordinate geometry: lines and planes. Implicite and parametric forms. Quadratic curves and surfaces. An introduction to Convex Geometry: convex sets and convex hulls. Carathéodory's theorem. Radon's lemma and Helly's theorem. Convex polygons and polyhedra. Euler's theorem, Descartes' theorem, regular convex polyhedra.

Literature

Compulsory/Recommended Readings:
S. R. Lay: Convex Sets and Their Applications, John Wiley & Sons, Inc., 1982.
John Roe: Elementary Geometry, Oxford University Press, 1993.
Csaba Vincze: Convex Geometry, TÁMOP-4.1.2.A/1-11/1-2011-0025, http://www.tankonyvtar.hu/hu/tartalom/tamop412A/2011_0025_mat_14/index.html

Schedule:

1st week

Euclidean-Affin Geometry: vectors.

2nd week

Affine transformations, translations and central similarities.

3rd week

The ratio of three collinear points. Some representative results in Affine Geometry: Ceva's

theorem, Menelaus' theorem.
4th week
Analytic Euclidean-Affine geometry. Linear transformations, the general linear group.
5th week
The analytic description of affine transformations. The fundamental theorem.
6th week
Dot and cross product: the geometric characterization and the analytic formulas.
7th week
Vector triple product: the geometric characterization and the analytic formula.
8th week
Higher dimensional analytic geometry: reflections and isometries of the n-dimensional Euclidean space.
9th week
The orthogonal group.
10th week
Lower dimensional cases: two- and three-dimesnional spaces.
11th week
Coordinate geometry: lines and planes. Implicite and parametric forms.
12th week
Quadratic curves and surfaces.
13th week
An introduction to Convex Geometry: convex sets and convex hulls. Carathéodory's theorem. Radon's lemma and Helly's theorem.
14th week
Convex polygons and polyhedra. Euler's theorem, Descartes' theorem, regular convex polyhedra

Requirements:
- *for a signature*
- *for a grade*

Attendance at **lectures** is recommended, but not compulsory. The course ends in an **examination**. A practice grade at least 2 (pass) is a prerequisite to take an exam. The minimum requirement of the exam is more than 60 %. The grade is given according to the following table:

Percent	Grade
0-60	fail (1)
61-70	pass (2)
71-80	satisfactory (3)
81-90	good (4)
91-100	excellent (5)

-an offered grade:

Person responsible for course: Prof. Dr. Csaba Vincze, university professor, PhD

Lecturer: Prof. Dr. Csaba Vincze, university professor, PhD

Title of course: Geometry 2. **Code**: TTMBG0302	**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: 28 hours
- practice: -
- laboratory: -
- home assignment: -
- preparation for the exam: 32 hours

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): TTMEG0301

Further courses built on it: Differential geometry

Topics of course

The solution of geometric problems by vector algebra. The barycenter of a triangle and a tetrahedron. Linear dependency and independency, basis, coordinates. The simple ratio. The ellipse as the affine image of a circle. The area of an ellipse, compass-and-ruler constructions and the coordinate geometry of conics. Scalar, vector and mixed products. Computations in higher dimensional Euclidean vector spaces. Hyperplanes and reflections (analytic description). Reflections about lines and planes, rotations around lines and points. Lines, circles, planes and spheres. Intersections, distance and angles. Curves and surfaces (ruled- and revolution surfaces) implicit forms and parametrizations. Rolling without slipping: the cycloid. Twisted surfaces. Convex geometry.

Literature

Compulsory/Recommended Readings:

Csaba Vincze and László Kozma: College Geometry, TÁMOP-4.1.2.A/1-11/1-2011-0098,
http://www.tankonyvtar.hu/hu/tartalom/tamop412A/2011-0098_college_geometry/index.html
John Roe: Elementary Geometry, Oxford University Press, 1993.
Vincze Csaba: Convex Geometry, University of Debrecen, 2013, TÁMOP-4.1.2.A/1-11/1-2011-0025.

Schedule:

1st week

The solution of geometric problems by vector algebra.

2nd week

The barycenter of a triangle and a tetrahedron.

3rd week

Linear dependency and independency, basis, coordinates.

4th week

The simple ratio.

5th week

The ellipse as the affine image of a circle. The area of an ellipse.

6th week

Compass-and-ruler constructions.

7th week

The coordinate geometry of conics.

8th week

Scalar, vector and mixed products.

9th week

Computations in higher dimensional Euclidean vector spaces. Hyperplanes and reflections (analytic description).

10th week

Reflections about lines and planes, rotations around lines and points

11th week

Lines, circles, planes and spheres. Intersections, distance and angles.

12th week

Curves and surfaces (ruled- and revolution surfaces) implicit forms and parametrizations.

13th week

Rolling without slipping: the cycloid. Twisted surfaces.

14th week

Convex geometry.

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. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence.

- for a grade

During the semester there are two tests. The minimum requirement for a grade is to get more than 60% of the total score of the two tests, separately. The grade is given according to the following table:

Percent	Grade
0-60	fail (1)
61-70	pass (2)
71-80	satisfactory (3)
81-90	good (4)
91-100	excellent (5)

If the score of any test is below 60%, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS. The final grade is the average of the grades of the two tests by the usual rules of rounding.

-an offered grade: -

Person responsible for course: Prof. Dr. Csaba Vincze, university professor, PhD

Lecturer: Prof. Dr. Csaba Vincze, university professor, PhD

Title of course: Differential geometry **Code**: TTMBE0303	**ECTS Credit points: 3**
Type of teaching, contact hours - lecture: 2 hours/week - practice: - - laboratory: -	
Evaluation: exam	
Workload (estimated), divided into contact hours: - lecture: 28 hours - practice: - - laboratory: - - home assignment: 22 hours - preparation for the exam: 40 hours Total: 90 hours	
Year, semester: 3rd year, 1st semester	
Its prerequisite(s): TTMBE0302, TTMBE0216	
Further courses built on it: -	

Topics of course

Introduction to the basic concepts, methods and theories of classical differential geometry: A curve in the 2- or 3-dimensional Euclidean plane space. Curvature and torsion. Surfaces in the Euclidean space. The first and second fundamental form of parameterized surfaces. Measurement on a surface. Curvature of a surface. Relationships between basic fundamental quantities. Parallelism on a surface. Geodesics. Variation of arc length. The minimizing properties of geodesics.

Literature

Compulsory: -
Recommended:
M. do Carmo: Differential Geometry of curves and Surfaces,
M. Spivak: A Comprehensive Introduction to Differential Geometry, Vol. 3,
B. O'Neill: Elementary Differential Geometry

Schedule:

1st week

A regular smooth curve in the Euclidean space. Parametrization and reparametrization of curves. Arc-length. Natural parametrization.

2nd week

Curvature of regular planar curves. Frenet base. Winding number of closed curves. Fundamental theorem of planar curves.

3rd week

Biregular curves in the 3-dimensional Euclidean space. Frenet-basis, curvature and torsion of a biregular curve.

4th week

Cartan matrix associated to a biregular curve. Fundamental theorem of curves in the 3-dimensional Euclidean space.

5th week
Surfaces in the Euclidean space. Parametrization of surfaces. Tangent space, normal direction at a point.
6th week
Measurement on surfaces. The first fundamental form of parametrized elemental surfaces. The arc length and angle of curves on surfaces. Surface area.
7th week
The second fundamental form of parametrized surfaces. Osculating paraboloids, Dupin indicatrix, classification of points on surfaces.
8th week
Gauss and Weingarten maps. Curvature curves on surfaces. Normal curvature. Meusnier's theorem.
9th week
Main or principal curvatures and directions. Rodriguez's theorem, Euler's formula. Product curvature and average curvature.
10th week
The Gauss basis associated to the parametrized surfaces. Christoffel symbols. Relationships between basic fundamental quantities. Theorema egregium. Bonnet's theorem.
11th week
Parallelism on a surface. Parallel translation along a curve. Geodesic curves on a surface. Geodesic curvature.
12th week
Variation problem of arc length. The minimizing properties of geodesics.
13th week
The Gauss-Bonnet theorem.
14th week
Surfaces with constant curvature.

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

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-74	satisfactory (3)
75-86	good (4)
87-100	excellent (5)

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

Lecturer: Prof. Dr. Zoltán Muzsnay, university professor, DSc

Title of course: Differential geometry **Code**: TTMBG0303	**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: 42 hours - laboratory: - - home assignment: 18 hours - preparation for the exam: Total: 60 hours	
Year, semester: 3rd year, 1st semester	
Its prerequisite(s): TTMBE0302, TTMBE0216	
Further courses built on it: -	

Topics of course

Introduction to the basic concepts, methods and theories of classical differential geometry: A curve in the 2- or 3-dimensional Euclidean plane space. Curvature and torsion. Surfaces in the Euclidean space. The first and second fundamental form of parameterized surfaces. Measurement on a surface. Curvature of a surface. Relationships between basic fundamental quantities. Parallelism on a surface. Geodesics. Variation of arc length. The minimizing properties of geodesics.

Literature

Compulsory: -
Recommended:
M. do Carmo: Differential Geometry of curves and Surfaces,
M. Spivak: A Comprehensive Introduction to Differential Geometry, Vol. 3,
B. O'Neill: Elementary Differential Geometry

Schedule:

1st week

A regular smooth curve in the Euclidean space. Parametrization and reparametrization of curves. Arc-length. Natural parametrization.

2nd week

Curvature of regular planar curves. Frenet base. Winding number of closed curves. Fundamental theorem of planar curves.

3rd week

Biregular curves in the 3-dimensional Euclidean space. Frenet-basis, curvature and torsion of a biregular curve.

4th week

Cartan matrix associated to a biregular curve. Fundamental theorem of curves in the 3-dimensional Euclidean space.

5th week

Surfaces in the Euclidean space. Parametrization of surfaces. Tangent space, normal direction at a point.

6th week

Measurement on surfaces. The first fundamental form of parametrized elemental surfaces. The arc length and angle of curves on surfaces. Surface area.

7th week

The second fundamental form of parametrized surfaces. Osculating paraboloids, Dupin indicatrix, classification of points on surfaces.

8th week

Test. Gauss and Weingarten maps. Curvature curves on surfaces. Normal curvature. Meusnier's theorem.

9th week

Main or principal curvatures and directions. Rodriguez's theorem, Euler's formula. Product curvature and average curvature.

10th week

The Gauss basis associated to the parametrized surfaces. Christoffel symbols. Relationships between basic fundamental quantities. Theorema egregium. Bonnet's theorem.

11th week

Parallelism on a surface. Parallel translation along a curve. Geodesic curves on a surface. Geodesic curvature.

12th week

Variation problem of arc length. The minimizing properties of geodesics.

13th week

Surfaces with constant curvature.

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. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence.

- for a grade

During the semester one test is written. The grade is given according to the following table:

Score	Grade
0-49	fail (1)
50-59	pass (2)
60-74	satisfactory (3)
75-84	good (4)
85-100	excellent (5)

Students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.

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

Lecturer: Prof. Dr. Zoltán Muzsnay, university professor, DSc

Title of course: Vector Analysis Code: TTMBE0304	ECTS Credit points: 3

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

Evaluation: exam

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

Total: 90 hours

Year, semester: 3rd year, 2nd semester

Its prerequisite(s): TTMBE0216, TTMBG0304(p)

Further courses built on it: -

Topics of course

Scalar fields: level curves and surfaces. The gradient and its geometric interpretation. Vector fields, the invariants of the Jacobian matrix: divergence and rotation (the vector invariant of the skew-symmetric part of the Jacobian). The Laplace operator. Parametrized curves, line integrals and work done. Stokes' theorem and its applications in the plane: conservative vector fields and potential (path independence for line integrals, rotation-free vector fields, exact differential equations). Parametrized surfaces, surface integrals: the flux. Gauss-Ostrogradsky theorem and Stokes' theorem in the space. Divergence and flux density. Rotation and circulation density. Identities and computational rules for vector operators: gradient, divergence and rotation. The derivative of the determinant function: the special linear group and its Lie algebra. The orthogonal group and its Lie algebra. Displacement fields: strain and rotational tensors. Integral curves and flows. Divergence-free vector fileds (Liouville theorem, incompressible flows). Harmonic, subharmonic and superharmonic functions, the maximum principle.

Literature

Compulsory/Recommended Readings:

M. H. Protter, H. F. Weinberger: Maximum Principles in Differential Equations, Springer New York, 1984.

E. C. Young: Vector and Tensor Analysis, New York : M. Dekker, 1978.

Schedule:

1st week

Scalar fields: level curves and surfaces. The gradient and its geometric interpretation.

2nd week

Vector fields, the invariants of the Jacobian matrix: divergence and rotation (the vector invariant of the skew-symmetric part of the Jacobian). The Laplace operator.

3rd week

Parametrized curves, line integrals and work done.

4th week
Stokes' theorem and its applications in the plane: conservative vector fields and potential (path independence for line integrals, rotation-free vector fields, exact differential equations).
5th week
Parametrized surfaces, surface integrals: the flux.
6th week
Gauss-Ostrogradsky theorem.
7th week
Stokes' theorem in the space.
8th week
Divergence and flux density. Rotation and circulation density.
9th week
Identities and computational rules for vector operators: gradient, divergence and rotation.
10th week
The derivative of the determinant function: the special linear group and its Lie algebra.
11th week
The orthogonal group and its Lie algebra.
12th week
Displacement fields: strain and rotational tensors.
13th week
Integral curves and flows. Divergence-free vector fields (Liouville theorem, incompressible flows).
14th week
Harmonic, subharmonic and superharmonic functions, the maximum principle.

Requirements:
- *for a signature*
- *for a grade*

Attendance at **lectures** is recommended, but not compulsory. The course ends in an **examination**. A practice grade at least 2 (pass) is a prerequisite to take an exam. The minimum requirement of the exam is more than 60 %. The grade is given according to the following table:

Percent	Grade
0-60	fail (1)
61-70	pass (2)
71-80	satisfactory (3)
81-90	good (4)
91-100	excellent (5)

-an offered grade:

Person responsible for course: Prof. Dr. Csaba Vincze, university professor, PhD

Lecturer: Prof. Dr. Csaba Vincze, university professor, PhD

Title of course: Vector analysis **Code**: TTMBG0302	**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: 28 hours - practice: - - laboratory: - - home assignment: - - preparation for the exam: 32 hours Total: 60 hours	
Year, semester: 3rd year, 2nd semester	
Its prerequisite(s): TTMBE0216, TTMBG0304(p)	
Further courses built on it: -	

Topics of course

Scalar fields. Gradient and its geometric interpretation (level sets). Vector fields. Divergence and rotation. Laplacian. Identities. Parameterized curves. Line integrals. Stokes theorem in the plane and its applications: conservativity, potential, exact differential equations. Paremeterized surfaces. Surface integrals. Gauss-Ostrogradsky theorem and its consequences. Stokes theorem in the space and its applications. Newton's law of gravitation and its consequences: the conservativity of the gravitational field. Kepler's laws. Coordinate transforms and Jacobian (polar coordinates in the plane and in the space, cylindrical coordinates). The special linear group. The orthogonal group and its tangent space at the identity. Vector fields, integral curves and flows. Applications in the theory of differential equations. The maximum principle and its applications.

Literature

M. H. Protter, H. F. Weinberger: Maximum Principles in Differential Equations, Springer New York, 1984.
E. C. Young: Vector and tensor analysis, New York : M. Dekker, 1978.

Schedule:

1st week

Scalar fields and the gradient.

2nd week

Vector fields. Divergence and rotation. Laplacian.

3rd week

Identities and computational rules.

4th week

The parameterization of curves. Line integrals.

5th week

Stokes theorem in the plane and its applications: conservativity, potential, exact differential equations.

6th week

The parametrization of surfaces. Surface integrals.

7th week

Gauss-Ostrogradsky theorem and Stokes theorem in the space.

8th week

Newton's law of gravitation and its consequences: the conservativity of the gravitational field.

9th week

Kepler's laws.

10th week

Coordinate transforms and Jacobian (polar coordinates in the plane and in the space, cylindrical coordinates).

11th week

The special linear group. The orthogonal group and its tangent space at the identity.

12th week

Vector fields, integral curves and flows.

13th week

Applications in the theory of differential equations.

14th week

The maximum principle. Harmonic-, subharmonic and superharmonic functions.

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. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence.

- for a grade

During the semester there are two tests. The minimum requirement for a grade is to get more than 60% of the total score of the two tests, separately. The grade is given according to the following table:

Percent	Grade
0-60	fail (1)
61-70	pass (2)
71-80	satisfactory (3)
81-90	good (4)
91-100	excellent (5)

If the score of any test is below 60%, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS. The final grade is the average of the grades of the two tests by the usual rules of rounding.

-an offered grade: -

Person responsible for course: Prof. Dr. Csaba Vincze, university professor, PhD

Lecturer: Prof. Dr. Csaba Vincze, university professor, PhD

Title of course: Measure and integral theory **Code**: TTMBE0205	**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): TTMBE0215

Further courses built on it: TTMBE0401, TTMBG0401

Topics of course

Measure spaces and measures, their properties. Outer measures, pre-measures. Construction of measures. Lebesgue measure and its topological properties. Borel sets. The structure theorem of open sets. Approximation theorem. The properties of the Cantor set. Existence of non Lebesgue measurable sets. The Lebesgue–Stieltjes measure. Measurable functions and their basic properties, Lusin's theorem. Sequences of measurable functions. heorems of Lebesgue and Egoroff, Riesz's theorem on convergence in measure, approximation lemma. The Lebesgue integral of non-negative measurable functions. Beppo Levi's theorem, Fatou's lemma. The relation between the integral and the sum. Integrable functions. Lebesgue's majorized convergence theorem. The σ-additivity and the absolute continuity of the integral. The Lebesgue integral of complex functions. Lp spaces. Minkowski and Hölder inequality. The Riesz–Fischer theorem. The relation between the Riemann and the Lebesgue integral. Fubini's theorem. The n-dimensional Lebesgue measure. Lebesgue's differentiability theorem. Functions of bounded variation and absolute continuous functions. Basic properties of antiderivatives. The Newton–Leibniz formula.

Literature

Compulsory:
- H. Federer (1969): Geometric Measure Theory, Springer-Verlag
- Paul R. Halmos (1950): Measure Theory, D. Van Nostrand Company, Inc.

Recommended:
- Anthony W. Knapp (2005): Basic Real Analysis, Birkhauser

Schedule:

1st week

The definition of measure spaces and measures, and their most important properties.

2nd week

Outer measures and their characterization, the notion of premeasures. Construction of measures.

The definition of the Lebesgue measure.

3rd week

The notion of the Lebesgue measure and its most important topological properties. Borel sets. The structure theorem of open sets. Approximation theorem.

4th week

The construction and most important properties of the Cantor set. Existence of not Lebesgue measurable sets.

5th week

Lebesgue-Stieltjes measure. The definition and fundamental properties of measurable functions, Luzin theorem.

6th week

Sequences of measurable functions. The definition of convergence in measure and results related to it: theorems of Lebesgue and Egoroff, the selection theorem of Riesz, approximation lemma.

7th week

The Lebesgue integral of nonnegative measurable functions and its basic properties. The theorem of Beppo Levi. Fatou lemma.

8th week

The relation between the integral and the sum. Integrable functions and their fundamental properties.

9th week

Lebesgue’s majorized convergence theorem. The σ-additivity and the absolute continuity of the integral.

10th week

The Lebesgue integral of complex functions. Lp spaces. Minkowski and Hölder inequality. The Riesz–Fischer theorem.

11th week

The relation between the Riemann and the Lebesgue integral. Fubini’s theorem. The n-dimensional Lebesgue measure.

12th week

Lebesgue’s differentiability theorem.

13th week

Functions of bounded variation and absolute continuous functions. Basic properties of antiderivatives.

14th week

The Newton-Leibniz formula.
Requirements: The course ends in an **oral examination**. The process of the exam is as follows. First, a topic out of cca. eight is chosen randomly. The list of possible topics is made available for the students before the exam period. Then, the chosen topic should be elaborated in writing. Based partly on what has been written, an oral discussion of the topic follows, which also contains a few questions about other topics. The performance of the student during the exam is evaluated by a grade. Attendance of lectures is recommended, but not obligatory.
Person responsible for course: Dr. Gergő Nagy, associate professor, PhD
Lecturer: Dr. Gergő Nagy, associate professor, PhD

Title of course: Probability theory **Code**: TTMBE0401	**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: 40 hours
- preparation for the exam: 38 hours

Total: 120 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0205

Further courses built on it: -

Topics of course

Probability, random variables, distributions. Asymptotic theorems of probability theory.

Literature

Compulsory:
- A. N. Shiryayev: Probability, Springer-Verlag, Berlin, 1984.
- Ash, R. B.: Real Analysis and Probability. Academic Press, New York-London, 1972.
- Bauer, H.: Probability Theory. Walter de Gruyter, Berlin-New York. 1996.

Schedule:

1st week

Statistical observations. Numerical and graphical characteristics of the sample. Relative frequency, events, probability. Classical probability. Finite probability space.

2nd week

Kolmogorov's probability space. Properties of probability. Finite and countable probability spaces. Conditional probability, independence of events. Borel-Cantelli lemma.

3rd week

Total probability theorem, the Bayes rule. Discrete random variables. Expectation, Standard deviation. Binomial, hypergeometric, and Poisson distributions.

4th week

Random variables, distribution, cumulative distribution function. Absolutely continuous distribution, probability density function. The general notion of distribution.

5th week

Expectation, variance and median. Uniform, exponential, normal distributions.

6th week

Joint distribution function and joint probability density function of random variables. Independent random variables, correlation coefficient.

7th week

Multivariate distributions. Expectation vector and variance matrix of random a random vector. Independence of random variables.

8th week

Multivariate normal distribution, concentration ellipsoid. Sample from normal distribution. Chi-squared, Student's t, F-distributions.

9th week

Weak law of large numbers. Almost sure convergence, convergence in distribution, convergence in probability, Lp convergence.

10th week

Kolmogorov's inequality. Kolmogorov's three-series theorem. Strong laws of large numbers.

11th week

Characteristic function and its properties. Inversion formulas. Continuity theorem

12th week

Central limit theorem. Law of the iterated logarithm. Arcsine laws.

13th week

Conditional distribution function, conditional density function, conditional expectation.

14th week

Comparison of the limit theorems.

Requirements:

- for a grade

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

Lecturer: Prof. Dr. István Fazekas, university professor, DSc

Title of course: Probability theory **Code**: TTMBG0401	**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: 16 hours
- preparation for the exam: 16 hours

Total: 60 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0205

Further courses built on it: -

Topics of course

Probability, random variables, distributions. Asymptotic theorems of probability theory.

Literature

Compulsory:
- A. N. Shiryayev: Probability, Springer-Verlag, Berlin, 1984.
- Ash, R. B.: Real Analysis and Probability. Academic Press, New York-London, 1972.
- Bauer, H.: Probability Theory. Walter de Gruyter, Berlin-New York. 1996.

Schedule:

1st week

Statistical observations. Numerical and graphical characteristics of the sample. Relative frequency, events, probability. Classical probability. Finite probability space.

2nd week

Kolmogorov's probability space. Properties of probability. Finite and countable probability spaces. Conditional probability, independence of events. Borel-Cantelli lemma.

3rd week

Total probability theorem, the Bayes rule. Discrete random variables. Expectation, Standard deviation. Binomial, hypergeometric, and Poisson distributions.

4th week

Random variables, distribution, cumulative distribution function. Absolutely continuous distribution, probability density function. The general notion of distribution.

5th week

Expectation, variance and median. Uniform, exponential, normal distributions.

6th week

Joint distribution function and joint probability density function of random variables. Independent random variables, correlation coefficient.

7th week

Multivariate distributions. Expectation vector and variance matrix of random a random vector. Independence of random variables.

8th week

Multivariate normal distribution, concentration ellipsoid. Sample from normal distribution. Chi-squared, Student's t, F-distributions.

9th week

Weak law of large numbers. Almost sure convergence, convergence in distribution, convergence in probability, Lp convergence.

10th week

Kolmogorov's inequality. Kolmogorov's three-series theorem. Strong laws of large numbers.

11th week

Characteristic function and its properties. Inversion formulas. Continuity theorem

12th week

Central limit theorem. Law of the iterated logarithm. Arcsine laws.

13th week

Conditional distribution function, conditional density function, conditional expectation.

14th week

Comparison of the limit theorems.

Requirements:

- for a grade

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

Lecturer: Prof. Dr. István Fazekas, university professor, DSc

Title of course: Introduction to informatics **Code**: TTMBG0601	**ECTS Credit points:** 2

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

Evaluation: mid-semester grade

Workload (estimated), divided into contact hours:
- lecture: -
- practice: 42 hours
- laboratory: -
- home assignment: -
- preparation for the exam: 18 hours

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

An introduction to LaTeX, a document preparation system for high-quality typesetting. Typesetting of complex mathematical formulas in LaTeX. Presentation creation using the Beamer class. Writing a formal or business letter in LaTeX. Using the moderncv class for typesetting curricula vitae. The memoire class, a tool to create BSc/MSc thesis. Introduction to SageMath, a computer algebra package. The Jupyter Notebook interface and the SageMathCloud. Basic tools, assignment, equality, and arithmetic. Boolean expressions, loops, lists and sets. Writing functions in SageMath.

Literature

Compulsory:
-
Recommended:
T. Oetiker: The Not So Short Introduction to LaTeX.
Gregory Bard: SageMath for Undergraduates (http://www.gregorybard.com/Sage.html)

Schedule:

1st week
Basic usage of LaTeX. MikTeX and TeXLive distributions. The TeXmaker editor.

2nd week
Preparing LaTeX documents, basic mathematical formulas in LaTeX.

3rd week
Complex mathematical formulas, matrices, tables in LaTeX.

4th week
Presentation in LaTeX, the beamer package and its usage. Special LaTeX commands in presentations.

5th week
Definitions, theorems in LaTeX, the memoire package and its usage to prepare thesis. The bibtex

package.

6th week

The moderncv package, curriculum vitae and formal letter in LaTeX.

7th week

First test.

8th week

The SageMath computer algebra package, basic mathematical usage.

9th week

Functions related to the rings of integers, computing the gcd and the extended euclidean algorithm.

10th week

Polynomial rings in SageMath, rational functions and related commands.

11th week

Sets and lists in SageMath, basic operations, loops in lists and sets.

12th week

Trigonometric functions in SageMath, expanding and simplifying expressions.

13th week

Defining functions in SageMath, preparing plots. Solving special equations, systems of equations.

14th week

Second test.

Requirements:

- *for a signature*

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- *for a grade*

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	**Grade**
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Szabolcs Tengely, university professor, DSc

Lecturer: Prof. Dr. Szabolcs Tengely, university professor, DSc

Title of course: Programming languages **Code**: TTMBG0602	**ECTS Credit points:** 2

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

Evaluation: practice

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

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Brief introduction to programming, programming languages, and architecture in general. Sequential, conditional, and repeated execution, reuse. Values and types, expressions. Container data types and standard uses. Reading and writing files. Text processing with string methods and regular expressions. Object-oriented design in practice. Basics of networked programming, working with data over the internet. Fundamentals of using databases and visualisation of data. Complex programming exercises.

Literature

Compulsory:

-

Recommended:

Charles Severance, Python for Everybody: Exploring Data in Python 3, 2016.

Allen B. Downey, Think Python, 2012

Schedule:

1st week

General introduction to programming and programming languages. Simplified structure of programs: sequential, conditional, and repeated execution, reuse. Flowcharts, errors and debugging. About Python.

2nd week

Values and types, standard types in Python, differences between classes and types. Variables: assignment, naming conventions, and aliasing. Expressions: numerical and Boolean operations, orders of operations, short-circuit evaluation of logical expressions.

3rd week

Blocks and indentation in Python. Conditional execution: single conditionals, alternative executions, chained and nested conditionals, try and except. Repeated execution: definite loops, the range type, indefinite loops, infinite loops, and loop controls.

4th week

Functions: function calls, arguments and parameters, built-in and user-defined functions, fruitful and void functions, modules.

5th week

Classification of container data types: iterable, mutable, and ordered types. Strings, lists, tuples, sets, and dictionaries and their basic roles.

6th week

Files: open and close, read and write, creating new files and directories. Parsing strings with string methods.

7th week

Regular expressions as a formal language and as strings with standard and meta characters. Parsing strings with regular expression methods.

8th week

Object-oriented design: goals, principles, and patterns. Instances and methods: accessor, mutator, and manager methods. Classes in Python.

9th week

Networked programming: a brief introduction to HTML, XML, and JSON. Retrieving and processing content over the internet.

10th week

Networked programming continued.

11th week

Databases: a brief introduction to databases and SQL. Reading, writing, and processing data from databases.

12th week

Visualization of data.

13th week

Extensive programming class.

14th week

Final exam.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- for a grade

The course is evaluated on the basis of one written test and a homework project submitted during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the test is possible.

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Dr. András Bazsó, assistant professor, PhD
Lecturer: Dr. András Bazsó, assistant professor, PhD

Title of course: Algorithms **Code**: TTMBE0606	**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): -

Further courses built on it: -

Topics of course

Classification of programming languages. Multi-character symbols. Data types. Instruction types. Loops. Subprograms. The role of algorithms in computing. Functions, recursive functions. Probabilistic analysis. Randomized algorithms. Heap, heapsort. Quicksort. Sorting in linear time. Elementary data structures.

Literature

Compulsory:

-

Recommended:

T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein: Introduction to Algorithms, MIT Press, Cambridge, 2009 (3rd ed.)

István Juhász: Programming Languages.,
http://www.tankonyvtar.hu/en/tartalom/tamop425/0046_programming_languages/index.html

Schedule:

1st week

Introduction, foundations. Classification of programming languages.

2nd week

Multi-character symbols, symbolic names, labels, comments, literals, (constants.) Data types (simple, composite and pointer types).

3rd week

Assignment statements, the empty statements, the GOTO statement, selection statements, conditional statements, case/switch statement.

4th week

Loop statements, conditional loops, count-controlled loops, enumeration-controlled loops, infinite loops, composite loops.

5th week

Subprograms, the call chain and recursion, secondary entry points, parameter evaluation and parameter passing, block, scope, compilation unit.

6th week

The role of algorithms in computing. Algorithms as a technology, insertion sort, analyzing algorithms, designing algorithms.

7th week

Functions, recursive functions. Grow of functions, asymptotic notation, standard notations and common functions. Recurrences, the substitution method and the recursion-tree method for solving recurrences.

8th week

The master method and proof of the master method.

9th week

Probabilistic analysis, the hiring problem, indicator random variables.

10th week

Randomized algorithms and further examples of probabilistic analysis.

11th week

Heap, heapsort, maintaining the heap property, building the heap, the heapsort algorithm, priority queues.

12th week

Quicksort, description of quicksort, performance of quicksort, a randomized version of quicksort, analysis of quicksort.

13th week

Sorting in linear time, lower bounds for sorting, counting sort, radix sort, bucket sort.

14th week

Elementary data structures, stacks and queues, linked lists, implementing pointers and objects, representing rooted trees.

Requirements:

- *for a signature*

If the student fail the course TTMBG0606, then the signature is automatically denied.

- *for a grade*

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

-an offered grade:

It is possible to obtain an offered grade on the basis of two written test during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)

86 – 100	excellent (5)

Person responsible for course: Dr. Nóra Györkös-Varga, assistant professor, PhD

Lecturer: Dr. Nóra Györkös-Varga, assistant professor, PhD

Title of course: Algorithms **Code**: TTMBG0606	**ECTS Credit points:** 2

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

Evaluation: practice

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

Total: 60 hours

Year, semester: 1st year, 2nd semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Classification of programming languages. Multi-character symbols. Data types. Instruction types. Cycles. Subprograms. The role of algorithms in computing. Functions, recursive functions. Probabilistic analysis. Randomized algorithms. Heap, heapsort. Quicksort. Sorting in linear time. Elementary data structures.

Literature

Compulsory:

-

Recommended:

T. H. Cormen, C. E. Leiserson, R. L. Rivest, C. Stein: Introduction to Algorithms, MIT Press, Cambridge, 2009 (3rd ed.)

István Juhász: Programming Languages.,
http://www.tankonyvtar.hu/en/tartalom/tamop425/0046_programming_languages/index.html

Schedule:

1st week

Presentation of procedural and object-oriented languages, emphasizing the main differences and presentation of structures, parts of methods.

2nd week

Presentation of data types (simple, composite and special), emphasizing the main differences of the types static and dynamic. Using the simpler and known data types (array, chain, list, structure), their creation from simple types.

3rd week

Description of main types of statements, the difference of selection statements. Representing conditional statements (if-else) and case/switch statement (if-else if, or switch); presentation of the differences of „if-else if” and „switch” in case/switch statement. Recapitulate and exercise of notations and logical foundations required for conditional statements.

4th week

Loop statements, conditional loops, count-controlled loops, enumeration-controlled loops, infinite loops, composite loops. Programming loops „while” and „do-while”, investigation of effect of different initialization and termination conditions concerning certain problems.

5th week

Functions, planning of methods, determination of return values. Connection, linking of functions and methods. Presentation of recursive functions through some examples (e.g. Fibonacci sequence). Simultaneous determination of different return values with indicators.

6th week

The role of algorithms in computing. Algorithms as a technology, insertion sort, bubble sort, analyzing algorithms, designing algorithms. Presentation and examination of different types of the (above) sorts with reference to efficiency.

7th week

Grow of functions, asymptotic notation, standard notations and common functions. Recurrences, the substitution method and the recursion-tree method for solving recurrences.

8th week

The master method, practical importance of the master method.

9th week

Probabilistic analysis, the hiring problem, indicator random variables.

10th week

Randomized algorithms and further examples of probabilistic analysis.

11th week

Heap, heapsort, maintaining the heap property, building the heap, the heapsort algorithm, priority queues.

12th week

Quicksort, description of quicksort, performance of quicksort, a randomized version of quicksort, analysis of quicksort.

13th week

Sorting in linear time, lower bounds for sorting; programming the counting sort, radix sort, bucket sort. Presentation of foundation of Hash functions and using them for sort of certain array.

14th week

Elementary data structures, stacks and queues, linked lists, implementing pointers and objects, representing rooted trees.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- for a grade

The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the test is possible. *-an offered grade:* It is not possible to obtain an offered grade in this course.
Person responsible for course: Dr. Nóra Györkös-Varga, assistant professor, PhD
Lecturer: Dr. Nóra Györkös-Varga, assistant professor, PhD

Title of course: Applied number theory **Code**: TTMBE0109	**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): TTMBE0106

Further courses built on it: TTMBE0111

Topics of course

Basic notions of complexity theory. Some basic algorithms and their complexity. Approximation of real numbers by rationals, the theorem of Dirichlet. Liouville's theorem, a construction of transcendental numbers. Continued fractions and their properties. Finite and infinite continued fractions. Approximation with continued fractions. The LLL-algorithm and some of its applications. Pseudoprimes and their properties. Carmichael-numbers and their role in probabilistic prime tests. Euler-pseudoprimes and their properties. The Soloway-Strassen probabilistic prime test. Strong pseudoprimes and their properties. The Miller-Rabin probabilistic prime test. Deterministic prime tests, Wilson's theorem, the description of the Agrawal-Kayal-Saxena test. The birthday paradox and Pollard's ρ–method. Fermat-factorization. Factorization with a factor basis. Factorization with continued fractions.

Literature

Compulsory:

-

Recommended:

Neal Koblitz: A Course in Number Theory and Cryptography, Springer Verlag, 1994.

I. Niven, H. S. Zuckerman, H. L. Montgomery: An Introduction to the Theory of Numbers, Wiley, 1991.

Nigel Smart: The Algorithmic Resolution of Diophantine Equations, London Mathematical Society Student Text 41, Cambridge University Press, 1998.

Schedule:

1st week

Basic concepts of complexity theory. Some fundamental algorithms and their complexity. Solution of related problems.

2nd week

Approximation of real numbers by rationals, Dirichlet's theorem. Solution of related problems.

3rd week

Liouville's theorem, construction of transcendental numbers. Solution of related problems.

4th week

Continued fractions and their properties. Finite and infinite continued fractions. Solution of related problems.

5th week

Approximation by continued fractions. Solution of related problems.

6th week

The LLL-algorithm and some of its applications. Solution of related problems.

7th week

Pseudoprimes and their properties. Carmichael-numbers and their role in probabilistic prime tests. Solution of related problems.

8th week

Euler-pseudoprimes and their properties. The Soloway-Strassen probabilistic prime test. Solution of related problems.

9th week

Strong pseudoprimes and their properties. The Miller-Rabin probabilistic prime test. Solution of related problems.

10th week

Deterministic prime tests, Wilson's theorem, the Agrawal-Kayal-Saxena test. Solution of related problems.

11th week

The birthday paradox and Pollard's- ρ–method. Solution of related problems.

12th week

Fermat-factorization. The background of the method and its variants. Solution of related problems.

13th week

Factorization with a factor basis.. Solution of related problems.

14th week

Continued fraction factorization. The background of the method and its applications. Solution of related problems.

Requirements:

- *for a signature*

Signature is not a basis of evaluation in this course.

- *for a grade*

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 80	good (4)
81 – 100	excellent (5)

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Lajos Hajdu, university professor, DSc

Lecturer: Prof. Dr. Lajos Hajdu, university professor, DSc

Title of course: Algorithms in algebra and number theory **Code**: TTMBG0110	**ECTS Credit points:** 3

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

Evaluation: practice

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

Total: 90 hours

Year, semester: 2nd year, 2nd semester

Its prerequisite(s): TTMBE0106

Further courses built on it: -

Topics of course

Linear algebra and applications using SageMath. Factoring polynomials over finite fields, the Berlekamp algorithm. Shamir's secret sharing algorithm. Lattices, the LLL-algorithm and applications. Number theoretic functions in SageMath. Linear Diophantine equations, the Frobenious problem. Conics and elliptic curves in SageMath.

Literature

Compulsory:

-

Recommended:

Victor Shoup: A Computational Introduction to Number Theory and Algebra, Cambridge University Press, 2005.

William Stein: Elementary Number Theory: Primes, Congruences, and Secrets, Springer-Verlag, 2008

Schedule:

1st week

A short introduction of SageMath (basic structures, lists, sets, programming tools).

2nd week

Linear algebra over the reals, complex numbers and finite fields. The Berlekamp algorithm. Computing formulas for recurrence sequences.

3rd week

Polynomials and matrices over finite fields, the Samir secret sharing procedure.

4th week

The NTRU cryptosystem and its implementation in SageMath.

5th week

Polinomial equations and applications.

6th week
Number theoretical functions in SageMath, linear Diophantine equations. Combinatorial
7th week
First test.
8th week
Lattices and the LLL-algorithm in SageMath. The knapsack problem.
9th week
The Frobenius problem. Solutions of the Frobenius problem via Wilf-method and Brauer-method.
10th week
Computations related to quadratic residues, the Legendre symbol.
11th week
The ternary Diophantine equation $ax^2+by^2+cz^2=0$. Descent algorithm to determine integral solutions, parametrization of rational and integral points.
12th week
Elliptic curves, points on elliptic curves over the rationals, finite fields. Applications of elliptic curves.
13th week
Points on elliptic curves over finite fields, determining the order, the baby step-giant step algorithm.
14th week
Second test.

Requirements:
- for a signature
Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.
- for a grade
The course is evaluated on the basis of two written tests during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
91 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the tests is possible.
-an offered grade:
It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Szabolcs Tengely, university professor, DSc

Lecturer: Prof. Dr. Szabolcs Tengely, university professor, DSc

Title of course: Introduction to cryptography **Code**: TTMBE0111	**ECTS Credit points:** 3

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

Evaluation: exam

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

Total: 90 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTMBE0109

Further courses built on it: -

Topics of course

Basic cryptographic concepts. Symmetric and asymmetric cryptosystems. The Cesar and the linear cryptosystems, DES, AES. The RSA cryptosystem and the analysis of its security. The discrete logarithm problem. Algorithms for solving the discrete logarithm problem. Cryptosystems based on the discrete logarithm problem. Elliptic curve cryptography. Basic cryptographic protocols. Digital signature. The basics of PGP.

Literature

Compulsory:

-

Recommended:

J. Buchmann: Einführung in die Kryptographie, Springer, 1999.

N. Koblitz: A Course in Number Theory and Cryptography, Springer, 1987.

Schedule:

1st week

The models of information transfer. The Shannon model, modulator, demodulator and their parts. The two branches of cryptology: cryptography and cryptanalysis. Major applications of cryptography. Requirements of a modern cryptosystem. The notion of cryptosystem and its mathematical model.

2nd week

Classical cryptosystems. Symmetric versus asymmetric cryptosystems. The Caesar cryptosystem, substitution ciphers, the affine cryptosystem. Frequency analysis. Breaking the classical cryptosystems.

3rd week

Block-cyphers. Feistel-type ciphers. The history of the DES, requirements for a cryptosystem in those times. Description of the DES. Security of the DES. Double DES and triple DES.

4th week

The field GF(2^8). Operations in GF(2^8). Bytes as elements of GF(2^8). The structure of the polynomial ring GF(2^8)[x] and of the factor ring GF(2^8)[x]/(x^4+1), operations in the factor ring GF(2^8)[x]/(x^4+1).

5th week

The call for proposals for AES. Requirements concerning AES. The winner of the call: the Rijndael. Description of the Rijndael cryptosystem: number of rounds, round-transformation final round, round-key generation.

6th week

The basic idea behind the public-key cryptosystems, the infrastructure of public key cryptosystems. The idea behind the RSA cryptosystem. Description of the RSA cipher.

7th week

First test.

8th week

The security of the RSA – correct choice of the parameters. Known protocol errors and possibilities of attacking the RSA in case of wrong parametrization or programming.

9th week

The discrete logarithm problem. The Pohlig-Hellman algorithm, the Baby-step Giant-step algorithm, the Pollard-rho algorithm, and the Index-calculus algorithm.

10th week

Public-key cryptosystems based on the hardness of the discrete logarithm problem: the El Gamal cryptosystem, the Diffie-Hellmann key-exchange protocol, the Massey-Omura cryptosystem.

11th week

Definition of elliptic curves. Points on elliptic curves over a given field. Definition of the group of an elliptic curve. The real case. Elliptic curves over finite fields. Hasse's theorem.

12th week

Encoding the plaintext as a point of an elliptic curve. Cryptosystems based on the discrete logarithm problem over elliptic curves: the El Gamal cryptosystem, the Massey-Omura cryptosystem.

13th week

Protocols for key-exchange, digital signature and authentication. Zero-knowledge proofs.

14th week

Second test.

Requirements:

- for a signature

If the student fail the course TTMBG0111, then the signature is automatically denied.

- for a grade

The course ends in oral examination. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

-an offered grade:

It is possible to obtain an offered grade on the basis of two written test during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

Person responsible for course: Prof. Dr. Attila Bérczes, university professor, DSc

Lecturer: Prof. Dr. Attila Bérczes, university professor, DSc

Title of course: Introduction to cryptography **Code**: TTMBG0111	**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: 16 hours
- preparation for the exam: 16 hours

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTMBE0109

Further courses built on it: -

Topics of course

Basic cryptographic concepts. Symmetric and asymmetric cryptosystems. The Cesar and the linear cryptosystems, DES, AES. The RSA cryptosystem and the analysis of its security. The discrete logarithm problem. Algorithms for solving the discrete logarithm problem. Cryptosystems based on the discrete logarithm problem. Elliptic curve cryptography. Basic cryptographic protocols. Digital signature. The basics of PGP.

Literature

Compulsory:

-

Recommended:

J. Buchmann: Einführung in die Kryptographie, Springer, 1999.

N. Koblitz: A Course in Number Theory and Cryptography, Springer, 1987.

Schedule:

1st week

Introduction to the Magma computer algebra system.

2nd week

Realization of the Caesar cryptosystem, a substitution cypher, or an affine cryptosystem.

3rd week

Programming the DES in frame of group work.

4th week

Continuing the implementation of DES. Combining the individually produced programme-parts.

5th week

Computer aided computations in the field GF(2^8), the polynomial ring GF(2^8)[x] and the factor ring GF(2^8)[x]/(x^4+1) using Magma.

6th week

Group work: programming the encryption/decryption function of the Rijndael cryptosystem.

7th week

Continuing the implementation of the Rijndael cryptosystem. Combining the individually produced programme-parts.

8th week

Implementing the RSA cryptosystem.

9th week

Programming one of the algorithms for solving the DLP.

10th week

Implementing one of the cryptosystems based on the hardness of the DLP.

11th week

Defining and manipulating elliptic curves in Magma.

12th week

Writing a programme to encode plaintext as a point on an elliptic curve.

13th week

Implementing the Diffie-Hellmann key-exchange protocol.

14th week

Evaluation, decision of the marks of the students.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

- for a grade

The course is evaluated on the basis of one written test and a homework project submitted during the semester. The grade is given according to the following table:

Total Score (%)	Grade
0 – 50	fail (1)
51 – 60	pass (2)
61 – 70	satisfactory (3)
71 – 85	good (4)
86 – 100	excellent (5)

If a student fail to pass at first attempt, then a retake of the test is possible.

-an offered grade:

It is not possible to obtain an offered grade in this course.

Person responsible for course: Prof. Dr. Attila Bérczes, university professor, DSc

Lecturer: Prof. Dr. Attila Bérczes, university professor, DSc

Title of course: Numerical analysis **Code**: TTMBE0209	**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: 2nd year, 2nd semester	
Its prerequisite(s): TTMBE0102, TTMBE0215, TTMBG0209(p)	
Further courses built on it: -	

Topics of course

Features of computions by computer, error propagation. Some important matrix transformations for solving linear systems and eigenvalue problems. Gaussian elimination and its variants: its algorithms, operational complexity, pivoting. Decompositions of matrices: Schur complement, LU decomposition, LDU decomposition, Cholesky decomposition, QR decomposition. Iterative methods for solving linear and nonlinear systems: Gauss-Seidel iteration, gradient method, conjugate gradient method, Newton method, local and global convergence, quasi-Newton method, Levenberg–Marquardt algorithm, Broyden method. Solving eigenvalue problems: power method, inverse iteration, translation, QR method. Interpolation and approximation problems: Lagrange and Hermite interpolation, spline interpolation, Chebyshev-approximation. Quadrature rules: Newton-Cotes formulas, Gauss quadrature. Numerical methods for ordinary differential equations: Euler method, Runge-Kutta methods, finite-difference methods, finite element method.

Literature

Compulsory:

-

Recommended:

- Atkinson, K.E.: Elementary Numerical Analysis. John Wiley, New York, 1993.
- Lange, K.: Numerical analysis for statisticians. Springer, New York, 1999.
- Press, W.H. – Flannery, B.P. – Tenkolsky, S.A. – Vetterling, W.T.: Numerical recipes in C. Cambridge University Press, Cambridge, 1988.
- Engeln-Mullgens, G. – Uhling, F.: Numerical algorithms with C. Springer, Berlin, 1996.

Schedule:

1st week Features of computions by computer, error propagation. Some important matrix transformations for solving linear systems and eigenvalue problems.

2nd week Solution of system of linear equations: Gaussian elimination and its variants

3rd week Algorithms of the Gauss elimination and its operational comlexity. Pivoting.

4th week Decompositions of matrices: Schur complement, LU decomposition, LDU decomposition, Cholesky factorisation, QR factorisation of matrices.

5th week Iterative methods for solving linear systems: Gauss-Seidel iteration and its convergence

6th week Preconditioning. The gradient method and the conjugate gradient method

7th week Approximate solution of nonlinear equations: Newton method, local and global convergence, quasi-Newton method, Levenberg–Marquardt algorithm, Broyden-method

8th week Numerical methods for solving eigenvalue problems: power method and inverse iteration

9th week Numerical methods for solving eigenvalue problems: shift method, the QR algorithm

10th week Interpolation and approximation problems: Lagrange-interpolation, Hermite-interpolation. Spline interpolation. Error of the approximation. Tschebisev-approximation

11th week Numerical integration: Newton-Cotes formulas. Composite quadrature formulas

12th week Gauss quadrature. Existence, convergence, error estimation

13th week Numerical methods for solving initial value problems of ordinary differential equations: Euler method, Runge-Kutta method

14th week Numerical methods for solving boundary value problems of ordinary differential equations: finite difference methods, finite element method

Requirements:

- for a grade

The course ends in an **examination**. The minimum requirement for the examination is 50%. Based on the score of the exam the grade for the examination is given according to the following table

Score	Grade
0-49	fail (1)
50-59	pass (2)
60-74	satisfactory (3)
75-89	good (4)
90-100	excellent (5)

Person responsible for course: Dr. Borbála Fazekas, associate professor, PhD

Lecturer: Dr. Borbála Fazekas, associate professor, PhD

Title of course: Numerical analysis **Code**: TTMBG0209	**ECTS Credit points:** 2
Type of teaching, contact hours - lecture: - - practice: 2 hours/week - laboratory: -	
Evaluation: practical	
Workload (estimated), divided into contact hours: - lecture: - - practice: 28 hours - laboratory: - - home assignment: - - preparation for the tests: 32 hours Total: 60 hours	
Year, semester: 2^{nd} year, 2^{nd} semester	
Its prerequisite(s): TTMBE0102, TTMBE0215	
Further courses built on it: -	

Topics of course

Features of computions by computer, error propagation. Some important matrix transformations for solving linear systems and eigenvalue problems. Gaussian elimination and its variants: its algorithms, operational complexity, pivoting. Decompositions of matrices: Schur complement, LU decomposition, LDU decomposition, Cholesky decomposition, QR decomposition. Iterative methods for solving linear and nonlinear systems: Gauss-Seidel iteration, gradient method, conjugate gradient method, Newton method, local and global convergence, quasi-Newton method, Levenberg–Marquardt algorithm, Broyden method. Solving eigenvalue problems: power method, inverse iteration, translation, QR method. Interpolation and approximation problems: Lagrange and Hermite interpolation, spline interpolation, Chebyshev-approximation. Quadrature rules: Newton-Cotes formulas, Gauss quadrature. Numerical methods for solving ordinary differential equations: Euler method, Runge-Kutta methods, finite-difference methods, finite element method.

Literature

Compulsory:

-

Recommended:

- Atkinson, K.E.: Elementary Numerical Analysis. John Wiley, New York, 1993.
- Lange, K.: Numerical analysis for statisticians. Springer, New York, 1999.
- Press, W.H. – Flannery, B.P. – Tenkolsky, S.A. – Vetterling, W.T.: Numerical recipes in C. Cambridge University Press, Cambridge, 1988.
- Engeln-Mullgens, G. – Uhling, F.: Numerical algorithms with C. Springer, Berlin, 1996.

Schedule:

1^{st} week Features of computions by computer, error propagation. Some important matrix transformations for solving linear systems and eigenvalue problems. Solution of system of linear equations: Gaussian elimination and its variants

2^{nd} week Algorithms of the Gauss elimination and its operational complexity. Pivoting.

3^{rd} week Decompositions of matrices: Schur complement, LU decomposition, LDU decomposition, Cholesky factorisation, QR factorisation of matrices

4^{th} week Iterative methods for solving linear systems: Gauss-Seidel iteration and its convergence

5^{th} week Preconditioning. The gradient method and the conjugate gradient method

6^{th} week Approximate solution of nonlinear equations: Newton method, local and global

convergence, quasi-Newton method, Levenberg–Marquardt algorithm, Broyden-method

7th week Test

8th week Numerical methods for solving eigenvalue problems: power method and inverse iteration. Shift method, the QR algorithm

9th week Interpolation and approximation problems: Lagrange-interpolation, Hermite-interpolation. Spline interpolation. Error of the approximation. Tschebisev-approximation

10th week Numerical integration: Newton-Cotes formulas. Composite quadrature formulas

11th week Gauss quadrature. Existence, convergence, error estimation

12th week Numerical methods for solving initial value problems of ordinary differential equations: Euler method, Runge-Kutta method

13th week Numerical methods for solving boundary value problems of ordinary differential equations: finite difference methods, finite element method

14th week 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. 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: one test in the 7th week and the other test in the 14th week. The minimum requirement for the tests respectively is 50%. Based on the score of the tests, the grade for the tests is given according to the following table:

Score	Grade
0-49	fail (1)
50-59	pass (2)
60-74	satisfactory (3)
75-89	good (4)
90-100	excellent (5)

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

Person responsible for course: Dr. Borbála Fazekas, associate professor, PhD

Lecturer: Dr. Borbála Fazekas, associate professor, PhD

Title of course: Economic mathematics **Code**: TTMBE0211	**ECTS Credit points:** 3

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

Evaluation: exam

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

Total: 90 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTMBE0211

Further courses built on it:-

Topics of course

Computation of future and present values, discounted present value and investment projects. Bounds for the budget, change of the budget line, consumer preferences, preference order. Indifference curves, marginal rate of substitution, utility, utility functions, Cobb-Douglas preferences, marginal utility. Optimal choice, consumer demand, demand curves, inverse demand curve, market demand, elasticity. Demands of constant elasticity, elasticity and marginal revenue, marginal revenue curves, income elasticity. Production functions, marginal rate of substitution. CES property, Cobb–Douglas type production function and its properties, Arrow–Chenery–Minhas–Solow type production function. Equilibrium points of two-person games, the best response mapping, game theoretic model of Bertrand and Cournot type duopoly. Individual and social preferences, social welfare function. Arrow's impossibility theorem. Consistent aggregation, bisymmetry equation. Influencing the distribution of incomes, the discounted present value of continuous income stream, Lorenz curve, Gini coefficient. Leontieff models.

Literature

Compulsory:

-

Recommended:

- M. Carter: Foundations of Mathematical Economics, MIT Press, 2001.
- K. Sydsaeter, P. Hammond, Mathematics for Economic Analysis, Pearson Publishing, 1995.
- H. R. Varian: Intermediate Microeconomics: A Modern Approach, W.W. Norton, 1987.

Schedule:

1st week

Computation of future and present values, discounted present value and investment projects.

2nd week

Bounds for the budget, change of the budget line, consumer preferences, preference order.

3rd week

Indifference curves, marginal rate of substitution, utility, utility functions, Cobb-Douglas preferences, marginal utility.

4th week

Optimal choice, consumer demand, demand curves, inverse demand curve, market demand, elasticity.

5th week

Demands of constant elasticity, elasticity and marginal revenue, marginal revenue curves, income elasticity.

6th week

Production functions, marginal rate of substitution.

7th week

CES property, Cobb–Douglas type production function and its properties, Arrow–Chenery–Minhas–Solow type production function.

8th week

Equilibrium points of two-person games, the best response mapping, game theoretic model of Bertrand and Cournot type duopoly.

9th week

Individual and social preferences, social welfare function.

10th week

Arrow's impossibility theorem.

11th week

Consistent aggregation, bisymmetry equation.

12th week

Influencing the distribution of incomes, the discounted present value of continuous income stream,

13th week

Lorenz curve, Gini coefficient.

14th week

Leontieff models.

Requirements:

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

- for a grade

The course ends in an **examination**. The minimum requirement for the examination is 50%. Based on the score of the exam the grade for the examination is given according to the following table:

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-76	satisfactory (3)
77-88	good (4)
89-100	excellent (5)

Person responsible for course: Dr. Fruzsina Mészáros, assistant professor, PhD

Lecturer: Dr. Fruzsina Mészáros, assistant professor, PhD

Title of course: Economic mathematics **Code**: TTMBG0211	**ECTS Credit points: 2**

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

Evaluation: practical

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

Total: 60 hours

Year, semester: 3rd year, 1st semester

Its prerequisite(s): TTMBE0211

Further courses built on it:-

Topics of course

Computation of future and present values, discounted present value and investment projects. Bounds for the budget, change of the budget line, consumer preferences, preference order. Indifference curves, marginal rate of substitution, utility, utility functions, Cobb-Douglas preferences, marginal utility. Optimal choice, consumer demand, demand curves, inverse demand curve, market demand, elasticity. Demands of constant elasticity, elasticity and marginal revenue, marginal revenue curves, income elasticity. Production functions, marginal rate of substitution. CES property, Cobb–Douglas type production function and its properties, Arrow–Chenery–Minhas–Solow type production function. Equilibrium points of two-person games, the best response mapping, game theoretic model of Bertrand and Cournot type duopoly. Individual and social preferences, social welfare function. Arrow's impossibility theorem. Consistent aggregation, bisymmetry equation. Influencing the distribution of incomes, the discounted present value of continuous income stream, Lorenz curve, Gini coefficient. Leontieff models.

Literature

Compulsory:

-

Recommended:

- M. Carter: Foundations of Mathematical Economics, MIT Press, 2001.
- K. Sydsaeter, P. Hammond, Mathematics for Economic Analysis, Pearson Publishing, 1995.
- H. R. Varian: Intermediate Microeconomics: A Modern Approach, W.W. Norton, 1987.

Schedule:

1st week

Computation of future and present values, discounted present value and investment projects.

2nd week

Bounds for the budget, change of the budget line, consumer preferences, preference order.

3rd week

Indifference curves, marginal rate of substitution, utility, utility functions, Cobb-Douglas preferences, marginal utility.

4th week

Optimal choice, consumer demand, demand curves, inverse demand curve, market demand, elasticity.

5th week

Demands of constant elasticity, elasticity and marginal revenue, marginal revenue curves, income elasticity.

6th week

Production functions, marginal rate of substitution.

7th week

CES property, Cobb–Douglas type production function and its properties, Arrow–Chenery–Minhas–Solow type production function.

8th week

Equilibrium points of two-person games, the best response mapping, game theoretic model of Bertrand and Cournot type duopoly.

9th week

Individual and social preferences, social welfare function.

10th week

Arrow's impossibility theorem.

11th week

Consistent aggregation, bisymmetry equation.

12th week

Influencing the distribution of incomes, the discounted present value of continuous income stream,

13th week

Lorenz curve, Gini coefficient.

14th week

Leontieff models.

Requirements:

- for a practical

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. 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: one test in the 7th week and the other test in the 14th week. The minimum requirement for the tests respectively is 50%. Based on the score of the tests, the grade for the tests is given according to the following table:

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-76	satisfactory (3)
77-88	good (4)

89-100 excellent (5) If the score of any test is below 50, students can take a retake test in conformity with the EDUCATION AND EXAMINATION RULES AND REGULATIONS.
Person responsible for course: Dr. Fruzsina Mészáros, assistant professor, PhD
Lecturer: Dr. Fruzsina Mészáros, assistant professor, PhD

Title of course: Analysis with computer **Code**: TTMBG0210	**ECTS Credit points:** 4
Type of teaching, contact hours - lecture: - - practice: - - laboratory: 3 hours/week	
Evaluation: mid-semester grade	
Workload (estimated), divided into contact hours: - lecture: - - practice: - - laboratory: 42 hours - home assignment: - - preparation for the test: 78 hours Total: 120 hours	
Year, semester: 3rd year, 2nd semester	
Its prerequisite(s): TTMBE0215	
Further courses built on it: -	

Topics of course

The Maple; types of data, simple for-cycles, defining functions. Examination of functions; continuity, limit, zeros, extrema, constrained extrema. Differentiation, integration and numerical integration. Programming of simple quadrature rules. Solving differential equations with analytic methods and visualizing the solutions. Solving differential equations with numerical methods, programming Runge–Kutta fomulas. Ways of defining vectors and matrces. Vector and matrix operations, decompositions of matrices. Solving linear systems of equations with direct and iterative methods. Graphic tools in two dimension: making figures, rotation, reflection, parametrized curves. Graphic tools in three dimension: functions of two variables, space curves, surfaces, solid figures. Making animations, illustrating geometric and physical problems. Curve fitting; Lagrange and Hermite interpolation, Bezier curves and spline interpolation. For-cycle and while-cycle, conditional branches. Writing simple procedures: searching for primes, recursive functions, divisibility problems. Writing complex procedures: numerical differentiation and integration, approximation of functions, orthogonal polynomials and differential equations.

Literature

Compulsory: -

Recommended:

- W. Gander, J. Hrebicek: Solving Problems in Scientific Computing Using Maple and MATLAB. Springer-Verlag, Berlin, Heidelberg, New York, 1993, 1995.

Schedule:

1st week Introduction. Data types of Maple: simple data types, complex data types.

2nd week Simple for-cycles. Defining functions. Examination of functions; continuity, limit, zeros, extrema, constrained extrema.

3rd week Differentiation, integration and numerical integration. Programming of simple quadrature rules.

4th week Solving differential equations with analytic methods and visualizing the solutions. Solving differential equations with numerical methods, programming simple Runge–Kutta fomulas.

5th week Ways of defining vectors and matrces. Vector and matrix operations, decompositions of matrices.

6th week Solving linear systems of equations with direct and iterative methods. Programming of simple iterative methods.

7th week Graphic tools in two dimension: making figures, rotation, reflection, parametrized curves.

8th week Graphic tools in three dimension: functions of two variables, space curves, surfaces, solid figures.

9th week Making animations, illustrating geometric and physical problems.

10th week Curve fitting; Lagrange and Hermite interpolation, Bezier curves and spline interpolation.

11th week For-cycle and while-cycle, conditional branches.

12th week Writing simple procedures: sequences, Taylor-series, extrema of functions.

13th week Writing complex procedures: numerical differentiation and integration, approximation of functions, orthogonal polynomials and differential equations.

14th week 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. 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 is one test in the 14th week.
The minimum requirement for the test is 50%. Based on the score of the test, the grade for the test is given according to the following table:

Score	Grade
0-49	fail (1)
50-59	pass (2)
60-74	satisfactory (3)
75-89	good (4)
90-100	excellent (5)

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

Person responsible for course: Dr. Borbála Fazekas, assistant professor, PhD

Lecturer: Dr. Borbála Fazekas, assistant professor, PhD

Title of course: Computer geometry **Code**: TTMBG0308	**ECTS Credit points: 3**

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

Evaluation: mid-semester grade

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

Total: 90 hours

Year, semester: 2nd year, 1st semester

Its prerequisite(s): TTMBE0302

Further courses built on it: -

Topics of course

Analytical tools of descriptive geometry: analytical geometry of projections, oblique and orthogonal axonometry, central projection, central axonometry. Curves and surfaces. Hermite, Bézier curves and surfaces, B-splines. Representation of polyhedra.

Literature

Recommended:
- M. K. Agoston. Computer Graphics and Geometric Modeling. Springer-Verlag London Limited, 2005 ISBN 978-1-85233-818-3
- G. Farin. Curves and surfaces for computer-aided geometric design. Morgan Kaufmann, 5th edition, 2002 ISBN 978-1-55860-737-8

Schedule:

1st week

Basics of computer graphics I.

2nd week

Basics of computer graphics II.

3rd week

Realization of affine transformations.

4th week

Plotting functions of one variable.

5th week

Plotting curves in the plane.

6th week

Projections.

7th week
Representation of convex polyhedra.
8th week
Representation of surfaces.
9th week
Models of curves, Hermite curves.
10th week
Models of curves, Bézier curves.
11th week
Spline interpolation
12th week
Models of surfaces, Hermite and Bézier surfaces
13th week
B-spline surfaces
14th week
Representation of fractals

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. Attendance at practice classes will be recorded by the practice leader. Being late is equivalent with an absence.

- for a grade

During the semester there are two tests. The minimum requirement for a grade is to get 50% of the total score of the two tests. The grade is given according to the following table:

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-74	satisfactory (3)
75-86	good (4)
87-100	excellent (5)

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

Person responsible for course: Dr. Ábris Nagy, assistant professor, PhD

Lecturer: Dr. Ábris Nagy, assistant professor, PhD

Title of course: Linear programming **Code**: TTMBE0607	**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): TTMBE0102

Further courses built on it: -

Topics of course

The subject of linear programming. The simplex algorithm, optimality, degenerateness, unbounded objective function. Cycling and its avoidance; the lexicographic method and the Bland rule. Duality theory: reflexivity, weak and strong duality theorems; the complementary slackness theorem. Sensitivity analysis. Geometric aspects of linear programming. Applications: Carathéodory theorem, Farkas lemma, von Neumann's minimax theorem. Linear programming tasks in models.

Literature

Compulsory:

-

Recommended:

- Vanderbei, R.: Linear Programming, Foundations and Extensions, Kluwer Academic Publishers, 1998.
- Bertsimas, D.; Tsitsiklis, J.: Introduction to Linear Optimization, Athena Scientific Series in Optimization and Neural Computation, 6, Athena Scientific, Belmont, 1997.

Schedule:

1st week

Introduction: Constrained optimization problems; linear programs in standard form; examples.

2nd week

Terminology; the simplex method.

3rd week

Unboundedness and degeneracy. Cycling.

4th week

Perturbation method and the Bland rule. The basic theorem of linear programming.

5th week

Duality theory: reflexivity and the weak duality theorem.

6th week

Duality theory: the strong duality theorem; complementary slackness; dual simplex method.

7th week

Linear programs in matrix form.

8th week

The primal and dual simplex methods in matrix form.

9th week

The primal-dual method; sensitivity analysis.

10th week

Convex geometry in linear programming.

11th week

Linear programming in convex geometry: Carathéodory theorem and Farkas' lemma.

12th week

Matrix games.

13th week

Neumann's minimax theorem.

14th week

Further examples and applications.

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

- *for a grade*

The course ends in an **examination**. The minimum requirement for the examination is 50%. Based on the score of the exam the grade for the examination is given according to the following table:

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-76	satisfactory (3)
77-88	good (4)
89-100	excellent (5)

Person responsible for course: Dr. Fruzsina Mészáros, senior assistant professor, PhD

Lecturer: Dr. Fruzsina Mészáros, senior assistant professor, PhD

Title of course: Linear programming **Code**: TTMBG0607	**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: -
- preparation for the tests: 32 hours

Total: 60 hours

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

Its prerequisite(s): TTMBE0102

Further courses built on it:-

Topics of course

The subject of linear programming. The simplex algorithm, optimality, degenerateness, unbounded objective function. Cycling and its avoidance; the lexicographic method and the Bland rule. Duality theory: reflexivity, weak and strong duality theorems; the complementary slackness theorem. Sensitivity analysis. Geometric aspects of linear programming. Applications: Carathéodory theorem, Farkas lemma, von Neumann's minimax theorem. Linear programming tasks in models.

Literature

Compulsory:

-

Recommended:

- Vanderbei, R.: Linear Programming, Foundations and Extensions, Kluwer Academic Publishers, 1998.
- Bertsimas, D.; Tsitsiklis, J.: Introduction to Linear Optimization, Athena Scientific Series in Optimization and Neural Computation, 6, Athena Scientific, Belmont, 1997.

Schedule:

1^{st} week

The graphical method.

2^{nd} week

Simplex algorithm via dictionaries.

3^{rd} week

Simplex algorithm via dictionaries; discovering unboundedness and degeneracy.
4th week
Simplex algorithm via dictionaries; perturbation and Bland's rule.
5th week
Simplex algorithm via simplex tableau.
6th week
Primal-dual problems; the dual simplex method.
7th week
Sensitivity analysis.
8th week
Using computers in linear programming.
9th week
Using computers in linear programming.
10th week
Using computers in linear programming.
11th week
Using computers in linear programming.
12th week
Matrix games.
13th week
Modeling.
14th week
Modeling.

Requirements:
- *for a practical*
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. 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: one test in the 7th week and the other test in the 14th week. The minimum requirement for the tests respectively is 50%. Based on the score of the tests, the grade for the tests is given according to the following table:

Score	Grade
0-49	fail (1)
50-62	pass (2)
63-76	satisfactory (3)
77-88	good (4)
89-100	excellent (5)

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

Person responsible for course: Dr. Fruzsina Mészáros, senior assistant professor, PhD
Lecturer: Dr. Fruzsina Mészáros, senior assistant professor, PhD

Title of course: Basics of mathematics **Code**: TTMBG0001	**ECTS Credit points:** 0

Type of teaching, contact hours

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

Evaluation: signature

Workload (estimated), divided into contact hours:

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

Total: 28 hours

Year, semester: 1st year, 1st semester

Its prerequisite(s): -

Further courses built on it: -

Topics of course

Algebraic transformations. Solution of different type equations, equation systems, inequalities and inequality systems. Basic notions of trigonometry and coordinate geometry.

Literature

Compulsory:

-

Recommended:

A. Bérczes and Á. Pintér: College Algebra. University of Debrecen, 2013.
R. D. Gustafson: College algebra and trigonometry. Pacific Grove, Brooks/Cole, 1986.

Schedule:

1st week
Algebraic transformations, identities, simplification of rational algebraic expressions.
2nd week
Simplification of irrational algebraic expressions, rationalization of denominator.
3rd week
Parametric linear equations, equation systems.
4th week
Quadratic equations, equation systems.
5th week
Parametric quadratic equations.
6th week
Sign of linear and quadratic expressions, inequalities, inequality systems (table of signs).
7th week
Equations containing absolute value.
8th week

Trigonometry: geometric interpretation of trigonometric functions and basic properties.

9th week

Identities of sum and difference of angle and trigonometric identities.

10th week

Trigonometric equations, inequalities. Method of phase shift.

11th week

Coordinate geometry: lines and circles in a plane, intersectional exercises. Distance of points and of point and line.

12th week

Lines and circles in the plane, exercises concerning tangent line.

13th week

Exponential function and its inverse, the logarithm.

14th week

Exponential and logarithmic equations, inequality.

Requirements:

- for a signature

Attendance of classes are compulsory with the possibility of missing at most three classes during the semester. In case of further absences, a medical certificate needs to be presented, otherwise the signature is denied.

The course is evaluated on the basis of two written tests during the semester. The signature is given if the student obtains at least 60 percent of the total points.

If a student fail to pass at first attempt, then a retake of the tests is possible.

- for a grade

There is no grading in this course.

-an offered grade:

There is no grading in this course.

Person responsible for course: Dr. Nóra Györkös-Varga, assistant professor, PhD

Lecturer: Dr. Nóra Györkös-Varga, assistant professor, PhD