Appendix No. 1.5 to the Resolution No. 61/2025
of the Rector of the University of Rzeszów

# SYLLABUS

**REGARDING THE QUALIFICATION CYCLE FROM 2026 TO 2029**

**ACADEMIC YEAR 2026/2027.**

## 1. BASIC COURSE/MODULE INFORMATION

| | |
|---|---|
| Course/Module title | Linear Algebra with Geometry 1 |
| Course/Module code* | |
| Faculty (name of the unit offering the field of study) | Faculty of Exact and Technical Sciences |
| Name of the unit running the course | Institute of Mathematics |
| Field of study | Mathematics |
| Qualification level | First-cycle studies (Bachelor's) |
| Profile | General academic |
| Study mode | Full-time |
| Year and semester of studies | Year 1, Semester 1 |
| Course type | Major subject |
| Language of instruction | English |
| Coordinator | Ewa Rak, PhD |
| Course instructor(s) | |

* - as agreed at the faculty

### 1.1.Learning format – number of hours and ECTS credits

| Semester (no.) | Lectures | Classes | Laboratories | Seminars | Practical classes | Internships | others | **ECTS credits** |
|---|---|---|---|---|---|---|---|---|
| 1 | 30 | 30 | | | | | | 6 |

### 1.2. Course delivery methods

☒ conducted in a traditional way

☐ involving distance education methods and techniques

**1.3. Course/Module assessment** (exam, pass with a grade, pass without a grade)

Lectures – exam
Classes – pass with a grade

## 2. PREREQUISITES

Knowledge of mathematics at the level of the basic secondary school leaving examination.

## 3. OBJECTIVES, LEARNING OUTCOMES, COURSE CONTENT, AND INSTRUCTIONAL METHODS

### 3.1. Course/Module objectives

| | |
|---|---|
| O1 | To introduce the basic concepts of linear algebra. |
| O2 | To introduce the basic concepts of analytic geometry. |
| O3 | To introduce the basic proof methods used in linear algebra and analytic geometry. |
| O4 | To introduce the basic computational techniques used in linear algebra and analytic geometry. |

### 3.2. COURSE/MODULE LEARNING OUTCOMES

| Learning Outcome | The description of the learning outcome defined for the course/module | Relation to the degree programme outcomes |
|---|---|---|
| LO_01 | The student defines classical concepts and formulates basic theorems in the field of linear algebra. | K_W01, K_W02, K_W03, K_W04 |
| LO_02 | The student has knowledge of proof methods used in linear algebra. | K_W02, K_W04 |
| LO_03 | The student has knowledge of methods for solving problems in linear algebra; | K_W03 |
| LO_04 | The student proves basic theorems in the field of linear algebra. | K_U01 |
| LO_05 | The student uses the concepts of: group, field, linear space, vector, matrix, linear transformation. | K_U01, K_U02, K_U07, |
| LO_06 | The student can perform operations on complex numbers (in various forms), interpret various sets of complex numbers, and solve equations in the set of complex numbers. | K_U01, K_U02, K_U07, |
| LO_07 | The student can calculate determinants and knows their properties. | K_U01, K_U02, K_U07, |
| LO_08 | The student solves systems of linear equations with constant coefficients and can use the geometric interpretation of solutions. | K_U01, K_U02, K_U07, |
| LO_09 | The student is ready to critically evaluate the content acquired in the field of linear algebra and to recognise the need to improve their own competencies in this area. | K_K01 |
| LO_10 | The student is ready to adopt a critical stance towards content received in the field of linear algebra in terms of its logical justification. | K_K02 |
| LO_11 | The student is ready to ask questions aimed at understanding the studied problem in | K_K03 |

| | | |
|---|---|---|
| | the field of linear algebra when solving theoretical and practical mathematical issues. | |

### 3.3. Course content (to be completed by the coordinator)

A. Lectures

| Content outline |
|---|
| **Operations**: basic properties and examples. **Algebraic structures and homomorphisms**: overview of basic algebraic structures: groups, fields, group homomorphisms. |
| **The field of complex numbers**: algebraic, trigonometric and exponential form of a complex number, operations on complex numbers, de Moivre's formula, roots of a complex number, geometric interpretations of sets of complex numbers. |
| **Linear spaces**: linear combination of vectors, linear dependence and independence of vectors, basis of a linear space, dimension of a linear space, linear subspace, direct sum of linear subspaces, quotient space. |
| **Matrices**: basic concepts, various types of matrices, operations on matrices. |
| **Determinant of a square matrix**: definition of a determinant, properties of determinants, methods of calculating determinants, Laplace's formula, inverse matrix, minors and rank of a matrix. |
| **Systems of linear equations:** Kronecker-Capelli theorem, general form of solutions of a system of linear equations, analysis of a system of equations, Cramer's formulas. |

B. Classes, laboratories, seminars, practical classes

| Content outline |
|---|
| **Operations**: investigating properties of operations. |
| **Algebraic structures and homomorphisms**: checking whether an algebraic structure is a group or a field; checking whether a function is a group homomorphism; determining the kernel and image of a homomorphism. |
| **The field of complex numbers**: algebraic, trigonometric and exponential form of a complex number, operations on complex numbers in various forms, powers and roots of complex numbers. |
| **The field of complex numbers**: geometric interpretations of sets of complex numbers, solving equations in the set of complex numbers. |
| **Linear spaces**: investigating linear dependence and independence of vectors. |
| **Linear spaces**: determining the basis of a linear space; finding coordinates of a vector in a basis; determining the dimension of a linear space. |
| **Linear spaces**: linear subspace. |
| **Matrices**: operations on matrices. |
| **Determinant of a square matrix**: calculating determinants using their properties. |
| **Inverse matrix:** determining the inverse of a given matrix from the definition and using the formula. |
| **Rank of a matrix:** determining the rank of a matrix. |
| **Systems of linear equations:** investigating the consistency of a system of linear equations using the Kronecker-Capelli theorem; solving various systems of equations; Cramer's system and formulas; using the inverse matrix to solve Cramer systems. |

### 3.4. Methods of Instruction

**Lectures:** traditional lecture with multimedia elements
**Classes:** problem analysis with discussion, problem solving

## 4. Assessment techniques and criteria

### 4.1. Methods of evaluating learning outcomes

| Learning outcome | Methods of assessment of learning outcomes (e.g. test, oral exam, written exam, project, report, observation during classes) | Learning format (lectures, classes,...) |
|---|---|---|
| LO_01 | test, exam, observation during classes | lectures, classes |
| LO_02 | exam, observation during classes | lectures, classes |
| LO_03 | test, exam, observation during classes | lectures, classes |
| LO_04 | exam, observation during classes | lectures, classes |
| LO_05 | test, exam, observation during classes | lectures, classes |
| LO_06 | test, exam, observation during classes | lectures, classes |
| LO_07 | test, exam, observation during classes | lectures, classes |
| LO_08 | test, exam, observation during classes | lectures, classes |
| LO_09 | observation during classes | lectures, classes |
| LO_10 | observation during classes | lectures, classes |
| LO_11 | observation during classes | lectures, classes |

### 4.2. Course assessment criteria

Class credit is awarded on the basis of written tests (colloquia) and activity during classes. The condition for obtaining class credit is achieving at least 50% of points from each test. The final grade for classes is then determined according to the following scale:
below 50% pts. – fail,
[50 – 60%] pts. – satisfactory, [60 – 70%] pts. – satisfactory plus, [70 – 80%] pts. – good, [80 – 90%] pts. – good plus, [90 – 100%] pts. – very good.

Lecture credit is awarded on the basis of a test during the lecture.

Exam: The condition for taking the examination is obtaining credit for lectures and classes. The condition for passing is achieving at least 50% of the points. The final examination grade is determined according to the following scale:
below 50% pts. – fail, [50 – 60%] pts. – satisfactory, [60 – 70%] pts. – satisfactory plus, [70 – 80%] pts. – good, [80 – 90%] pts. – good plus, [90 – 100%] pts. – very good.

## 5. Total student workload needed to achieve the intended learning outcomes – number of hours and ECTS credits

| Activity | Number of hours |
|---|---|
| Course hours | 60 |
| Other contact hours involving the teacher | 10 |

| | |
|---|---|
| (consultation hours, examinations) | |
| Non-contact hours – student's own work (preparation for classes or examinations, projects, etc.) | 80 |
| Total number of hours | 150 |
| **Total number of ECTS credits** | 6 |

* One ECTS point corresponds to 25-30 hours of total student workload

## 6. Internships related to the course/module

| | |
|---|---|
| Number of hours | *Not applicable* |
| Internship regulations and procedures | *Not applicable* |

## 7. Instructional materials

Compulsory literature:

1. Igor R. Shafarevich, Alexey O. Remizov, Linear Algebra and Geometry, Springer, 2012.
2. P. K. Suetin, Alexandra I. Kostrikin, Yu I Manin, Linear Algebra and Geometry, Taylor & Francis Ltd, 1990.
3. Jim Hefferon, Linear algebra 4th edition, Mathematics and Statistics, Saint Michael's College Colchester, Vermont USA ,2020. https://www.cs.ox.ac.uk/files/12921/book.pdf
4. John M. Erdman, Exercises And Problems In Linear Algebra, World Scientific Publishing Co Pte Ltd, 2020.

Complementary literature:

1. Alan Beardon, Algebra and Geometry, Cambridge University, 2005.
2. Nathaniel Johnston, Introduction to Linear and Matrix Algebra, Springer, 2021.
3. Sheldon Axler, Linear Algebra Done Right, fourth edition, Springer, 2024 https://linear.axler.net/LADR4e.pdf
4. Alexandra I. Kostrikin, Exercises in Algebra
5. A Collection of Exercises, in Algebra, Linear Algebra and Geometry, Taylor & Francis Ltd, 1996.

Approved by the Head of the Department or an authorised person