Federal State Autonomous Educational Institution of Higher Education
PEOPLES' FRIENDSHIP UNIVERSITY OF RUSSIA NAMED AFTER PATRICE LUMUMBA
RUDN University

Academy of Engineering
educational division (faculty/institute/academy) as higher education programme developer

COURSE SYLLABUS

Mathematical Modelling
course title

Recommended by the Didactic Council for the Education Field of:
08.04.01 Civil Engineering
field of studies / speciality code and title

The course instruction is implemented within the professional education programme of higher education:
Civil Engineering and Built Environment
higher education programme profile/specialisation title

2024

1. COURSE GOAL(s)

The goal of the course Mathematical Modelling is to gain knowledge, skills, skills and experience in the field of correct calculation of structures that characterize the stages of competence formation and ensure the achievement of the planned results of the development of the educational program.

The main objectives of the course are the following.

Various structures and structures, the design and construction of which the engineer is engaged in, must be correctly calculated from the point of view of mathematics and physics. For the calculation of complex structures, and especially when taking into account time factors, knowledge of partial differential equations is simply necessary.

The task of the course is to teach the student to solve complex mathematical problems, to be able to classify them and apply them in practice with different boundary conditions

2. REQUIREMENTS FOR LEARNING OUTCOMES

The course Mathematical Modelling implementation is aimed at the development of the following competences (competences in part):

Table 2.1. List of competences that students acquire during the course «Mathematical Modelling»

Competence code	**Competence descriptor**	**Competence formation indicators** (within this course)
GC-1	Able to critically analyze problem situations on the basis of a systematic approach, to develop a strategy of action	GC-1.1 Analyzes the problem, identifying its basic components; GC-1.2 Identifies and ranks the information required to solve the task; GC-1.3 Selects ways to solve the problem, analyzes the possible consequences of their use
GPC-1	Able to solve problems of professional activity on the basis of theoretical and prac-tical foundations, the math-ematical apparatus of the fundamental sciences	GPC-1.1 Selects a mathematical model suitable for the professional problem to be solved, sets the required parameters and boundary conditions; GPC-1.2 Solves mathematical modeling problems using suitable analytical, numerical, or numerical-analytical methods; GPC-1.3 Solves professional problems using modern software systems for mathematical, digital modeling of structures
GPC-3	Able to set and solve scientific and technical problems in the field of construction, construction industry and housing and communal services on the basis of knowledge of industry problems and experience in their solution	GPC-3.1 Able to formulate and solve scientific and technical tasks in the field of building structures design
GPC-6	Able to carry out research of objects and processes in the field of construction and housing and communal services	GPC-6.2 Able to choose appropriate research methods and carry out research according to the chosen methodology; GPC-6.3 Capable of processing, analyzing and drawing up research results

3. COURSE IN HIGHER EDUCATION PROGRAMME STRUCTURE

The course Mathematical Modelling refers to the *core component* of (B1) block of the higher educational programme curriculum.

Within the higher education programme students also master other disciplines (modules) and / or internships that contribute to the achievement of the expected learning outcomes as results of the course Mathematical Modelling.

Table 3.1. The list of the higher education programme components that contribute to the achievement of the expected learning outcomes as the internship results.

Competence code	Competence descriptor	Previous courses / modules, internships	Subsequent courses / modules, internships
GC-1	Able to critically analyze problem situations on the basis of a systematic approach, to develop a strategy of action		Geoinformation Systems and Applications; Independent Research Work (obtaining basic skills of research work); Introductory Practice; Desin Practice; Technological Practice; Independent Research Work
GPC-1	Able to solve problems of professional activity on the basis of theoretical and prac-tical foundations, the math-ematical apparatus of the fundamental sciences		Independent Research Work (obtaining basic skills of research work); Desin Practice; Independent Research Work
GPC-3	Able to set and solve scientific and technical problems in the field of construction, construction industry and housing and communal services on the basis of knowledge of industry problems and experience in their solution		BIM-Technology in Construction Management; Independent Research Work (obtaining basic skills of research work); Desin Practice; Technological Practice; Independent Research Work
GPC-6	Able to carry out research of objects and processes in the field of construction and housing and communal services		Geoinformation Systems and Applications; Independent Research Work (obtaining basic skills of research work); Independent Research Work

4. COURSE WORKLOAD

The total workload of the course Mathematical Modelling is 3 credits.

Table 4.1. Academic activities types by periods of the higher education programme

Type of academic activities	Total academic hours	Semester(s)			
		1			
Contact academic hours	36	36			
including:					

Type of academic activities		Total academic hours	Semester(s)			
			1			
Lectures (LC)		18	18			
Lab works (LW)		18	18			
Seminars (workshops / tutorials) (S)		0	0			
Self-studies academic hours		72	72			
Evaluation and assessment academic hours		0	0			
Course work / project, credits						
Course workload	academic hours	108	108			
	credits	3	3			

5. COURSE CONTENTS

Modules	Contents (topics)	Academic activities types *
Section 1. The subject and tasks of the course "mathematical modeling of spatial structures"	Topic 1.1 Place, purpose and advantage of mathematical modelling in the process of knowledge of objects and natural phenomena. Model, as a tool for the investigation of objects and phenomena and as a tool for managing them. Prerequisites for the successful application of mathematical modelling. Abstract model by R. Kalman. Classification of objects by type of behavior. Analytical and simulation models. Topic 1.2 Stages of mathematical modelling. Historical experience in the formation of mathematical models and solving practical problems by means of mathematics. The task of the trajectory of a ray of light reflecting from a mirror. The problem of the trajectory of a refractive Brachistochrone problem. Models based on the principle of least action and the principle of equilibrium.	LC, LW
Section 2. Basic fundamental laws in mechanics	Topic 2.1 Principles of causality. Equations of state. Postulates about space and time. The law of conservation. Topic 2.2 The least action. The principle of Lagrange. Hamilton-Ostrogradsky principle. Topic 2.3 Stable and unstable equilibrium. Euler equations. Principle d'Alembert.	LC, LW
Section 3. The concept of a mathematical model	Topic 3.1 The concept of the model of the object or phenomenon. Mathematical model. The requirement for a mathematical model. Topic 3.2 General technology for solving practical problems using mathematics. The sequence of	LC, LW

Modules	Contents (topics)	Academic activities types *
	construction and testing of mathematical models on the examples of the simplest problems of mechanics: stretching and compression of the beam. Bending of the beam, loss of stability of the beam. Topic 3.3 The test of a mathematical model is an assessment of the state of an object. Models for controlling the parameters of objects and phenomena. The multiplicity of questions about the manifestations of objects and phenomena and the generality of models. Check the adequacy of mathematical models. Simplified models.	
Section 4. Formation of mathematical models	Topic 4.1 Ideas used as the basis of mathematical models. Reflection of properties and characteristics of objects in a mathematical model. Idealization and abstraction. Mathematical language of the formation of a practical problem. Characteristic concepts for describing objects and phenomena (energy, mass, force, space, time, etc.) and qualitative and quantitative representation in models. Topic 4.2 Covariance Tasks of analysis and synthesis. Determining relationships and empirical dependencies in mathematical models. Dimension of the quantities and formulas expressing the problem. Simplification and refinement of the mathematical model. The dimension of the tasks. Analysis of the impact of simplifications and clarifications.	LC, LW
Section 5. Types of mathematical models	Topic 5.1 Structural and functional models. Discrete and continuous, linear and nonlinear models. Simulation of partial differential equations. The problem of the shapes of the searchlight mirror. Linearization. Variational models. Likely models. Other types of models. Hierarchy of mathematical models. Mathematics Mode Closure	LC, LW
Section 6. Methods for solving problems formulated by mathematical models	Topic 6.1 The investigation of the mathematical problem generated by the created mathematical model. Existence, multiplicity and uniqueness of solutions. The choice of mathematical methods for solving the formulated problem. Exact and close solution. Variational tasks. Topic 6.2 The boundary value problem and the Cauchy problem. Analytical solution. Asymptotic expansions. Ritz method. Bubnov-Galerkin Method. Discretization of tasks. Euler method. Reduction of the solution to the solution of problems of linear algebra. Finite difference method and finite element method.	LC, LW

Modules	Contents (topics)	Academic activities types *
	Topic 6.3 Systems of linear equations and their solution. The problem of eigenvalues. Search for extremums of functions and functionals. Newton's method for solving nonlinear problems. Research solutions. Selection and control of solution accuracy. Dimensional control. Verification of models.	
Section 7. The use of computing in mathematical modelling	Topic 7.1 The concept of computational experiment. Triad "model-algorithm-program". Numerical simulation. A preliminary investigation of mathematical models. Qualitative analysis. Dimensionless analysis of the problem. Topic 7.2 Approximate solutions. Exact solutions. Algorithm solutions. Programming and problem solving software. Carrying out computer calculations and their analysis. Planning calculations. Processing calculation results. Refinement of computational models.	LC, LW
Section 8. Mathematical modelling in problems of mechanics of a deformable solid	Topic 8.1 Representation of a solid body as a continuum. Other simplifying hypotheses and assumptions. Elastic body Plastic body Internal forces, stresses, deformations, displacements. Stress-strain state of a solid. Strain tensor, stress tensor and principal stress. Hooke's law as an equation of state. Static equilibrium equations and equilibrium equations in motion. Compatibility equations of deformations. Topic 8.2 The expression of the change of energy.The formulation and solution of problems of statics and dynamics of a rigid body. Two dimensional and one-dimensional problems of the theory of elasticity. Topic 8.3 Construction of mathematical models and solving problems of mechanics of liquids and gases. Ideal incompressible fluid. Viscous fluid. Perfect gas. Setting goals. Euler's equation for the motion of an ideal fluid. Tasks hydrostatics. Perfect fluid movement and viscous fluid movement. Navier-Stokes equation. Waves in liquid and gas.	LC, LW
Section 9. Problems of finding the optimal solution and their mathematical modelling	Topic 9.1 Ideas involved in the construction of mathematical models of optimization problems. Variational tasks. The formulation and solution of the Brachistochrone problem. The simplest problems of finding the optimal solution and solving them mathematically. Tasks on the best size of a tin can. Economical tasks in construction. Mathematical programming. Modelling by goal function and constraint inequalities	LC, LW

* - to be filled in only for full -time training: LC - lectures; LW - lab work; S - seminars.

6. CLASSROOM EQUIPMENT AND TECHNOLOGY SUPPORT REQUIREMENTS

Table 6.1. Classroom equipment and technology support requirements

Type of academic activities	Classroom equipment	Specialized educational / laboratory equipment, software and materials for course study (if necessary)
Lectures	An auditorium for conducting lectures, equipped with a set of specialized furniture; a blackboard (screen) and technical means for multi-media presentations.	
Lab works	An auditorium for laboratory work, equipped with a set of specialized furniture and equipment.	Computer laboratory
Computer Labs	A classroom for conducting classes, group and individual consultations, current and mid-term assessment, equipped with personal computers (in the amount of 14 pcs), a board (screen) and technical means of multimedia presentations.	Software: MS Ofiice MathCAD Lira SCAD Office
Self-studies	A classroom for independent work of students (can be used for seminars and consultations), equipped with a set of specialised furniture and computers with access to the electronic information and educational environment	

7. RESOURCES RECOMMENDED FOR INTERNSHIP

Main readings:

1. Jódar L., Carlos Cortés, Juan, Rodríguez L. A. Mathematical Modelling in Engineering & Human Behaviour 2022 ISBN 9783038978046 URL:https://mdpi.com/books/pdfview/book/1233

Additional readings:

1.Alder M. An Introduction to Mathematical Modelling //Heavenforbooks. com. – 2023 http://www.mtm.ufsc.br/~daniel/matap/IntMatMod.pdf

2. Knox, Gordon D. Engineering / by Gordon D. Knox ; edited by Ellison Hawes 275p. URL:http://dlib.rsl.ru/rsl01004000000/rsl01004445000/rsl01004445020/rsl01004445020.pdf

3. Jurgita Antuchevičienė (Ed.), Edmundas Kazimieras Zavadskas (Ed.), Jonas Šaparauskas (Ed.). Sustainability in Construction Engineering 2018 1 c. ISBN 9783038971665 URL: http://www.mdpi.com/books/pdfview/book/754 Resources of the Internet information and telecommunications network»

Internet sources:

1. Electronic libraries (EL) of RUDN University and other institutions, to which university students have access on the basis of concluded agreements:

- RUDN Electronic Library System (RUDN ELS) http://lib.rudn.ru/MegaPro/Web
- EL "University Library Online" http://www.biblioclub.ru
- EL "Yurayt" http://www.biblio-online.ru
- EL "Student Consultant" www.studentlibrary.ru
- EL "Lan" http://e.lanbook.com/
- EL "Trinity Bridge"

2. Databases and search engines:

- electronic foundation of legal and normative-technical documentation http://docs.cntd.ru/
- Yandex search engine https:// www .yandex.ru/

- Google search engine https://www.google.ru/
- Scopus abstract database http://www.elsevierscience.ru/products/scopus/

The training toolkit and guidelines for a student:

1. Collection of lectures on the course Mathematical Modelling.

* The training toolkit and guidelines for the course are placed on the internship page in the university telecommunication training and information system under the set procedure.

8. ASSESSMENT TOOLKIT AND GRADING SYSTEM* FOR EVALUATION OF STUDENTS' COMPETENCES LEVEL AS INTERNSHIP RESULTS

The assessment toolkit and the grading system* to evaluate the level of competences (competences in part) formation as the course Mathematical Modelling results are specified in the Appendix to the internship syllabus.

* The assessment toolkit and the grading system are formed on the basis of the requirements of the relevant local normative act of RUDN University (regulations / order).

DEVELOPERS:

Associate Professor in the Department of Construction Technology and Structural Materials		Elsheikh A.M.
position, educational department	signature	name and surname
position, educational department	signature	name and surname

HEAD OF EDUCATIONAL DEPARTMENT:

Head of the Department of Construction Technology and Structural Materials		A.V. Solovyeva
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