MASTER'S PROGRAM CONTENT
«Mechanics and Mathematical Modeling»
(2019-2020 academic year)

Graduating Institute: Institute of Applied Mathematics and Mechanics, SPbPU
Program scientific supervisor: Corr. member RAS, Dr.Sci. Anton M. Krivtsov
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Program outline

Discipline	ECTS
I academic year	
I semester (28 ECTS)	
History and Methodology of Science	3
Foreign Language in the Professional Sphere I	2
Scientific Discussion	3
Computer Technology in Mechanics I	2
Mechanics of Thin-Walled Structures	4
Mathematical Methods in Mechanics	6
Methods for Solving Elasticity Problems	2
Fundamentals of Geology and Development of Oil and Gas Fields I	2
Thesis Research in Mechanics and Mathematical Modeling	4
II semester (32 ECTS)	
Foreign Language in the Professional Sphere II	2
Computer Technology in Mechanics II	3
Thermodynamics	4
Finite Element Modeling and Machine Learning	5
Computational Mechanics	2
Advanced Problems in Continuum Mechanics	2
Mechanics of Shells	2
Professional Skills Development	6
Thesis Research in Mechanics and Mathematical Modeling	6
II academic year	
III semester (27 ECTS)	
Mechanics of Heterogeneous Media	3
Mechanics of Media with Complex Structure	4
Fundamentals of Geology and Development of Oil and Gas Fields II	3
Hydrodynamic Modeling	4
Thesis Research in Mechanics and Mathematical Modeling	8
Online courses	5
IV semester (33 ECTS)	
Thesis Research	24
State final certification	9

Program contents

- ✓ **History and Methodology of Science**

Description: Modular courses by visiting professors.

- ✓ **Foreign Language in the Professional Sphere I, II**

Description: The course provides students with practical skills in foreign language to make it possible to communicate in scientific society and professional sphere. Practicing in correct understanding, translation and processing of foreign texts. Development of communicative academic competence allowing students to present scientific products (articles, abstracts, reports, etc.) in academic environment.

- ✓ **Scientific Discussion**

Description: The course provides students with professional skills in writing scientific papers for peer-reviewed journals and preparing presentations for conferences. Students who have completed the course become more competitive and successful in communication with international scientific society, as well as in their professional career development.

- ✓ **Computer Technology in Mechanics I, II**

Description: The course provides students with knowledge of basic concepts of computer science and basic data processing algorithms, as well as with programming skills. In addition to the main objectives of the course, students are supposed to master the numerical methods and the ability to test and implement them.

- ✓ **Mechanics of Thin-Walled Structures**

Description: The course includes the nonlinear dynamic theory of spatially curved and naturally twisted thermoviscoelastic rods. This theory take into account the rotational inertia and all the basic types of deformation: bending, twisting, stretching, and transverse shear. The theory of rods includes all the known versions of rod theory, but it has a wider range of applicability. In particular, it describes the experimentally discovered Pointing's effect, which consists in shortening of a rod under twisting deformations. The main peculiarity of the theory is that it can be used to model the dynamics of thin objects with complex internal structure. In particular, it can model multi-layer rods and rods with internal cavities, as well as rods with complex microstructure. In the course the use of the following methods is demonstrated: the general methods of the continuum mechanics with rotational degrees of freedom, the differential geometry, the direct tensor calculus, the generalized theory of symmetry, the dimension theory, methods for constructing exact solutions of differential equations, asymptotic methods for solving differential equations, and in particular, differential equations with a small parameter at the highest derivative.

- ✓ **Mathematical Methods in Mechanics**

Description: The course consists of two parts. The first part is devoted to tensor calculus and the second one is devoted to nonlinear dynamics.

Tensor Calculus: This part of course provides students with invariant formulations of theory of tensor calculus. Concepts and techniques of tensor algebra, theory of tensor functions and tensor analysis are introduced. The symmetries of tensors and tensor functions are considered. The attention is drawn to application of tensor algebra and calculus in various fields of science. Students who have completed the course should be aware of application of techniques of tensor calculus to solve a wide range of problems in different area of mechanics.

Nonlinear Dynamics: The course introduces students to the current state of nonlinear wave mechanics problems. Students learn how to solve these problems and apply methods of mathematical and numerical modeling by using Wolfram Mathematica. Students who have completed the course should be aware of up-to-date state of mechanics of deformable media, theoretical and applied mechanics. They should know how to formulate the major mechanics problems. Students have to be able to apply this knowledge to solve nonlinear dynamic problems of mechanics and conduct experimental studies using software packages. Students have to use methods of mathematical modelling for the analysis and solution of problems of natural science.

- ✓ **Methods for Solving Elasticity Problems**

Description: Students who have completed the course should be able to use analytical methods of mathematical physics, offer models for solving problems in the professional field and justify the necessity and restrictions of their application.

- ✓ **Fundamentals of Geology and Development of Oil and Gas Fields I, II**

Description: The course includes study of the geological processes occurring inside the Earth and the formation of oil and gas resources. Students are provided with knowledge and ideas about the processes of oil, gas and water filtration in rocks.

- ✓ **Thermodynamics**

Description: The course provides a foundation to treat non-stationary phenomena in materials science including heat transfer in metals and dielectrics, phase transition and coupled thermoelastic wave propagation. It introduces basics of rational thermodynamics. It also develops practical skills to set and solve various problems in continuum thermodynamics, to check and visualize the obtained results. The course covers the most general principles of energy production and transfer.

- ✓ **Finite Element Modeling and Machine Learning**

Description: The course consists of two parts. The first part is devoted to FEM and the second one is devoted to machine learning.
Finite Element Modeling: The course provides students with practical skills in applying finite element methods and numerical calculations to solve real-life problems.
Machine Learning: The course introduces students to the fundamentals of machine learning theory, including discriminant, cluster and regression analysis and provides them with practical skills of solving data mining problems.

- ✓ **Computational Mechanics**

Description: The course includes study and research in the development and application of numerical and computational methods for the solution of a wide range of problems in solid mechanics, fluid mechanics, and materials science. Students will gain experience in developing models of physical systems, formulating the discretized equations for the model systems of partial differential equations, and implementing these equations in computer codes for their solution and analysis. Students who have completed the course have an understanding of the modern scientific concepts of mechanical processes modelling. They have to be aware of modern computing tools used in mechanics as well as of the possibilities of modern commercial software packages available on the market.

- ✓ **Advanced Problems in Continuum Mechanics**

Description: Modular courses by visiting professors

- ✓ **Mechanics of Shells**

Description: The course includes the linear dynamic theory of thermoelastic shells. Theory of shells includes the most general shell theory of 12th order, which is useful when describing the nanosized scale level objects, the shell theory of 10th order, designed for engineering applications in the case of sufficiently thick shells, as well as the Kirchhoff-Love shell theory. The main peculiarity of the theory is that it can be used to model the dynamics of thin objects with complex internal structure. In particular, it can model multi-layer shells, as well as shells with complex microstructure. In the course the use of the following methods is demonstrated: the general methods of the continuum mechanics with rotational degrees of freedom, the differential geometry, the direct tensor calculus, the generalized theory of symmetry, the dimension theory, methods for constructing exact solutions of differential equations, asymptotic methods for solving differential equations, and in particular, differential equations with a small parameter at the highest derivative.

- ✓ **Micromechanics of Heterogeneous Media**

Description: The course provides methods to identify the proper microstructural parameters in terms of which the given effective property is to be expressed. Different approaches to the problem of effective property are studied: the non-interaction approximation, rigorous bounds, approximate schemes aimed at accounting for interactions.

- ✓ **Mechanics of Media with Complex Structure**

Description: The course focuses on continua consisting of complex particles. Such models may have applications, in particular, in mechanics of granular media, magnetoelastic continua, acoustic metamaterials. The course provides students with constitutive theory and wave propagation, making an emphasis on the elastic continua.

- ✓ **Hydrodynamic Modeling**

Description: The course provides students with theoretical framework and practical skills in programing in relation to the problems in the oil and gas industry, in particular in hydrodynamic modeling. Within the course students are using Python language.