Federal State Autonomous Educational Institution of Higher Education
PEOPLES' FRIENDSHIP UNIVERSITY OF RUSSIA
Patrice Lumumba RUDN University

Science Faculty/Institute for Physical Research and Technologies
educational division (faculty/institute/academy) as higher education program developer

COURSE SYLLABUS

Computational experiment in the physics of complex systems
(course title)

Recommended by the Didactic Council for the Education Field of:

03.04.02. Physics
field of studies / speciality code and title

The course instruction is implemented within the professional educational program of higher education:

Fundamental and Applied Physics
higher education program profile/specialisation title

2025

1. COURSE GOAL(s)

The purpose of mastering the discipline “Computational experiment in the physics of complex systems” is to provide basic training for master's students in the field of computational experiment; study of the foundations of setting up a numerical experiment in modern applied physics; studying the principles of organizing and conducting a computational experiment; study of the principles and methods underlying the computational experiment; familiarization of students with the main directions in the computational experiment in physics, as well as the acquisition by students of knowledge and skills in the independent development of numerical models for the study of complex physical phenomena and processes occurring in existing and designed experimental facilities.

2. REQUIREMENTS FOR LEARNING OUTCOMES

Mastering the discipline “Computational experiment in the physics of complex systems” is aimed at developing the following competencies (parts of competencies):

Table 2.1. List of competences that students acquire through the course study

Competence code	Competence descriptor	Competence formation indicators (within this course)
GC-7	Capable to: search for the necessary sources of information and data, perceive, analyze, memorize and transmit information using digital means, as well as using algorithms when working with data obtained from various sources in order to effectively use the information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data.	GC-7.1. Searches for the necessary sources of information and data, perceives, analyzes, memorizes and transmits information using digital means, as well as using algorithms when working with data received from various sources in order to effectively use the information received to solve problems.
		GC-7.2. Evaluates information, its reliability, builds logical conclusions based on incoming information and data.
GPC-3	Able to apply knowledge in the field of information technology, use modern computer networks, software products and resources of the	GPC-3.1 Uses specialized Internet resources to search for scientific information and analyze trends in the development of sciences.

Competence code	Competence descriptor	Competence formation indicators (within this course)
	information and telecommunications network "Internet" (hereinafter referred to as the "Internet") to solve problems of professional activity, including those outside the scope of specialized training.	GPC-3.2 Uses modern software for analyzing scientific data and preparing scientific presentations.
GPC-4	Able to determine the scope of implementation of the results of scientific research in the field of his professional activity.	GPC -4.1 Knows the main stages of implementing the results of scientific research in the field of his professional activity. GPC -4.2 Formulates the practical significance of the results of scientific research, taking into account the trends in the development of science and technology

3. COURSE IN HIGHER EDUCATION PROGRAMME STRUCTURE

The discipline "Computational experiment in the physics of complex systems" refers to the mandatory part of block B1 of the Education Program of Higher Education.

As part of the Education Program of Higher Education, students also master other disciplines and / or practices that contribute to the achievement of the planned results of mastering the discipline "Computational experiment in the physics of complex systems".

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

Competence code	Competence descriptor	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
GC-7	Capable to: search for the necessary sources of information and data, perceive, analyze, memorize and transmit information using digital means, as well as using algorithms when working with data obtained from various sources in order to effectively use the		Undergraduate practice

Competence code	Competence descriptor	Previous disciplines/modules, practices*	Subsequent disciplines/modules, practices*
	information received to solve problems; evaluate information, its reliability, build logical conclusions based on incoming information and data.		
GPC-3	GPC-3. Able to apply knowledge in the field of information technology, use modern computer networks, software products and resources of the information and telecommunications network "Internet" (hereinafter referred to as the "Internet") to solve problems of professional activity, including those outside the scope of specialized training.	Research work	
GPC-4	Able to determine the scope of implementation of the results of scientific research in the field of his professional activity.	Research work	Undergraduate practice

* To be filled in according to the competence matrix of the higher education programme.

4. COURSE WORKLOAD AND ACADEMIC ACTIVITIES

The total workload of the course "Computational experiment in the physics of complex systems" is 288 academic hours, 8 credits.

Table 4.1. Types of academic activities during the periods of higher education program mastering ***(full-time training)****

Type of academic activities	Total academic hours	Semesters/training modules			
		1	2	3	4
Contact academic hours	*144*	-	-	*144*	-
including:					

Type of academic activities		Total academic hours	Semesters/training modules			
			1	2	3	4
Lectures (LC)		-	-	-	-	-
Lab works (LW)		144	-	-	144	-
Seminars (workshops/tutorials) (S)		-	-	-	-	-
Self-studies		*108*	*-*	*-*	*108*	*-*
Evaluation and assessment (exam/passing/failing grade)		*36*	*-*	*-*	*36*	*-*
Course workload	academic hours_	**288**	**-**	**-**	**288**	**-**
	credits	**8**	**-**	**-**	**8**	**-**

5. COURSE CONTENTS

Table 5.1. Course contents and academic activities types

Course module title	Course module contents (topics)	Academic activities types
Section 1. Mathematical modeling and computational experiment – a new technology of scientific research.	Topic 1.1. Mathematical modeling and computational experiment.	LW
	Topic 1.2. Cycle of computational experiment.	LW
	Topic 1.3. Features of the computational experiment.	LW
	Topic 1.4. The main features of the new technology of scientific research.	LW
	Topic 1.5. Computational experiment in applied physics.	LW
Section 2. Modeling of physical systems, consisting of a large number of interacting particles.	Topic 2.1. The particle method and its implementation.	LW
	Topic 2.2. Simulation of a real gas by the method of molecular dynamics.	LW
	Topic 2.3. Particle-in-cell method for modeling a collisionless plasma.	LW
	Topic 2.4. Simulation of galaxies.	LW
	Topic 2.5. Particle method for modeling the flow of an incompressible fluid.	LW
Section 3. Plasma models based on the Vlasov equation.	Topic 3.1. Vlasov equation.	LW
	Topic 3.2. Solution of the system of Vlasov-Poisson equations by the method of transformations.	LW

Course module title	Course module contents (topics)	Academic activities types
	Topic 3.3. "Water bag" method.	LW
	Topic 3.4. Numerical solution of the Vlasov equation.	LW
Section 4. The particle-in-cell method for describing one-dimensional electrostatic processes.	Topic 4.1. General scheme of modeling.	LW
	Topic 4.2. Calculation of the charge density distribution.	LW
	Topic 4.3. Finding a self-consistent electric field.	LW
	Topic 4.4. Sweep method for solving the Poisson equation with non-periodic boundary conditions.	LW
	Topic 4.5. Fourier method for periodic boundary conditions.	LW
	Topic 4.6. Formation of the initial distribution of particles on the phase plane.	LW
Section 5. Examples of modeling one-dimensional plasma systems.	Topic 5.1. Two-stream instability.	LW
	Topic 5.2. Nonlinear plasma oscillations in a cylindrical waveguide under the action of a localized electric pulse.	LW
	Topic 5.3. Electronic oscillations in a beam double layer.	LW
Section 6. Modeling of one-dimensional electromagnetic processes.	Topic 6.1. One-dimensional electromagnetic model of plasma.	LW
	Topic 6.2. Numerical solution of relativistic equations of motion of particles in an electromagnetic field.	LW
	Topic 6.3. Setting the electromagnetic pulse field in the vacuum region.	LW
Section 7. Examples of one-dimensional electromagnetic modeling.	Topic 7.1. Excitation of wake waves in a plasma by a powerful laser pulse.	LW
	Topic 7.2. Self-modulation of a right-hand polarized wave in the region of electron cyclotron resonance.	LW
	Topic 7.3. Propagation of electromagnetic solitons across a strong magnetic field in a plasma.	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	Specialised educational / laboratory equipment, software, and materials for course study (if necessary)
Lab work	A classroom for laboratory work, individual consultations, current control and intermediate certification, equipped with a set of specialized furniture and equipment.	Lab. 171, 355.
Self-studies	A classroom for individual work of students (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the EIOS.	Lab. 355.

* - the audience for individual work of students is indicated **MANDATORY**!

7. RESOURCES RECOMMENDED FOR COURSE STUDY

Main literature:

1. Kalitkin N.N., Kostomarov D.P. Mathematical models of plasma physics // Mathematical Modeling. – 2006. – V. 18. – No 11. – P. 67–94.
2. Tsvetkov, I.V. Application of numerical methods for modeling processes in plasma: a tutorial. – Moscow: MEPhI, 2007. – 84 p.

Additional literature:

1. Samarsky A. A., Vabishchevich P. N. Additive schemes for problems of mathematical physics. – Moscow: Nauka, 2001. – 312 p.
2. Samarsky A.A., Vabishchevich P.N. Mathematical modeling and numerical experiment. – Institute of Mathematical Modeling MM RAS, 2000. - (Internet publication). – http://www.imamod.ru/~vab/matmod/MatMod.htm.
3. Samarsky A.A., Vabishchevich P.N. Computational heat transfer. – Moscow: URSS, 2003. – 784 p.
4. Sigov Yu.S. Computational experiment: a bridge between the past and the future of plasma physics. – Moscow: Fizmatlit, 2001. – 286 p.

Resources of the information and telecommunications network «Internet»:

1. RUDN ELS and third-party ELS, to which university students have access on the basis of concluded agreements:

– RUDN Electronic Library System - RUDN ELS http://lib.rudn.ru/MegaPro/Web
– ELS “University Library Online” http://www.biblioclub.ru
– ELS URAIT http://www.biblio-online.ru
– ELS “Student Advisor” www.studentlibrary.ru
– EBS “Lan” http://e.lanbook.com/
– ELS “Troitsky Most”

2. Databases and search engines:
– electronic fund of legal and normative-technical documentation http://docs.cntd.ru/
– Yandex search engine https://www.yandex.ru/
– Google search engine https://www.google.ru/
– abstract database SCOPUS http://www.elsevierscience.ru/products/scopus/

Educational and methodological materials for individual work of students in the development of the discipline/module:*

1. Laboratory workshop on the discipline "Computational experiment in the physics of complex systems".

* - all educational and methodological materials for individual work of students are placed in accordance with the current procedure on the page of the discipline in TUIS (LMS)!

DEVELOPERS:

Associate Professor, IPRT (IFIT)		**Nikolaev N.E.**
Position, BEU	Signature	Family Name

HEAD OF BEU:

Acting Director of IPRT (IFIT)		**Kravchenko N.Yu.**
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HEAD OF EDUCATIONAL PROGRAM OF HIGHER EDUCATION:

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