Federal State Autonomous Educational Institution of Higher Education "Moscow Institute of Physics and Technology (National Research University)"

APPROVED
Head of the Phystech School of Aerospace Technology
S.S. Negodyaev

Work program of the course (training module)

course:	Selected Sections of Computer Science: Special Software/Избранные главы информатики: специальное программное обеспечение
major:	Applied Mathematics and Physics
specialization:	Beam-Plasma Systems and Technologies/Пучково-плазменные системы и технологии
	Phystech School of Aerospace Technology
	Chair of Logistics Systems and Technologies
term:	1
qualification:	Master

Semester, form of interim assessment: 2 (spring) - Pass/fail exam

Academic hours: 30 AH in total, including:
- lectures: 15 AH.
- seminars: 0 AH.
- laboratory practical: 15 AH.

Independent work: 15 AH.

In total: 45 AH, credits in total: 1

Author of the program: N.L. Aleksandrov, doctor of physics and mathematical sciences, full professor

The program was discussed at the Chair of Logistics Systems and Technologies 09.02.2022

Annotation

The course familiarizes students with computer simulation of physical phenomena on the example concerning the problem of electron beam propagation in a dense medium. PYTHON and FORTRAN languages are used for simulation of the electron beam scattering and absorption by Monte-Carlo technique. The training course ends with the development and testing of the program for Monte-Carlo simulation of the electron beam propagation in reaction chamber of real plasma chemical reactor.

1. Study objective

Purpose of the course

To provide students with preliminary knowledge and general understanding of physical phenomena computer simulation using PYTHON and FORTRAN (optionally) language and to enhance these knowledge in simulating the electron beam propagation in a dense medium by the Monte-Carlo technique.

Tasks of the course

- Students will get a skill of programming on PYTHON and FORTRAN languages.
- Students will practice developing numerical codes using the Monte-Carlo technique.
- The course will help students to understand physical problem of the electron beam interaction with a dense medium and possibility to develop a code of numerical simulation of the beam propagation in a gas by the Monte-Carlo technique.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
	Gen.Pro.C-3.2 Employ research methods to solve new problems and apply knowledge from various fields of science (technology)
	Gen.Pro.C-3.3 Gain knowledge of analytical and computational methods of problem-solving, understand the limitations of the implementation of the obtained solutions in practice
Pro.C-1 Assign, formalize, and solve tasks, develop and research mathematical models of the studied phenomena and processes, systematically analyze scientific problems and obtain new scientific results	Pro.C-1.3 Apply theoretical and/or experimental research methods to a specific scientific task and interpret the obtained results

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- The numerical techniques for simulation of the electron beam propagation in a medium using the Monte-Carlo method.
- Basic information about the languages PYTHON and FORTRAN, especially the organization of code in PYTHON.
- Features of the object-oriented model in PYTHON.

be able to:

- To program on PYTHON and FORTRAN (optional) language.
- To develop numerical codes using Monte-Carlo technique.

master:

- To work with standard data structures in PYTHON, write functions in PYTHON, apply the functional features of the language, work with files using the PYTHON language.
- To numerically simulate the electron beams propagation in dense media typical for real beam-plasma systems and facilities.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	Principles of programming	2			
2	FORTRAN language learning	2		2	2
3	Programming on FORTRAN language	2		3	3
4	Monte-Carlo technique	2		3	3
5	Elastic and inelastic electron scattering on atoms and molecules	2			
6	Electron energy losses in collisions with atoms and molecules	2			
7	Modeling of electron motion in a medium by Monte-Carlo technique	2		2	2
8	Modeling of electron energy losses in a medium by Monte-Carlo technique	1		2	2
9	Numerical simulation of e-beam propagation in a medium			3	3
AH in total		15		15	15
Exam preparation		0 AH.			
Total complexity		45 AH., credits in total 1			

4.2. Content of the course (training module), structured by topics (sections)

Semester: 2 (Spring)

1. Principles of programming

Main principles of programming, structure of the code, compilation and linking processes, the shell of the code (Visual Studio, Developer Studio).

2. FORTRAN language learning

FORTRAN language learning: constants, variables, operators, arrays, types of the data, intrinsic functions, subroutines and functions, input and output data.

3. Programming on FORTRAN language

Developing of simple programs following the study of different aspects and items of FORTRAN.

4. Monte-Carlo technique

The idea and realization of Monte-Carlo technique to model the processes described by probability distribution functions. Modeling of the electron diffusion in noble gases.

5. Elastic and inelastic electron scattering on atoms and molecules

Differential and integral cross sections for electron interaction with atoms and molecules, elastic and inelastic processes. Classical and quantum approximations for the cross sections, comparison with experimental data.

6. Electron energy losses in collisions with atoms and molecules

Energy losing by electrons in collisions with atoms and molecules. Excitation and ionization of atom by electron impact. Secondary electrons. The models of continuous and discrete losses, Landau function.

7. Modeling of electron motion in a medium by Monte-Carlo technique

The features of the modeling of electron motion in a medium, each collision modeling and multi-scattering approximation, Moliere layers.

8. Modeling of electron energy losses in a medium by Monte-Carlo technique

Formulation of the probability functions for electron energy losses in a medium.

9. Numerical simulation of e-beam propagation in a medium

Development of the program for e-beam propagation in a medium by Monte-Carlo technique accounting for secondary electrons.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

Standard classroom equipped with computers and presentation facilities.

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature
1. Ed Jorgensen, Introduction to programming using Fortran 95, Version 2.1.25, Aug. 2015
2. Morten Hjorth-Jensen, Computational Physics, University of Oslo, 2010
3. N.F. Mott, H.S.W. Massey, The theory of atomic collisions, Oxford, Clarendon Press, 1965

Additional literature
1. K.Binder, Applications of Monte Carlo Method in Statistical Physics, Berlin, Springer, 1984
2. Henderson D.B., J. Appl. Phys., 44, 5513-5516, (1973)
3. Smith R.C., Appl. Phys. Lett., 21, 352-355 (1972)
4. Grosswendt B., Waibel E., Nuclear Instruments and Methods 155, 145-156 (1978)
5. Heaps M.G., Green A.E.S., J. Appl. Phys., 46, 4718-4725, (1975)
6. Banks P.M., Chappell C.R., Nagy A.F., J.Geophysical Recearch, 79, 1459 (1974)
7. Berger M.J, Seltzer S.M., Maeda K., J. Atmospheric Terrest. Phys. 32, 1015 (1970)

7. List of web resources that are necessary for the course (training module) mastering

Not used

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

Microsoft Office. Internet access.

9. Guidelines for students to master the course

Students will be required to develop a set of training computer programs at the intermediate stages of FORTRAN, PYTHON and Monte-Carlo technique studying. The PYTHON (or FORTRAN optionally) codes for electron beam propagation in air at selected modeling conditions must be presented.

To pass the final test every student must prepare the presentation on simulation of electron beam propagation in reaction chambers of real plasma chemical reactors based on its own computational results.

SUPPLEMENT

Assessment funds for course (training module)

major:	Applied Mathematics and Physics
specialization:	Beam-Plasma Systems and Technologies/Пучково-плазменные системы и технологии Phystech School of Aerospace Technology Chair of Logistics Systems and Technologies
term:	1
qualification:	Master

Semester, form of interim assessment: 2 (spring) - Pass/fail exam

Author: N.L. Aleksandrov, doctor of physics and mathematical sciences, full professor

1. Competencies formed during the process of studying the course

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Gen.Pro.C-3 Select and/or develop approaches to professional problem-solving with consideration to the limitations and specifics of different solution methods	Gen.Pro.C-3.1 Analyze problems, plan research strategy to achieve solution(s), propose, and combine solution approaches
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Pro.C-1 Assign, formalize, and solve tasks, develop and research mathematical models of the studied phenomena and processes, systematically analyze scientific problems and obtain new scientific results	Pro.C-1.3 Apply theoretical and/or experimental research methods to a specific scientific task and interpret the obtained results

2. Competency assessment indicators

As a result of studying the course the student should:

know:

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- Basic information about the languages PYTHON and FORTRAN, especially the organization of code in PYTHON.
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master:

- To work with standard data structures in PYTHON, write functions in PYTHON, apply the functional features of the language, work with files using the PYTHON language.
- To numerically simulate the electron beams propagation in dense media typical for real beam-plasma systems and facilities.

3. List of typical control tasks used to evaluate knowledge and skills

The list of laboratory works during the course:

- Modeling of electron motion in a medium by Monte-Carlo technique.
- Modeling of electron energy losses in a medium by Monte-Carlo technique

4. Evaluation criteria

1. Elements of combinatorics. Permutations. Combinations. Newton's binomial.
2. Probability space. The space of elementary events. Event algebras. Probability.
3. Conditional probability. Independence of events. The formula of total probability. The Bayes formula.
4. Sequence of independent tests. Bernoulli's scheme. The polynomial scheme.
5. Discrete random variables. Definition and properties of mathematical expectation. Variance. Joint distribution. Covariance.
6. Absolutely continuous random variables. Definition and properties of mathematical expectation. Variance. Joint distribution. Covariance.
7. Conditional mathematical expectation.

8. Types of distributions of random variables.
9. Chebyshev's inequality. The law of large numbers in the Chebyshev form.
10. Types of convergence of sequences of random variables.
11. Characteristic functions.
12. The simplest linear regression. Properties of estimates of unknown regression parameters.
13. Modeling of random variables.
14. The Monte Carlo method of calculating certain integrals.
15. Solving integral equations by the Monte Carlo method.

The test for the discipline is the final stage of studying the entire course and aims to check the knowledge of students in theory and identify the skills of their application in solving practical problems, as well as the skills of self tuition with recommended main and additional literature.

During the test, the student is asked 1-2 or more (no more than 5) questions, taking into account the student's activity in the classroom and the assessment of midterm control.

The “pass” mark is given to the student who showed systematized knowledge of the curriculum during the presentation and satisfactorily answered additional questions.

The “fail” mark is given if, during the presentation and answering questions, the student shows that he does not know most of the main content of the curriculum and mistakes in the basic provisions of the discipline being studied.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

To pass the final test every student must:

- Carry out and deliver laboratory works listed in section 3,
- Present own computational results simulation of electron beam propagation in reaction chambers of real plasma chemical reactors.
- Answer the question during the discussions on presentation.