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:	System Analysis and Simulation of Beam-Plasma Systems/Системный анализ и моделирование пучково-плазменных систем
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:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Grading test

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

Independent work: 15 AH.

In total: 45 AH, credits in total: 1

Author of the program: M.N. Vasilev, doctor of technical sciences, full professor

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

Annotation

The course subject is to familiarize students with the known schematic solutions of beam-plasma systems, principles of decomposition and synthesis of beam-plasma systems during their development. Development of students' initial practical knowledge and skills of physical and computer modeling of beam-plasma systems is the main subject of training. Initial skills in system analysis when beam-plasma systems are developed for real industrial or aerospace technology seem to be extremely useful for further graduate's professional activity.

1. Study objective

Purpose of the course

To acquaint students with the methods of system analysis, modeling and design principles of beam-plasma systems in relation to industrial and aerospace technologies, as well as to laboratory facilities.

Tasks of the course

- Familiarization of students with the known schematic solutions of beam-plasma systems;
- Familiarization of students with the principles of decomposition and synthesis of beam-plasma systems during their development;
- Development of students' initial practical knowledge and skills of physical and computer modeling of beam-plasma systems;
- Development of students' initial skills in designing beam-plasma systems in solving real technological problems.

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-1 Gain fundamental scientific knowledge in the field of physical and mathematical sciences	Gen.Pro.C-1.1 Apply fundamental scientific knowledge in the field of physical and mathematical sciences
	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
Gen.Pro.C-4 Successfully perform a task, analyze the results, and present conclusions, apply knowledge and skills in the field of physical and mathematical sciences and ICTs	Gen.Pro.C-4.2 Apply knowledge in the field of physical and mathematical sciences to solve problems, make conclusions, and evaluate the obtained results
	Gen.Pro.C-4.3 Justify the chosen method of scientific research
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-1.1 Locate, analyze, and summarize information on current research findings within the subject area
	Pro.C-1.2 Make hypotheses, build mathematical models of the studied phenomena and processes, evaluate the quality of the developed model
	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:

- principles of synthesis and decomposition of beam-plasma setups for various purposes;
- methods of system analysis and modeling of complex systems used in the calculation and design of beam-plasma installations for technological purposes, features of their operation and maintenance;
- principles of system compatibility as applied to the problems of designing beam-plasma modules intended for use in aerospace technologies;
- basic approaches to assessing the risks associated with the operation of beam-plasma installations for various purposes.

be able to:

• apply in practice the general methods of system analysis to design beam-plasma systems for various purposes;
• to carry out computational experiments related to the modeling of beam-plasma systems;
• perform calculations related to the optimization of beam-plasma setups in solving practical technological and engineering problems;
• carry out preliminary design of laboratory beam-plasma installations;
• master new subject areas, theoretical approaches and experimental techniques related to the analysis, design and application of beam-plasma systems for various purposes.

master:

• the skills of a large amount of interdisciplinary and special information analysis;
• a culture of setting problems in the field of system analysis and modeling of beam-plasma systems for various purposes and skills in appropriate computational experiments.

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	Introduction. Principles of beam-plasma systems synthesis and decomposition.		4		
2	Basic physical models of processes used in calculating the beam-plasma systems parameters.		4		
3	Methods of computer simulation and optimization used in calculating the characteristics and design of beam-plasma systems		4		
4	Principles of compatibility in the design of beam-plasma systems.		3		
5	Computational experiments on modeling beam-plasma systems for technological purposes.			5	
6	Computational experiments on modeling beam-plasma systems for aerospace technologies.			5	
7	Physical modeling of beam-plasma systems; verification of computer simulation methods for laboratory beam-plasma systems.			5	15
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: 3 (Fall)

1. Introduction. Principles of beam-plasma systems synthesis and decomposition.

Subject, goals and objectives of the course. Beam-plasma facility as a complex system. General methods for the analysis of complex systems. target function. Principles of synthesis and decomposition of systems. Efficiency, reliability, robustness of complex technical systems. Principles of compatibility in the design of beam-plasma systems. Basic approaches to assessing the risks associated with the operation of beam-plasma installations for various purposes.

2. Basic physical models of processes used in calculating the beam-plasma systems parameters.

Models describing the emission of electrons and the formation of electron beams. Simulation of electron-kinetic processes during the propagation of an electron beam in vacuum. Physical models of electron beam propagation in a dense gaseous medium. Physical models and calculation formulas for the analysis of the processes of interaction of an electron beam with a solid body. Physical models of radiation generation when during the operation of beam-plasma facility. Physical models of secondary emission processes in the working volume of beam-plasma installations

3. Methods of computer simulation and optimization used in calculating the characteristics and design of beam-plasma systems

Monte Carlo method for modeling the propagation of an electron beam in a dense medium. Application software packages for simulation of electron-beam plasma generation in free and closed volume: DOZA and MolKin packages. Methods of multicriteria optimization in the design of beam-plasma systems.

4. Principles of compatibility in the design of beam-plasma systems.

The main and auxiliary systems of beam-plasma installations: electron injectors, electron beam formation systems, high-voltage power supplies, output windows, working chambers, vacuum systems, radiation protection, cooling systems. Joint functioning of the listed systems. Optimization of weight and size characteristics of beam-plasma systems. Optimization of energy characteristics of beam-plasma systems. Ensuring safety and minimizing the harmful impact on the environment during the operation of beam-plasma systems.

5. Computational experiments on modeling beam-plasma systems for technological purposes.

Computer simulation of the plasma-chemical reactor for the metal nitrides and oxides synthesis as the example of the electron-beam plasma facility draft design.

6. Computational experiments on modeling beam-plasma systems for aerospace technologies.

Computer simulation of the plasma generation inside a closed container as an example of the draft design of the setup for experiments on aerospace applications of the electron-beam plasma.

7. Physical modeling of beam-plasma systems; verification of computer simulation methods for laboratory beam-plasma systems.

Physical experiments on temperature measurement in various zones of beam-plasma installations. Comparison of data obtained in physical experiments with the results of computer simulation.

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

Experimental complex "Beam-plasma systems and technologies" as part of the ELU-1 and ELU-2 installations, diagnostic equipment, auxiliary and special technological equipment (room 222 of the UPM building). Personal computers of the required performance.
Necessary equipment for lectures and practical exercises: computer and multimedia equipment (projector, marker board, Internet connection).

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

Main literature

1) M. Vasiliev, Applications of Electron-Beam Plasmas in Plasma chemistry. Encyclopedia of low-temperature plasma. V. XI, P. 436-445. Chief editor V. Fortov. Moscow. Nauka, 2001.4)
2) M.N. Vasiliev, A.H. Mahir. Electron–Beam Plasma Systems in Industrial and Aerospace Applications // Publications of the Astronomical Observatory of Belgrade, 2008, No. 84, P. 421-425.
3) N. L. Aleksandrov, M. N. Vasil'ev, S. L. Lysenko, and A. Kh. Makhir. Experimental and Theoretical Study of a Quasi-Steady Electron-Beam Plasma in Hot Argon. Plasma Physics Reports. 2005, vol. 31, no.5, pp. 425-435.

Additional literature

1) T. Vaislieva, S. Lysenko, D. Bayandina, M. Vasiliev. Electron beam transport in dusty plasma // Nuclear Instruments and Methods in Physics Research A – 2011. - V.645. – P. 90-95.
2) Bychkov, V.; Vasiliev, M.; Koroteev, A. Electron-Beam Plasma: Generation, Properties, Applications; Moscow State Open University Publishers: Moscow, Russia, 1993.
3) Khomyakov P.M. System analysis: a short course of lectures / Ed. V.P. Prokhorova - M .: KomKniga, 2006. - 216 p.

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

Successful mastering of the course " System Analysis and Simulation of Beam-Plasma Systems" requires significant self tuition of the student. Self tuition includes:

- reading and taking notes of the recommended literature;
- study of educational material (based on lecture notes, educational and scientific literature);
- solving problems offered to students at lectures;
- preparing to self tuition and tests.

The guidance and control over the student self tuition is carried out by the analysis of the self tuition results, tests, and individual consultations.

A student studying the discipline must consolidate the knowledge gained while studying the courses Plasma Physics, Plasma Chemistry, Plasma Engineering Systems, High Energy Chemistry of Inorganic, Organic and Bioorganic Compounds, System Analysis and Modeling of Beam-Plasma Systems. He must also acquire new basic knowledge related to the physical processes that occur during the interaction of an electron-beam plasma with matter. As a result of studying the discipline, the student should get a general idea about the design of beam-plasma installations for technological purposes and the principles of their safe operation. As an illustration of the educational material in practical classes, students are shown experiments on the use of electron-beam plasma in production technologies.

The program of the training course provides for students to get acquainted with the equipment and instruments used in experiments on technological applications of electron-beam plasma, the features of maintenance of the main and auxiliary systems of the technological complex and a number of independent measurements on operating installations. When performing laboratory work, the student is given the opportunity to study the properties of materials obtained by methods of beam-plasma impact on a substance. At the same time, the methodology for conducting such analyzes should be proposed by the student himself.

Successful mastering of the discipline requires intense independent work of the student. The course program provides the minimum required time for a student to work on a topic. Independent work includes:

- reading the recommended basic and additional literature;

- learning to read technical descriptions and operating instructions for the equipment used in the experiments;
- preparation of proposals for setting up experiments within the framework of individual and group projects;
- familiarity with publications on the subject of proposed projects.

The guidance and control of the student's self tuition is carried out by the teacher when listening to presentations prepared by students, as well as during discussions during practical classes.

The main indicators of mastery of the material are the ability to demonstrate knowledge obtained from lecture materials and recommended literature, the correctness and completeness of answers to the teacher's questions that are asked to them during classes and related discussions.

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:	2
qualification:	Master

Semester, form of interim assessment: 3 (fall) - Grading test

Author: M.N. Vasilev, doctor of technical sciences, full professor

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
Gen.Pro.C-1 Gain fundamental scientific knowledge in the field of physical and mathematical sciences	Gen.Pro.C-1.1 Apply fundamental scientific knowledge in the field of physical and mathematical sciences
	Gen.Pro.C-1.2 Consolidate and critically assess professional experience and research findings
Gen.Pro.C-4 Successfully perform a task, analyze the results, and present conclusions, apply knowledge and skills in the field of physical and mathematical sciences and ICTs	Gen.Pro.C-4.2 Apply knowledge in the field of physical and mathematical sciences to solve problems, make conclusions, and evaluate the obtained results
	Gen.Pro.C-4.3 Justify the chosen method of scientific research
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-1.1 Locate, analyze, and summarize information on current research findings within the subject area
	Pro.C-1.2 Make hypotheses, build mathematical models of the studied phenomena and processes, evaluate the quality of the developed model
	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

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master:

- the skills of a large amount of interdisciplinary and special information analysis;
- a culture of setting problems in the field of system analysis and modeling of beam-plasma systems for various purposes and skills in appropriate computational experiments.

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

The list of laboratory works, the implementation and delivery of which is required to receive a grade for a differentiated test.

- Electron-beam plasma generation in an unlimited volume and control of the plasma cloud. Physical experiment.
- Electron-beam plasma generation in an unlimited volume. Computational experiment.
- Electron-beam plasma generation in a container. Computational experiment.
- Electron-beam plasma generation in a container. Physical experiment.

4. Evaluation criteria

1. The principle of operation of beam-plasma facilities.
2. Systems for an electron beam formation, focusing and scanning.
3. Injection windows for electron beams and physical processes occurring in oinjection windows of various types.
4. Processes occurring in the reaction chambers of beam-plasma setups.
5. Algorithms for computer simulation of the fast electrons motion in dense media.
6. Monte Carlo method for modeling electron kinetics.
7. The principle of self-consistency in the analysis an electron-beam plasma generation process.
8. The principles of compatibility in the design of beam-plasma facilities for technological and aerospace applications.

The mark is excellent 10 points - given to a student who has shown comprehensive, systematized, deep knowledge of the curriculum of the discipline, who is interested in this subject area, who has demonstrated the ability to confidently and creatively apply them in practice in solving specific problems, free and correct justification of the decisions made.

An excellent mark of 9 points is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, free and correct justification of decisions made.

An excellent grade of 8 points is given to a student who has shown comprehensive, systematized, in-depth knowledge of the curriculum of the discipline and the ability to confidently apply them in practice in solving specific problems, the correct justification of the decisions made, with some drawbacks.

A good score of 7 points is given to a student if he firmly knows the material, expresses it competently and to the point, knows how to apply the knowledge gained in practice, but does not adequately substantiate the results obtained.

A good score of 6 points is given to a student if he firmly knows the material, expounds it competently and to the point, knows how to apply the knowledge gained in practice, but makes some inaccuracies in the answer or in solving problems.

A good score of 5 points is given to a student if he basically knows the material, expresses it competently and to the point, knows how to apply the knowledge gained in practice, but makes a large number of inaccuracies in the answer or in solving problems.

The mark is satisfactory 4 points - given to a student who has shown a fragmentary, scattered nature of knowledge, insufficiently correct formulations of basic concepts, a violation of the logical sequence in the presentation of the program material, but at the same time he has mastered the main sections of the curriculum necessary for further education and can apply the acquired knowledge in sample in a standard situation.

The mark is satisfactory 3 points - given to a student who has shown a fragmented, scattered nature of knowledge, makes mistakes in the formulation of basic concepts, disruptions in the logical sequence in the presentation of program material, poorly knows the main sections of the curriculum necessary for further education and hardly applies the acquired knowledge even in standard situations.

The score is unsatisfactory 2 points - given to a student who does not know most of the main content of the curriculum of the discipline, makes gross errors in the formulation of basic principles and does not know how to use the knowledge gained when solving typical problems.

The mark is unsatisfactory 1 point - given to a student who does not know the main content of the curriculum of the discipline, makes gross errors in the formulation of the basic concepts of the discipline and generally does not have the skills to solve typical practical problems.

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

To pass an oral differential test the student is given 60 minutes for preparing and 15 minutes for presentation. The discussion on the student presentation should not exceed 15 minutes.

When preparing differential testing, students can use the discipline program, lecture notes and any other information excluding on-line Internet resources.

The main indicators of the discipline mastering are the assessments of the teacher during the midterm control. Boundary control is applied in the following forms:

- assessment of answers to questions in the process of a short (up to 5 minutes) selective oral survey before the start of each practical lesson based on the materials of the previous lesson;
- assessment of the ability to perform quantitative assessments (at the blackboard and / or in writing) of the most significant quantities characterizing the operation of beam-plasma systems and plasma properties at various conditions;
- assessment of activity and answers to questions when solving typical problems in accordance with the program of practical classes.