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:	Beam-Plasma Technologies. Part 2. Aerospace Technologies/Пучково-плазменные технологии. Часть 2. Аэрокосмические технологии
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: 4 (spring) - Grading test

Academic hours: 60 AH in total, including:
- lectures: 30 AH.
- seminars: 30 AH.
- laboratory practical: 0 AH.

Independent work: 30 AH.

In total: 90 AH, credits in total: 2

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

Known applications of electron beams and electron-beam generated plasma in aerospace technologies are the course subject. Among them:

- Plasma aerodynamics
- Plasma-assisted combustion
- Simulation of the space flight
- Active plasma experiments in free space, ionosphere and atmosphere
- Ground-based experimental setups for aerospace technologies development

The basic concepts of plasma physics and plasma chemistry are given in the context of engineering solutions for techniques and equipment for aerospace technologies. Aerospace applications of theelectron beams and electron-beam generated plasma are considered from both the point of view of scientific fundamentals and practical realizations.

1. Study objective

Purpose of the course

To acquaint students with the applications of electron-beam plasma in modern aerospace technologies and the development trends of scientific research related to the use of plasma in aerospace technologies

Tasks of the course

• Familiarization of students with known applications of electron-beam plasma in aerospace technologies: active experiments in space, ionosphere and atmosphere of the Earth, plasma aerodynamics, modeling of space flight factors, etc.;

• Demonstration to students of the work of beam-plasma systems in solving scientific problems related to aerospace technologies;

• Development of students' initial practical knowledge and skills when working with beam-plasma systems intended for scientific research in the field of aerospace technologies;

• Development of students' skills in designing beam-plasma systems for their subsequent use in experiments related to aerospace technologies.

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-1.3 Understand interdisciplinary relations in applied mathematics and computer science and apply them in professional settings
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.2 Assess the relevance and practical importance of research in professional settings
	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
Pro.C-1 Assign, formalize, and solve tasks, develop and research mathematical models of the studied phenomena and processes, systematically analyze scientific problems and	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

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:

- principles of operation and design of beam-plasma setups intended for the implementation of known aerospace technologies;
- methods of work on beam-plasma setups used in scientific experiments on aerospace topics, features of operation and maintenance of such setups;
- methods for measuring the main parameters characterizing the modes of operation of beam-plasma setups;
- parameters and target characteristics of beam-plasma systems when they are used in industry.

be able to:

- apply in practice the basic concepts used in the analysis and synthesis of beam-plasma systems in the development of research setups;
- perform calculations of the main parameters characterizing the operating modes of beam-plasma installations in solving practical problems related to setting up scientific experiments;
- carry out preliminary design of beam-plasma installations intended for conducting experiments on aerospace topics;
- perform physical and computer modeling of work processes in beam-plasma experimental facilities;
- 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 mastering a large amount of interdisciplinary and special information;
- a culture of setting goals in the design and application of beam-plasma systems for scientific research;
- skills of working on beam-plasma setups, ensuring their reliable and safe operation.

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 to the subject. A review of well-known scientific research on aerospace applications of electron-beam plasma. Basic circuit solutions of beam-plasma installations intended for scientific research	8			
2	Control methods for electron-beam plasma experimental setups during experiments on aerospace topics	2	4		
3	Methods to measure physical quantities characterizing stationary beam-plasma formations and beam plasma flows.	2	6		
4	Generation of electron-beam plasma flows. Experiments in the field of plasma aerodynamics	4	4		

5	Dispersion of liquids in an electron-beam plasma flows. Plasma-stimulated combustion of propellants	4	4		
6	Simulation of space flight factors acting on spacecraft. Computational experiments	6	6		
7	Active plasma experiments in free space, ionosphere and atmosphere	4	6		30
AH in total		30	30		30
Exam preparation		0 AH.			
Total complexity		90 AH., credits in total 2			

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

Semester: 4 (Spring)

1. Introduction to the subject. A review of well-known scientific research on aerospace applications of electron-beam plasma. Basic circuit solutions of beam-plasma installations intended for scientific research

The course subject and objectives. Known electron-beam plasma applications for scientific research on aerospace topics. Plasma aerodynamics, plasma-assisted combustion, simulation of space flight factors, aerosols in space. Synthesis of beam-plasma systems intended for ground testing of aerospace technologies. Principles of designing small-sized beam-plasma systems. System compatibility of electron-beam plasma generators. Ensuring the safety of beam-plasma installations for research purposes.

2. Control methods for electron-beam plasma experimental setups during experiments on aerospace topics

Control of the energy release density in the working volume of beam-plasma setups. Control of pressure and component composition of the plasma-forming medium in motionless beam-plasma formations and in flows of electron-beam plasma. Formation of the working zone in a beam-plasma installation. Gas temperature control in immobile beam-plasma formations and in electron-beam plasma flows. Temperature control of the model during the experiment. Automatic maintenance of the set modes during the experiment.

3. Methods to measure physical quantities characterizing stationary beam-plasma formations and beam plasma flows.

Measurement of gas temperature and models. Measurement of heat fluxes incident on the surface of the model. Optical and X-ray spectroscopy of electron-beam plasma. Measurement of the electron concentration in an electron-beam plasma. Mass spectrometry of plasma-forming media. Visualization of electron-beam plasma flows.

4. Generation of electron-beam plasma flows. Experiments in the field of plasma aerodynamics

Nozzle devices for electron-beam plasma generators. Combined devices: output window - gas nozzle. Influence of blowing on the thermal regimes of a model placed in a plasma flow. Aerodynamic characteristics of bodies of the simplest geometry in an electron-beam plasma flow. Phase transitions and plasma-chemical processes on the surface of a body in an electron-beam plasma flow.

5. Dispersion of liquids in an electron-beam plasma flows. Plasma-stimulated combustion of propellants

Dispersion of liquids in subsonic and supersonic electron-beam plasma flows. Formation of a combustible mixture in stationary beam-plasma formations and flows of electron-beam plasma. Ignition and combustion of gas and gas-liquid mixtures in an electron-beam plasma flow. Combustion of methane and propane in a free flow of electron-beam plasma and in a flow localized by the channel wall.

6. Simulation of space flight factors acting on spacecraft. Computational experiments

Calculation of particle fluxes falling on the surface of a spacecraft. Simulation of the impact of atomic oxygen plasma on the surface of an artificial satellite of the Earth. Influence of the own atmosphere of a spacecraft on the fluxes of particles falling on its surface. Modeling the influence of space flight factors on the mechanical, electrical and optical properties of spacecraft structural materials. Simulation of electrostatic charging of spacecraft.

7. Active plasma experiments in free space, ionosphere and atmosphere

Artificial aurora. Simulation of aerodynamic heating. Energy transportation. Microwave absorption in plasma clouds. On-board experiments.

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.N. Vasiliev, Aung Tun Win. Generation and Applications of Electron-Beam Plasma Flows // Journal of Physics Conference Series. 2015, V. 591. doi:10.1088/1742-6596/591/1/012051
1) B2) V. E. Fortov, A. V. Gavrikov, O. F. Petrov, V. S. Sidorov, M. N. Vasiliev and N. A. Vorona. Superhigh dust charging by high-voltage electron beam // EPL (Europhysics Letters), 2011, V. 94, No. 5, P 55001. doi:10.1209/0295-5075/94/55001
3) 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.
4) Igor Matveev. Plasma Assisted Combustion, Gasification, and Pollution Control // Volume 1. MethodsofPlasmaGenerationfor PAC – 2013. – P. 50-75.

Additional literature

1) M. Vasiliev, T. Vasilieva. Materials production with Beam Plasmas. In Encyclopedia of Plasma Technology (Ed. J.L. Shohet, Taylor & Francis), 2017
2) Klimov A., Bityurin V., Vasiliev M., Vystavkin N., Kuznetsov A. Combined Discharge Plasma in Supersonic Airflow // 42-nd Aerospace Sciences Meeting and Exhibit, 5-8 January 2004, Reno, Nevada, AIAA 2004-0670.
3) M.N. Vasiliev, S.L. Lysenko, A.H. Mahir. Experimental Complex to Study Heterogeneous Electron-Beam Plasma Flows // Proc. of XII Int. Conf. On the Methods of Aerophysical Research (ICMAR 2004), 28June-3 July, 2004, Novosibirsk, Russia, Part III, P. 189-192.
4) 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.
5) Bychkov, V.; Vasiliev, M.; Koroteev, A. Electron-Beam Plasma: Generation, Properties, Applications; Moscow State Open University Publishers: Moscow, Russia, 1993.

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 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.

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: 4 (spring) - 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-1.3 Understand interdisciplinary relations in applied mathematics and computer science and apply them in professional settings
Gen.Pro.C-2 Acquire an understanding of current scientific and technological challenges in professional settings, and scientifically formulate professional objectives	Gen.Pro.C-2.1 Assess the current state of mathematical research within professional settings
	Gen.Pro.C-2.2 Assess the relevance and practical importance of research in professional settings
	Gen.Pro.C-2.3 Understand professional terminology used in modern scientific and technical literature and present scientific results in oral and written form within professional communication
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

As a result of studying the course the student should:

know:

- principles of operation and design of beam-plasma setups intended for the implementation of known aerospace technologies;
- methods of work on beam-plasma setups used in scientific experiments on aerospace topics, features of operation and maintenance of such setups;
- methods for measuring the main parameters characterizing the modes of operation of beam-plasma setups;
- parameters and target characteristics of beam-plasma systems when they are used in industry.

be able to:

- apply in practice the basic concepts used in the analysis and synthesis of beam-plasma systems in the development of research setups;
- perform calculations of the main parameters characterizing the operating modes of beam-plasma installations in solving practical problems related to setting up scientific experiments;
- carry out preliminary design of beam-plasma installations intended for conducting experiments on aerospace topics;
- perform physical and computer modeling of work processes in beam-plasma experimental facilities;
- 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 mastering a large amount of interdisciplinary and special information;
- a culture of setting goals in the design and application of beam-plasma systems for scientific research;
- skills of working on beam-plasma setups, ensuring their reliable and safe operation.

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

Current control is carried out in the form of independent work or written tests on each topic.
The management and control of the student's independent work is carried out as a result of the analysis of the results of control, independent work, as well as individual consultations.

4. Evaluation criteria

- Control of the energy release density in the working volume of beam-plasma setups.
- Control of pressure and component composition of the plasmagenerating medium in motionless beam-plasma formations and in flows of electron-beam plasma.
- Measurement of the electron concentration in an electron-beam plasma.
- Visualization of electron-beam plasma clouds and flows.
- Aerodynamic characteristics of bodies of the simplest geometry in an electron-beam plasma flow.
- Simulation of the heave particles impact on the surface of an artificial satellite of the Earth.
- Simulation of the electrons impact on the surface of an artificial satellite of the Earth.
- Combustion of gaseous mixtures and dispersed liquids assisted by electron-beam plasma (in a free volume and in channel).
- Active plasma experiments in free space, ionosphere and atmosphere on the example of artificial aurora.

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 the oral grading 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.