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
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Work program of the course (training module)

course: Plasma Technical Systems/Плазмотехнические системы
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) - Exam

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

Independent work: 30 AH.

Exam preparation: 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

The course subject is to familiarize students with the known schematic solutions of plasma technical systems of various types:

- Thermal plasma generators;
- Low pressure non-thermal plasma generators;
- Generators of non-thermal atmospheric pressure plasma;
- Hybrid plasma technical systems.

Constructions and operation of plasma technical systems are given in the context of basic concepts of electro physics, gas dynamics, heat transfer, plasma physics and plasma chemistry. Plasma technical systems applications are illustrated by real industrial and aerospace technologies. Operation features, reliability, technical and environment safety are discussed as well.

1. Study objective

Purpose of the course

To acquaint students with the principles of designing and real constructions of plasma technical systems in relation to the problems of developing industrial and aerospace technologies, as well as laboratory facilities.

Tasks of the course

- Familiarization of students with well-known schemes and designs of devices generating low-temperature plasmas in laboratory and industrial conditions.
- Familiarization of students with the use of thermal and non-thermal plasma generators in science, engineering and technology;
- Development of students' initial practical knowledge and skills of working with plasma torches, and gas-discharge plasma sources electron-beam plasma generators;
- Development of students' initial skills in designing 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-1.3 Understand interdisciplinary relations in applied mathematics and computer science and apply them in professional settings
Pro.C-3 Use research and testing equipment (devices and installations, specialized software) in a selected subject field	Pro.C-3.1 Understand the operating principles of the equipment and specialized software
	Pro.C-3.2 Conduct an experiment (simulation) using research equipment (software)
	Pro.C-3.3 Evaluate the accuracy of the experimental (numerical) results

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

As a result of studying the course the student should:

know:

- designs of low-temperature plasma generators of various types and for various purposes;
- methods for calculating working processes in thermal and non-thermal plasma generators;
- methods for studying the characteristics of thermal and non-thermal plasma generators;
- fundamentals of industrial and environmental safety in the operation of plasma technical systems for various purposes.

be able to:

• apply in practice the basic concepts used in the analysis and design of plasma technical systems for various purposes;
• carry out calculations of the characteristics of plasma technical systems during their design, as well as calculations related to the optimization of plasma technical systems in solving practical technological and engineering problems;
• carry out preliminary design of laboratory plasma technical systems;
• master new subject areas, theoretical approaches and experimental techniques related to the analysis, design and application of plasma technical systems for various purposes.

master:

• the skills of mastering a large amount of interdisciplinary and special information;
• the culture of setting goals in the field of design and application of plasma technology systems for technological purposes; skills in working on 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. Classification of plasma technical systems. Main parameters characterizing plasma technical systems.		2	2	5
2	Thermal plasma generators. Types, characteristics, designs, applications.		2	2	5
3	Low pressure non-thermal plasma generators. Types, designs, characteristics, applications.		4	4	5
4	Generators of non-thermal atmospheric pressure plasma.		2	2	5
5	Combined plasma technical systems for technological applications.		3	3	5
6	Assessment of plasma technical systems reliability and safety.		2	2	5
AH in total			15	15	30
Exam preparation		30 AH.			
Total complexity		90 AH., credits in total 2			

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

Semester: 3 (Fall)

1. Introduction. Classification of plasma technical systems. Main parameters characterizing plasma technical systems.

Subject, goals and objectives of the course. Principles of classification of plasma technical systems according to the method of plasma generation and design solutions. Power and efficiency of plasma generators, temperature of the working fluid, pressure in the working volume, plasma flow velocity. Known applications of plasma technical systems of various types. Promising areas of plasma technical systems application.

2. Thermal plasma generators. Types, characteristics, designs, applications.

Electric arc plasma torches. Electrode systems and working chambers of electric arc plasma torches. Thermal protection of structural elements of electric arc plasma torches. microwave plasmatrons. Technical characteristics of known thermal plasma generators. Generators of supersonic thermal plasma flows. Thermogasdynamic testing of materials and products using electric arc plasma torches. Plasmatrons in production technologies.

3. Low pressure non-thermal plasma generators. Types, designs, characteristics, applications.

Gas-discharge generators of non-thermal low-pressure plasma: plasma-technical systems with a glow discharge of various frequency ranges. Electrode and non-electrode systems. Thermodynamic characteristics of low-pressure gas-discharge plasma. Examples of schemes and design solutions for setups with non-thermal low-pressure plasma. The principle of electron-beam plasma generation in gases of intermediate pressures.

4. Generators of non-thermal atmospheric pressure plasma.

Dielectric barrier discharge and plasma installations based on it. Plasma needle, plasma torch. Crown. High voltage sliding discharge. Ionization of gases by radiations of different frequency ranges and corpuscular streams. laser plasma. ECR plasma. Known schemes and design solutions for generators of non-thermal atmospheric pressure plasma and their applications in science, engineering and technology.

5. Combined plasma technical systems for technological applications.

The concept of hybrid plasma. Combined action of several ionizers of various types and their compatibility. Known schematic solutions for hybrid plasma generators.

6. Assessment of plasma technical systems reliability and safety.

Reliability of plasma technical systems of various types and principles of predicting failures during their operation. Regulations for the maintenance of plasma setups. Electrical safety of plasma technical systems. Prevention of the environment chemical pollution during the operation of plasma systems of various types and a comparative analysis of their environmental characteristics. Radiation and electromagnetic safety of plasma technical systems.

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, the PPT-2 plasma torch, RF gas-discharge plasma generators, hybrid plasma systems, diagnostic equipment, auxiliary and special technological equipment (room 222 of the UPM building) . Necessary equipment for 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) Yuri P. Raizer, Gas Discharge Physics, Springer (1991).
2) Alexander Fridman, Lawrence A. Kennedy, Plasma Physics and Engineering, CRC Press (2011).
3) Encyclopedia of low-temperature plasma. Chief editor V. Fortov. Moscow. Nauka, 2001. V. XI, sections XI-2, XI-4.9, XI-5.
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.

Additional literature

1) 2) Bychkov, V.; Vasiliev, M.; Koroteev, A. Electron-Beam Plasma: Generation, Properties, Applications; Moscow State Open University Publishers: Moscow, Russia, 1993.
2) V. Kolikov, A. Bogomaz, A. Budin. Powerful Pulsed Plasma Generators. Spriger, 2018. 250 p.
3) Special Issue "Plasma Processes for Renewable Energy Technologies". Ed. Masaaki Okubo. MDPI, 2019. https://doi.org/10.3390/en12234416

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 "Plasma Technical 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, 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
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	Chair of Logistics Systems and Technologies
term:	2
qualification:	Master

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

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-1.3 Understand interdisciplinary relations in applied mathematics and computer science and apply them in professional settings
Pro.C-3 Use research and testing equipment (devices and installations, specialized software) in a selected subject field	Pro.C-3.1 Understand the operating principles of the equipment and specialized software
	Pro.C-3.2 Conduct an experiment (simulation) using research equipment (software)
	Pro.C-3.3 Evaluate the accuracy of the experimental (numerical) results

2. Competency assessment indicators

As a result of studying the course the student should:

know:

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- methods for calculating working processes in thermal and non-thermal plasma generators;
- methods for studying the characteristics of thermal and non-thermal plasma generators;
- fundamentals of industrial and environmental safety in the operation of plasma technical systems for various purposes.

be able to:

- apply in practice the basic concepts used in the analysis and design of plasma technical systems for various purposes;
- carry out calculations of the characteristics of plasma technical systems during their design, as well as calculations related to the optimization of plasma technical systems in solving practical technological and engineering problems;
- carry out preliminary design of laboratory plasma technical systems;
- master new subject areas, theoretical approaches and experimental techniques related to the analysis, design and application of plasma technical systems for various purposes.

master:

- the skills of mastering a large amount of interdisciplinary and special information;
- the culture of setting goals in the field of design and application of plasma technology systems for technological purposes; skills in working on plasma setups, ensuring their reliable and safe operation.

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 exam:

- Generation of thermal plasma by electric arc plasma torches.
- Generation of the RF discharge plasma.
- Electron-beam plasma generation in an unlimited volume
- Generation of hybrid plasma.

4. Evaluation criteria

Examples of exam questions:

1. Classifications of plasma technical systems, types of plasma systems
2. Electric arc plasma torches: principle of operation, variants of constructive solutions.
3. General properties of thermal plasma and characteristics of thermal plasma generators.
4. Thermogasdynamic tests using electric arc plasma torches.
5. Application of electric arc plasma torches in production technologies.

6. Gas-discharge generators of low-temperature low-pressure plasma, their classification and design options..

7. Main properties of DC discharge plasma.

8. Basic properties of high-frequency gas discharge plasma.

9. Industrial technologies based on gas-discharge plasma.

10. Plasma technical systems based on a dielectric barrier discharge: the principle of operation, options for constructive solutions.

11. Main properties of the dielectric barrier discharge plasma.

12. Plasma technical systems based on dielectric barrier discharge: technological applications.

13. Plasma technical systems based on ECR plasma: operating principle, options for constructive solutions, applications.

14. Plasma technical systems based on corona discharge: principle of operation, design options, applications.

15. Plasma technical systems based on a high-voltage discharge: principle of operation, options for constructive solutions, applications.

16. Ionization of gases by radiations of various frequency ranges and corpuscular beams.

17. Electron-beam plasma generators.

18. Combined action of several ionizers of various types and their compatibility. Known schematic solutions for hybrid plasma generators.

19. Electrical safety of plasma systems.

20. Environmental safety of plasma systems.

21. Radiation and electromagnetic safety of plasma systems.

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 exam 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 additional indicators of the discipline mastering at the final control arel:

- assessment of answers to questions in the process of a short (up to 5 minutes);
- assessment of answers to questions when discussion typical problems in accordance with the program of practical classes.