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:	Design and Maintenance of Beam-Plasma Systems/Проектирование и техническое обслуживание 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 known applications of electron-beam plasma in industrial and aerospace technologies. Development of students' initial practical knowledge and skills when working with various beam-plasma systems is the main subject of part of training in the laboratory equipped with plasma generators and plasma chemical reactors with various supporting facilities including safety sub-systems. Controlling systems for these setups and units are considered as well.

1. Study objective

Purpose of the course

To acquaint students with the real beam-plasma systems applied in industrial and aerospace technologies. Basic principles of these systems design and safe maintenance are demonstrated in typical experiments related to plasma chemistry and plasma aerodynamics

Tasks of the course

- Familiarization of students with known applications of electron-beam plasma in industrial and aerospace technologies:
- Demonstration to students of the work of beam-plasma systems for materials production and laboratory setups for plasma aerodynamic experiments
- Development of students' initial practical knowledge and skills when working with beam-plasma systems;
- Development of students' skills in designing main and supporting systems of beam-plasma setups including controlling their systems.

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 operation and design of beam-plasma setups used in typical industrial and aerospace technologies.
- methods of work on beam-plasma setups for various purposes, features of their operation and maintenance; principles for ensuring the reliability and safety of beam-plasma setups.
- methods for control the main parameters characterizing the operation modes of beam-plasma setups;

be able to:

- apply in practice the basic concepts used in the analysis and synthesis of beam-plasma systems;
- analyze the main parameters characterizing the operating modes of beam-plasma setups in solving practical technological and engineering problems;
- carry out preliminary design of beam-plasma setups for various experiments taking into account the features of the planned experiments;
- analyze possible danger under the electron-beam plasma generating setups operation and measures to avoid risks of any kind;
- master new subject areas, theoretical approaches and experimental techniques related to the analysis, design and application of beam-plasma systems for technological 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 in industrial and aerospace technologies;
- 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	Basic circuit solutions of beam-plasma installations designed for industrial and aerospace technologies		2	2	
2	Control methods for setups that realize combined beam-plasma effects on matter in gaseous, liquid and solid states.		2	2	
3	Methods for measuring physical quantities characterizing beam-plasma setups operation for various purposes.		2	2	
4	Processes in beam plasmas generating setups responsible for effective and safe equipment operation.		2	2	
5	Technological processes of low-temperature plasma-stimulated synthesis of inorganic compounds.		2	2	
6	Technological processes of controlled destruction of macromolecular compounds in electron-beam plasma.		2	2	
7	Generation of hybrid plasmas and technological processes of coating deposition in hybrid plasmas.		3	3	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. Basic circuit solutions of beam-plasma installations designed for industrial and aerospace technologies

Introduction. Subject, goals and objectives of the course. Technique of electron beams generation. Methods for injection of electron beams into dense gaseous media, injection windows. Electron guns, high voltage power supplies. Main systems and components of beam-plasma generators. Elements of internal equipment of plasma-chemical reactors. Ensuring the safety of beam-plasma installations.

2. Control methods for setups that realize combined beam-plasma effects on matter in gaseous, liquid and solid states.

Control of the accelerating voltage and current of the electron beam. Control of the energy release density in the working volume of beam-plasma installations. Control of pressure and component composition of the gaseous plasma-forming medium. Formation of the working zone containing dispersed powders and liquids in a beam-plasma setups Temperature control of the setup working volume. Automatic maintenance of the specified modes when the setup operates.

3. Methods for measuring physical quantities characterizing beam-plasma setups operation for various purposes.

Temperature measurements in beam-plasmas. Measurement of heat flows in the working zone of the reactor, calorimetry of the reaction volume. Optical measurements as a source of information about the parameters of the reaction volume. Mass spectrometry of the reaction volume. Dosimetry of X-ray radiation in beam-plasma setups.

4. Processes in beam plasmas generating setups responsible for effective and safe equipment operation.

Heating of solids contacting with electron-beam plasma, phase transitions. Plasma chemical processes in solids, liquids and gases. Radiation emission. Electrostatic effects.

5. Technological processes of low-temperature plasma-stimulated synthesis of inorganic compounds.

Synthesis of nitrides and oxides of metals in electron-beam plasma. Mechanical and chemical properties of oxides and nitrides synthesized in electron-beam plasma. Synthesis of coatings on the surface of dispersed powders.

6. Technological processes of controlled destruction of macromolecular compounds in electron-beam plasma.

Obtaining low molecular weight compounds by controlled destruction of polysaccharides. Obtaining valuable water-soluble products from natural organic raw materials. Beam-plasma modification of proteins. Control of hydrophilic-hydrophobic properties of polymers and biopolymers by beam-plasma treatment. Technologies for the disposal of household and industrial waste based on the beam-plasma effect on the substance. Conversion of liquid and gaseous hydrocarbons in non-equilibrium plasma.

7. Generation of hybrid plasmas and technological processes of coating deposition in hybrid plasmas.

Technique of generation of hybrid plasma generation and features of the organization of work processes in hybrid reactors. Hybrid plasma generation by joint action of electron beams and RF gas discharge. Deposition of coatings in hybrid plasma. Obtaining single-layer and multilayer coatings in hybrid plasma: various combinations of deposited materials and coating materials. Deposition of carbon coatings.

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, T. Vasilieva. Materials production with Beam Plasmas. In Encyclopedia of Plasma Technology (Ed. J.L. Shohet, Taylor & Francis), 2017.
2) 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)
3) 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) 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) M. Vasiliev, Aung Tun Win, I. Pobol. “New applications of the Beam-Plasma Systems for the materials production” Int. J. Nanotechnology. 2014, Vol. 11, Nos 5/6/7/8, P. 660-668.
3) Bychkov, V.; Vasiliev, M.; Koroteev, A. Electron-Beam Plasma: Generation, Properties, Applications; Moscow State Open University Publishers: Moscow, Russia, 1993.
4) T. Vasilieva, S. Lopatin, V. Varlamov, V. Miasnikov, Aung Myat Hein, M. Vasiliev. Hydrolisys of chitin and chitosan in low temperature electron-beam plasma // Pure and Applied Chemistry - – 2016. – V.88, N9 – P. 873-879.

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 "Design and Maintenance 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

As a result of studying the course the student should:

know:

- principles of operation and design of beam-plasma setups used in typical industrial and aerospace technologies.
- methods of work on beam-plasma setups for various purposes, features of their operation and maintenance; principles for ensuring the reliability and safety of beam-plasma setups.
- methods for control the main parameters characterizing the operation modes of beam-plasma setups;

be able to:

- apply in practice the basic concepts used in the analysis and synthesis of beam-plasma systems;
- analyze the main parameters characterizing the operating modes of beam-plasma setups in solving practical technological and engineering problems;
- carry out preliminary design of beam-plasma setups for various experiments taking into account the features of the planned experiments;
- analyze possible danger under the electron-beam plasma generating setups operation and measures to avoid risks of any kind;
- master new subject areas, theoretical approaches and experimental techniques related to the analysis, design and application of beam-plasma systems for technological 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 in industrial and aerospace technologies;
- 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

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

- Thermal and chemical-thermal treatment of steels in electron-beam plasma. Intensity of the X-ray radiation measurement when experiment carrying out.
- Low-temperature plasma-stimulated synthesis of titanium oxides. Supporting of the plasma chemical reactor reliability.
- Aerosol fly-out caused by the electron beam injection. Instabilities of the reaction volume.
- Generation of hybrid air plasma. Possible ignition of fuel-air mixtures in hybrid plasma

4. Evaluation criteria

1. The principle of operation of beam-plasma installations.
2. Formation of a plasma generating medium in beam-plasma reactors.
3. Physical processes occurring in the gaseous reaction volume.
4. Processes occurring at the interface between beam plasma and solid body.
5. Beam-plasma reactors for technological purposes: main and auxiliary systems.
6. X-ray radiation emission and radiation protection of beam-plasma setups.
7. Methods for measuring the main parameters characterizing the mode of operation of a beam-plasma reactor.
8. Experiment on thermal and non-thermal plasma chemical materials treatment^ arrangement and safety.
9. Mechanisms of stability loss in the gaseous reaction volume.
10. Mechanisms of stability loss in the reaction volume containing a condensed dispersed phase, and methods for suppressing instabilities.

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.

3. Перечень типовых контрольных заданий, используемых для оценки знаний, умений, навыков

3.1. Перечень лабораторных работ, выполнение и сдача которых обязательна для получения оценки по дифференцированному зачету.

- Термическая и химико-термическая конструкционных сталей в электронно-пучковой плазме.
- Низкотемпературный плазменно-стимулированный синтез оксидов титана.
- Управление гидрофильно-гидрофобными свойствами высокомолекулярных соединений с помощью неравновесной плазмы.
- Генерация гибридной плазмы воздуха.

3.2. Перечень контрольных вопросов (в произвольном порядке) для подготовки к сдаче лабораторных работ.

1. Принцип действия пучково-плазменных установок.
2. Формирование плазмообразующей среды в пучково-плазменных реакторах..
3. Физические процессы, происходящие в газообразном реакционном объеме.
4. Процессы, происходящие на границе контакта пучковая плазма - твердое тело.
5. Пучково-плазменные реакторы технологического назначения: основные и вспомогательные системы.
6. Методы диагностики электронно-пучковой плазмы
7. Методы измерения основных параметров, характеризующих режим работы пучково-плазменного реактора.
8. Физико-химические процессы, происходящие при термической и химико-термической обработке материалов в электронно-пучковой плазме.
9. Физико-химические процессы, происходящие при синтезе оксидов и нитридов в электронно-пучковой плазме. Плазмохимическая модель электронно-пучковой плазмы кислорода и азота.
10. Физико-химические процессы, приводящие к изменению гидрофильно-гидрофобных свойств высокомолекулярных соединений под действием низкотемпературной плазмы.
11. Механизмы потери устойчивости газообразного реакционного объема в пучково-плазменных установках технологического назначения.
12. Механизмы потери устойчивости реакционного объема, содержащего конденсированную дисперсную фазу, и способы подавления неустойчивостей.

4. Критерии оценивания

Основными показателями владения материалом являются умения демонстрировать знания, полученные из материалов лекций и рекомендуемой литературы, правильность и полнота ответов на вопросы преподавателя, которые им задаются при проведении занятий и сопутствующих дискуссий. Дополнительный опрос студентов при сдаче дифференцированного зачета не предусмотрен, однако оценка, выставляемая студенту, предполагает учет качества отчетов, подготавливаемых студентом для сдачи лабораторных работ.

оценка ***«отлично (10)»*** выставляется студенту, показавшему всесторонние, систематизированные, глубокие знания учебной программы дисциплины при ответе на вопросы экзаменационного билета, а также на дополнительные вопросы (вне экзаменационного билета) и задачи по программе дисциплины.

оценка ***«отлично (9)»*** выставляется студенту, показавшему систематизированные, глубокие знания учебной программы дисциплины при ответе на вопросы экзаменационного билета, а также на дополнительные вопросы (вне экзаменационного билета) по программе дисциплины.

оценка ***«отлично (8)»*** выставляется студенту, показавшему систематизированные, глубокие знания учебной программы дисциплины при ответе на вопросы экзаменационного билета и правильные ответы не менее чем на два из трех дополнительных вопросов (вне экзаменационного билета) по программе дисциплины.

оценка ***«хорошо (7)»*** выставляется студенту, продемонстрировавшему твердые, систематизированные знания материала экзаменационного билета, но допускающему в ответе на вопросы по билету или дополнительные, уточняющие вопросы в рамках билета неточности, не связанные с принципиальными ошибками или не знанием материала.

оценка ***«хорошо (6)»*** выставляется студенту продемонстрировавшему, систематизированные знания материала экзаменационного билета, но допускающему в ответе на дополнительные, уточняющие вопросы (не более пяти) в рамках билета не более двух ошибочных ответов, не связанных с принципиальным непониманием материала.

оценка ***«хорошо (5)»*** выставляется студенту продемонстрировавшему, систематизированные знания материала экзаменационного билета, но допускающему в ответе на дополнительные, уточняющие вопросы (не более пяти) в рамках билета не более четырех ошибочных ответов, не связанных с принципиальным непониманием материала.

оценка ***«удовлетворительно (4)»*** выставляется, если во время ответа на вопросы экзаменационного билета, а при необходимости и дополнительных вопросов (вне рамок билета) студент показывает нетвердое знание базовых положений, связанных с материалом билета и дополнительных вопросов (допускает ошибки в определениях, фундаментальные законах, и т.п.), допускает нарушение логической последовательности при ответах, но при этом демонстрирует знание основных разделов учебной программы.

оценка ***«удовлетворительно (3)»*** выставляется, если во время ответа на вопросы экзаменационного билета студент показывает разрозненный характер знаний, нечеткие, но без грубых ошибок, формулировки базовых положений, входящих в материалы билета, допускает нарушение логической последовательности в изложении программного материала, но при этом демонстрирует общее понимание и ключевые знания основных разделов учебной программы.

оценка ***«неудовлетворительно (2-1)»*** выставляется, если во время ответа на вопросы экзаменационного билета, студент показывает, что не знает большей части основного содержания материалов билета, допускает грубые ошибки при формулировках базовых положений, входящих в материалы билета; во время ответа на вопросы билета обращается к справочным материалам (конспектам лекций, семинаров и пр.).

5. Методические материалы, определяющие процедуры оценивания знаний навыков и (или) опыта деятельности

Основными показателями усвоения материалов изучения дисциплины являются оценки преподавателя в ходе рубежного контроля. Рубежный контроль применяется в следующих формах:

- оценка ответов на вопросы в процессе краткого (до 5 мин) выборочного устного опроса перед началом каждого практического занятия по материалам предыдущего занятия;

- оценка умения выполнять количественные оценки (у доски и/или в письменном виде) наиболее значимых величин, характеризующих работу пучково-плазменных систем технологического назначения и свойства плазмы в различных условиях;
- оценка активности и ответов на вопросы при решении типовых задач в соответствии с программой практических занятий.