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

**APPROVED**
**Vice Rector for Academic Affairs**

**A.A. Voronov**

**Work program of the course (training module)**

| | |
|---|---|
| **course:** | General Physics: Electricity and Magnetism/Общая физика: электричество и магнетизм |
| **major:** | Biotechnology |
| **specialization:** | Biomedical Engineering/Биомедицинская инженерия |
| | Phystech School of Biological and Medical Physics |
| | Chair of General Physics |
| **term:** | 2 |
| **qualification:** | Bachelor |

Semester, form of interim assessment: 4 (spring) - Exam

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

Independent work: 45 AH.

Exam preparation: 30 AH.

In total: 135 AH, credits in total: 3

Authors of the program:

P.V. Popov, candidate of physics and mathematical sciences
A.V. Ilin, candidate of physics and mathematical sciences, associate professor

The program was discussed at the Chair of General Physics 04.06.2020

## Annotation

Mastering basic knowledge by students for further study of other branches of physics.

### 1. Study objective

**Purpose of the course**

Development of students' basic knowledge in the field of physics of electromagnetic phenomena for further study of other branches of physics and in-depth study of the fundamentals of electricity and magnetism.

**Tasks of the course**

- Formation of students ' basic knowledge in the field of electricity and magnetism;
- formation of skills and abilities to apply the studied theoretical laws and mathematical tools to solve various physical problems;
- the formation of physical culture: the ability to distinguish the essential physical phenomena and to disregard the irrelevant; ability to conduct evaluations of physical quantities; ability to build a simple theoretical model is described serving the physical processes.

### 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 |
|---|---|
| UC-1 Search and identify, critically assess, and synthesize information, apply a systematic approach to problem-solving | UC-1.1 Analyze problems, highlight the stages of their solution, plan the actions required to solve them |
| | UC-1.2 Find, critically assess, and select information required for the task in hand |
| | UC-1.3 Consider various options for solving a problem, assess the advantages and disadvantages of each option |
| | UC-1.4 Make competent judgments and estimates supported by logic and reasoning |
| | UC-1.5 Identify and evaluate practical consequences of possible solutions to a problem |
| Gen.Pro.C-2 Use modern IT and software tools to perform professional tasks in compliance with information security requirements | Gen.Pro.C-2.1 Apply modern computing tools and Internet services in professional settings |
| | Gen.Pro.C-2.2 Apply numerical mathematical methods and use software applications for scientific problem-solving in professional settings |
| | Gen.Pro.C-2.3 Fulfill basic information security requirements |
| Pro.C-1 Plan and conduct scientific experiments (in a selected subject area) and/or theoretical (analytical and simulation) research | Pro.C-1.1 Understand the fundamental concepts, laws, and theories of modern physics and biology |

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

As a result of studying the course the student should:

know:

- fundamental laws and concepts of physics of electromagnetic phenomena, as well as the limits of their applicability:
- the law of conservation of charge, Coulomb's law, superposition principle, theorem Gaussa integral and differential form;
- the concept of potential and its relation to field strength;
- basic concepts in the calculation of the electric field in a substance: field vectors and electric induction, polarizability and dielectric permeability;
- Ohm's law in integral and differential forms, Kirchhoff's rules, Joule-Lenz's law;
- the law of Biot–Savart, the theorem of circulation of magnetic field in integral and differential form;
- basic concepts in the calculation of the magnetic field in matter: magnetic induction and field strength, magnetization vector, conduction currents and molecular currents;
- the law of electromagnetic induction, Lenz's law;
- basic concepts of oscillation theory: free damped oscillations, damping coefficient, logarithmic decrement and q-factor, forced oscillations, resonance, parametric excitation of oscillations, self-oscillations;
- Maxwell's equations in integral and differential form;
- the law of conservation of energy and Poynting's theorem;
- basic concepts of plasma and waveguides.

be able to:

- apply the studied General physical laws to solve specific problems of electricity and magnetism:
- apply the Gauss theorem to find the electric field in vacuum and in matter;
- to write and solve the equations of Poisson and Laplace;
- apply the circulation theorem to find the magnetic field in vacuum and in matter;
- use the "image" method to calculate electrical and magnetic fields;
- apply the energy method of calculating the forces in the electric and magnetic field;
- calculate electrical capacity and self - and mutual-induction coefficients;
- use a complex form of representation of oscillations and vector diagrams in the calculation of oscillatory circuits;
- analyze physical problems, highlighting the essential and non-essential aspects of the phenomenon, and on the basis of the analysis to build a simplified theoretical model of physical phenomena;
- apply various mathematical tools to solve problems based on the generated physical laws, and carry out the necessary analytical and numerical calculations.

master:

- the main methods of solving problems of physics of electromagnetic phenomena;
- basic mathematical tools specific to the problems of electricity and magnetism.

**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 | Electric field. Superposition principle. The field of a dipole. gauss theorem. | 2 | 2 | | 3 |
| 2 | Potential. Conductors in an electric field. The method of images. | 2 | 2 | | 3 |
| 3 | The electric field in the substance. Vectors →E and→D. | 2 | 2 | | 3 |
| 4 | The energy of the electric field. Energy method for calculating forces. Currents in non-confined environments. | 2 | 2 | | 3 |
| 5 | Magnetic current field. Circulation theorem. Magnetic moment. | 2 | 2 | | 3 |

| | | | | | |
|---|---|---|---|---|---|
| 6 | The magnetic field in the substance. Vectors →B and →H. | 2 | 2 | | 3 |
| 7 | Test. | 2 | 2 | | 3 |
| 8 | Analysis of control work. Delivery of the 1st task. | 2 | 2 | | 3 |
| 9 | Movement of charged particles in electric and magnetic fields. Electromagnetic induction. The theorem of reciprocity. | 2 | 2 | | 3 |
| 10 | Magnetic energy. Forces in a magnetic field. Superconductors in a magnetic field. | 2 | 2 | | 3 |
| 11 | Transients in electrical circuits. Free vibrations. | 2 | 2 | | 3 |
| 12 | Forced oscillations. The method of complex amplitudes. | 2 | 2 | | 3 |
| 13 | Modulated oscillations. Spectral analysis in linear systems. Para-metric fluctuations. Self-oscillation. | 2 | 2 | | 3 |
| 14 | Maxwell equation. Bias current. The Theorem Of Poynting. | 2 | 2 | | 3 |
| 15 | Electromagnetic waves in waveguides. Resonators. Plasma. | 2 | 2 | | 3 |
| AH in total | | 30 | 30 | | 45 |
| Exam preparation | | 30 AH. | | | |
| Total complexity | | 135 AH., credits in total 3 | | | |

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

Semester: 4 (Spring)

1. Electric field. Superposition principle. The field of a dipole. gauss theorem.

Application of the principle of superposition for calculation of electrostatic field of systems of point charges and the Gauss theorem to the symmetrical systems.

2. Potential. Conductors in an electric field. The method of images.

Calculation of the potential of electrostatic field. Accounting for induced charges on the surface of conductors by the method of images.

3. The electric field in the substance. Vectors →E and→D.

Problems on electrostatic phenomena in continuous media. Application of the Gauss theorem for the vector of electrical induction D to the calculation of the electric field of dielectrics.

4. The energy of the electric field. Energy method for calculating forces. Currents in non-confined environments.

Application of energy approach to calculation of forces resulting from the action of electrostatic field. The distribution of current in an infinite medium.

5. Magnetic current field. Circulation theorem. Magnetic moment.

Calculation of magnetic field produced by electrical currents using the principle of superposition and Ampere's circuital law.

6. The magnetic field in the substance. Vectors →B and →H.

Calculation of magnetic field in continuous media (paramagnetics,diamagnetics and ferromagnetics).

7. Test.

Written test on the material of previous seminars.

8. Analysis of control work. Delivery of the 1st task.

Feedback session. Submission of the first assignment.

9. Movement of charged particles in electric and magnetic fields. Electromagnetic induction. The theorem of reciprocity.

Study of motion of charged particles in the crossed electrical and magnetic fields. Electromagnetic induction.

10. Magnetic energy. Forces in a magnetic field. Superconductors in a magnetic field.

Calculation of the energy of magnetic field and forces, caused by magnetic field. Study of the behavior of superconductors in magnetic field.

11. Transients in electrical circuits. Free vibrations.

Problems related to transient processes and free oscillations in electrical circuits.

12. Forced oscillations. The method of complex amplitudes.

Study of stimulated oscillations and summation of oscillations using the method of complex amplitudes.

13. Modulated oscillations. Spectral analysis in linear systems. Para-metric fluctuations. Self-oscillation.

Analysis of the response of linear systems on the external influence, spectrum of the response. Modulated, parametric oscillations, self-oscillations.

14. Maxwell equation. Bias current. The Theorem Of Poynting.

Application of Maxwell’s equations to calculation of characteristics of electromagnetic waves and scattering amplitudes (the Fresnel equations).

15. Electromagnetic waves in waveguides. Resonators. Plasma.

Determination of modes of electromagnetic field in waveguides and resonators. Basicsof plasma physics.

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

Facilities and Resources:
- A lecture audience equipped with a multimedia projector and a screen.
- Equipment for lecture demonstrations.
- Classrooms equipped with a board.
- Libraries of educational and technical literature, including electronic libraries, necessary for individual work of students.

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

Main literature

1. Physics: A General Course v. 1: Mechanics, Molecular Physics (by I.V. Savelyev), Central Books Ltd (1981), Mir Publishers (1989)
2. General Physics: Mechanics and Molecular Physics (by L. Landau, A. Akhiezer, E. Lifshitz), Pergamon Press (1967)
3. Problems in General Physics (by I.E. Irodov), Mir Publishers (Revised edition 1988)

Additional literature

1. Fundamental Laws of Mechanics (by I.E. Irodov), Mir Publishers (Moscow), CBS Publishers & Distributors (India), 6th edition (2016)
2. Berkeley Physics Course: Vol. 1 - Mechanics (by C. Kittel, W.D. Knight, and M.A. Ruderman), McGraw-Hill, New York, second edition (1973)
3. The Feynman Lectures on Physics, The Definitive Edition Volume 1: (2nd Edition) by Richard P. Feynman and Robert B. Leighton, Addison Wesley; 2nd edition (2005)

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

1. http://mipt.ru/education/chair/physics/S_IV/Metod_4/— методический раздел сайта кафедры Общей физики
2. http://lib.mipt.ru/catalogue/1412/?t=750 – электронная библиотека МФТИ, раздел «Общая физика»

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

The List of Informational Resources:
1. Methodical section of the Department of General Physics website: http://mipt.ru/education/chair/physics/S_I/method/.
2. MIPT electronic library, the General Physics section: http://lib.mipt.ru/catalogue/1412/?t=750.

Lecture halls are equipped with multimedia and presentation facilities.

The recommended literature is available in electronic form (see paragraphs [1, 2] of the list of Internet resources necessary for mastering the discipline modules) so that the students may read textbooks using their tablets.

**9. Guidelines for students to master the course**

A student studying the course "General physics: Electricity and magnetism" should not only study the General physical laws and concepts, but learn to apply them in practice.

Successful development of the course requires intensive independent work of the student. The program of the course provides the minimum necessary time for the student to work on those-my. Independent work includes:

– reading and note-taking recommended reading,

– study of educational material (on lecture notes, educational and scientific literature), preparation of answers to questions intended for self-study;

– solving problems offered to students in lectures and practical classes,

– preparation for practical classes, test work, assignment, exam.

Management and control over the independent work of the student is carried out in the form of individual consultations.

An indicator of material ownership is the ability to solve problems. To form the ability to apply theoretical knowledge in practice, the student needs to solve as many problems as possible. When solving problems, each action must be argued, referring to the known theoretical information and carry out all the necessary calculations, bringing the problem to the final answer. The problem is considered solved if it contains a General solution: references to the applicable physical laws and correct calculations, as well as the correct numerical answer (if the problem has numerical data).

In preparation for the practical training, it is necessary to familiarize yourself with the basic concepts and laws that will be devoted to the lesson, and to solve the problems provided for the preparation of the seminar.

**SUPPLEMENT**

**Assessment funds for course (training module)**

| | |
|---|---|
| **major:** | Biotechnology |
| **specialization:** | Biomedical Engineering/Биомедицинская инженерия |
| | Phystech School of Biological and Medical Physics |
| | Chair of General Physics |
| **term:** | 2 |
| **qualification:** | Bachelor |

Semester, form of interim assessment: 4 (spring) - Exam

**Authors:**


P.V. Popov, candidate of physics and mathematical sciences

A.V. Ilin, candidate of physics and mathematical sciences, associate professor

**1. Competencies formed during the process of studying the course**

| Code and the name of the competence | Competency indicators |
|---|---|
| UC-1 Search and identify, critically assess, and synthesize information, apply a systematic approach to problem-solving | UC-1.1 Analyze problems, highlight the stages of their solution, plan the actions required to solve them |
| | UC-1.2 Find, critically assess, and select information required for the task in hand |
| | UC-1.3 Consider various options for solving a problem, assess the advantages and disadvantages of each option |
| | UC-1.4 Make competent judgments and estimates supported by logic and reasoning |
| | UC-1.5 Identify and evaluate practical consequences of possible solutions to a problem |
| Gen.Pro.C-2 Use modern IT and software tools to perform professional tasks in compliance with information security requirements | Gen.Pro.C-2.1 Apply modern computing tools and Internet services in professional settings |
| | Gen.Pro.C-2.2 Apply numerical mathematical methods and use software applications for scientific problem-solving in professional settings |
| | Gen.Pro.C-2.3 Fulfill basic information security requirements |
| Pro.C-1 Plan and conduct scientific experiments (in a selected subject area) and/or theoretical (analytical and simulation) research | Pro.C-1.1 Understand the fundamental concepts, laws, and theories of modern physics and biology |

**2. Competency assessment indicators**

As a result of studying the course the student should:

**know:**

- fundamental laws and concepts of physics of electromagnetic phenomena, as well as the limits of their applicability:
- the law of conservation of charge, Coulomb's law, superposition principle, theorem Gaussa integral and differential form;
- the concept of potential and its relation to field strength;
- basic concepts in the calculation of the electric field in a substance: field vectors and electric induction, polarizability and dielectric permeability;
- Ohm's law in integral and differential forms, Kirchhoff's rules, Joule-Lenz's law;
- the law of Biot–Savart, the theorem of circulation of magnetic field in integral and differential form;
- basic concepts in the calculation of the magnetic field in matter: magnetic induction and field strength, magnetization vector, conduction currents and molecular currents;
- the law of electromagnetic induction, Lenz's law;
- basic concepts of oscillation theory: free damped oscillations, damping coefficient, logarithmic decrement and q-factor, forced oscillations, resonance, parametric excitation of oscillations, self-oscillations;
- Maxwell's equations in integral and differential form;
- the law of conservation of energy and Poynting's theorem;
- basic concepts of plasma and waveguides.

**be able to:**

- apply the studied General physical laws to solve specific problems of electricity and magnetism:
- apply the Gauss theorem to find the electric field in vacuum and in matter;
- to write and solve the equations of Poisson and Laplace;
- apply the circulation theorem to find the magnetic field in vacuum and in matter;
- use the "image" method to calculate electrical and magnetic fields;
- apply the energy method of calculating the forces in the electric and magnetic field;
- calculate electrical capacity and self - and mutual-induction coefficients;
- use a complex form of representation of oscillations and vector diagrams in the calculation of oscillatory circuits;
- analyze physical problems, highlighting the essential and non-essential aspects of the phenomenon, and on the basis of the analysis to build a simplified theoretical model of physical phenomena;
- apply various mathematical tools to solve problems based on the generated physical laws, and carry out the necessary analytical and numerical calculations.

**master:**

- the main methods of solving problems of physics of electromagnetic phenomena;
- basic mathematical tools specific to the problems of electricity and magnetism.

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

Fundamentals of statistical physics of classical ideal systems. Macroscopic and microscopic states. Phase space. The statistical weight of a macrostate. Statisti-cal definition of entropy. Additivity of entropy. The law of increasing entropy. The concept of the Gibbs distribution. Maxwell and Boltzmann distributions as particular cases of the Gibbs distribution.

Entropy change in mixing two gases, Gibbs paradox.

The third law of thermodynamics. Changes in entropy and heat capacity as the temperature approaches zero.

Statistical definition of temperature. Properties of a two-level system, in-verse population.

**4. Evaluation criteria**

Fluctuations. Mean value and variance of particle energy. Fluctuations and Gaussian distribution. Fluctuations of thermodynamic variables. Fluctua-tions of temperature in a fixed volume. Volume fluctuation at constant energy and a constant temperature. Fluctuations of additive physical quantities. The dependence of fluctuations on the number of particles that make up the system. The influence of fluctuations on the accuracy of measuring devices.

Collisions. Effective collisional cross section. Mean free path. Molecu-lar free path distribution. The number of collisions between molecules.

Molecular transport phenomena: viscosity, thermal conductivity, and dif-fusion. Fick’s law of diffusion and Fourier’s law of thermal conduction. Esti-mation of transport coefficients of gases. The diffusion equation and the heat equation. Examples of stationary distributions of concentration and tempera-ture. Diffusion as a process of a random walk. Heat transfer speed of thermal conductivity.

The mark “excellent” (10 points) is given to a student who has shown comprehensive and sys-tematic knowledge of the syllabus and beyond, as well as the ability to confidently apply the knowledge in solving complicated non-standard problems.

The mark “excellent” (9 points) is given to a student who has shown comprehensive and system-atic knowledge of the syllabus and the ability to confidently apply the knowledge in solving non-standard problems.

The mark “excellent” (8 points) is given to a student who has shown comprehensive and system-atic knowledge of the syllabus and the ability to confidently apply the knowledge in solving non-standard problems but who has allowed for some inaccuracies.

The mark “good” (7 points) is given to a student who has demonstrated firm knowledge and confident understanding of the syllabus and the ability to apply physical laws in solving typical problems.

The mark “good” (6 points) is given to a student who has demonstrated a solid knowledge of the syllabus and the ability to apply physical laws in solving typical problems.

The mark “good” (5 points) is given to a student who has demonstrated firm knowledge and un-derstanding of the syllabus and the ability to apply physical laws in solving typical problems, however, made a number of gross inaccuracies when answering.

The mark “satisfactorily” (4 points) is given to a student who has shown a fragmentary knowledge and made mistakes in the formulation of basic laws and concepts, but at the same time demonstrated the ability to solve simple problems and understanding of the main sections of syllabus necessary for further education.

The mark “satisfactorily” (3 points) is given to a student who has shown a highly fragmented knowledge, made gross mistakes in the formulation of basic laws and concepts, but at the same time demonstrated the ability to solve simple problems and understand the main sections of the syllabus required for further education.

The mark “unsatisfactory” (2 points) or “unsatisfactory” (1 point) is given to a student who knows little of the main content of the syllabus, systematically makes gross mistakes in formulat-ing basic physical laws, or is unable to apply correctly physical laws even to solve simple prob-lems.

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

The duration of the written exam is four astronomical hours. The exam offers to solve five original problems, which correspond to the topics studied at seminars during the semester. A problem is considered solved if it contains a justified solution that includes references to the ap-plied physical laws and correct calculations, as well as the correct numerical answer (if the prob-lem contains numerical data). A student can use at the exam a sheet of paper with formulas pre-pared in advance. It is strictly forbidden to use any notebooks, or compendiums of lectures, or textbooks, or devices that can serve as means of communication, like laptops, tablets, phones, etc. Violators are removed from the exam with the "unsatisfactory" mark. It is allowed to use calcula-tors with no communication facilities. It is forbidden to use calculators in mobile phones, laptops, etc.