

MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION
FEDERAL STATE AUTONOMOUS EDUCATIONAL
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"NORTH CAUCASUS FEDERAL UNIVERSITY"

SUGGESTIONS FOR TEACHING

for the performance of practical work
in the discipline "Physics I/College Physics I"
for students of the field of study

11.03.02 Infocommunication Technologies and Communication Systems
Profile

"Intelligent Data Processing in Infocommunication
Systems and Networks"

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INTRODUCTION

The relevance of the academic discipline "Physics" is due to the need to form general professional competencies in future specialists, practical skills on which professional activity in physics is based. In modern conditions, the most important element of the training of bachelors in the field of physics is the formation of their independence and culture of scientific thinking, the ability to conduct scientific and professional activities, the skills of setting goals, tasks when solving problem situations.

The purpose of the practical classes is to form the professional competencies of the bachelor in the direction 11.03.02 Infocommunication technologies and communication systems related to the development of the necessary mathematical and physical apparatus with the help of which theoretical and experimental models of nanomaterials are developed and studied

The main objectives of the discipline:

- acquisition of knowledge about the methods of scientific cognition of nature; about the modern physical picture of the world; properties of matter and field; about the basics of fundamental physical theories; space-time regularities; dynamic and statistical legal nature; elementary particles and fundamental interactions; structure and evolution of the universe;
- mastering the ability to make observations, plan and perform experiments, process the results of experiments, apply theoretical knowledge in solving problems;
- fostering conviction about the need for the reasonable use of scientific and technological achievements for the further development of society; attitude to physics as an element of universal culture;
- application of knowledge in physics to explain natural phenomena, the principles of operation of technical devices, independent acquisition of knowledge, the use of modern information technologies for the search, processing and presentation of information in physics;

As a result of studying the discipline, students form the following competencies (in accordance with the educational standard):

ID-1OPK-1 Understands the fundamental laws of nature and the basic physical mathematical laws

ID-2OPK-1 Applies physical laws and mathematical methods to solve problems of theoretical and applied nature

ID-3OPK-1 Uses knowledge of physics and mathematics to solve practical problems

ID-1OPK-2 Finds and critically analyzes the information necessary to solve the problem.

ID-2OPK-2 develops a solution to a specific problem, choosing the best option, evaluating its advantages and disadvantages.

ID-3OPK-2 Understands the basic methods and means of conducting experimental research, standardization and certification systems.

ID-4OPK-2 selects methods and means of measurement and conducts experimental research.

ID-5OPK-2 is proficient in the methods of processing and presenting the data obtained and assessing the error of measurement results.

SECTION 1 MECHANICS

TOPIC 1. MECHANICS OF TRANSLATIONAL AND ROTATIONAL MOTION

Goal

To consider the kinematics of the translational motion of a material point. To consider the dynamics of the translational and rotational motion of a material point and a solid body. To define the concept of "work". To consider the work of constant and variable force. To define the concept of "power". To consider the relationship between work and power.

Typical tasks for performing practical

Example. The kinematic equation of motion of a material point in a straight line (x-axis) has the form $x = A + Bt + Ct^3$ where $A = 4 \text{ м}$, $B = 2 \text{ м/с}$, $C = -0,5 \text{ м/с}^2$. For the moment of time $t_1 = 2$, determine:

- 1) the coordinate of the point x_1
- 2) instantaneous speed v_1
- 3) instant acceleration a_1

Solution: 1. We will find the coordinate of the point for which the kinematic equation of motion is known by substituting the given value of time in the equation of motion instead of t :

$$x = A + Bt + Ct^3$$

Let's substitute the values A, B, C , into this expression t_1 and perform the calculations:

$$x_1 = 4 \text{ м}$$

2. We find the instantaneous velocity at an arbitrary moment of time by differentiating the coordinate x by time: $v = \frac{dx}{dt} = B + 3Ct^2$

Then, at a given point in time, the instantaneous speed v_1

$$v_1 = B + 3Ct_1^2$$

Let's substitute the values B, C, t_1 and make the calculations:

$$v_1 = -4 \text{ м/с}$$

The minus sign indicates that at the time c , point c is moving in the negative direction of the coordinate axis. $t_1 = 2$

3. We will find the instantaneous acceleration at an arbitrary moment of time by taking the second derivative of the coordinate x in time: $a = \frac{d^2x}{dt^2} = 6Ct$

The instantaneous acceleration at a given time is $a_1 = -6Ct_1$. Substitute the values of C , t_1 and perform the calculations:

$$a_1 = -6M/c^2$$

The minus sign indicates that the direction of the acceleration vector coincides with the negative direction of the coordinate axis, and in the conditions of this problem this is the case for any moment of time.

Task 1. Two straight roads intersect at an angle. Cars move away from the intersection along them: one at speed, the other at speed. Determine the speeds at which one car moves away from the other. Cars passed the intersection at the same time. $\alpha = 60^\circ$, $v_1 = 60 \text{ км/ч}$, $v_2 = 80 \text{ км/ч}$.

Problem 2. A material point moves along a plane according to the equation $\vec{r}(t) = \vec{A}t^3 + \vec{B}t^2$. Write dependencies: 1) $\vec{v}(t)$; 2) $\vec{a}(t)$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What is called a radius-vector?
2. Define Instantaneous Velocity
3. What is Normal Acceleration? How to Determine It
4. Write down the kinematic equation of uniform rotation
5. How are linear and angular velocities related?
6. What is called ω ?
7. Define acceleration
8. Write down the kinematic equation of equivariable motion along the x-axis
9. Define instantaneous angular velocity
10. How to calculate the path traveled by a point along a circular arc with radius R
11. Define Average Speed
12. How to find acceleration in curvilinear motion?
13. How do you find the velocity of a point in equialternating motion?
14. Write down the kinematic equation of equivariable motion?
15. How are linear and angular velocities related?
16. Define the average ground speed
17. What is Called Tangent Acceleration? How to Determine It
18. Write down the kinematic equation of uniform rotation
19. Define the mean angular velocity
20. Write down the kinematic equation of equivariable motion

Problem 1. The body traveled the first half of the way in time $t_1 = 2$ s, the second half t_2 in time $t_2 = 8$ s. Determine the average ground speed of the body if the length of the path $S = 20$ m.

Problem 2. During the time t , the point has traveled a path equal to half the circumference of the circle radius R . Determine the average ground speed for this time and the modulus of the average velocity vector $v = 6R = 0,8 \text{ m/s}$.

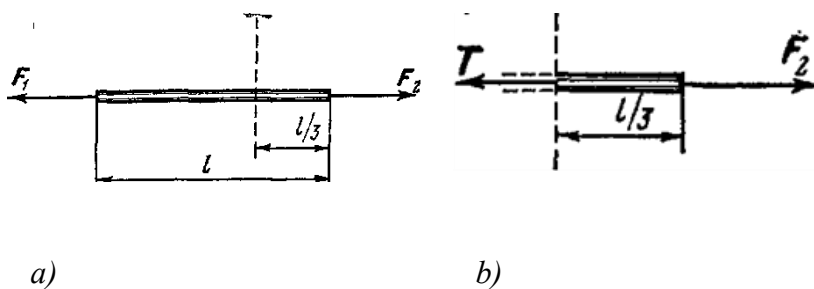
TOPIC 2. CONSERVATION LAWS IN MECHANICS

Goal

To define the concept of "momentum of a body". To formulate the law of conservation of momentum. To define the concept of "angular momentum". To define the concepts of "kinetic energy", "potential energy" and "total mechanical energy". To formulate the laws of conservation of energy. To formulate the law of conservation of angular momentum of a body. To consider the issues of symmetry in nature.

Typical tasks for performing practical

Example. Two oppositely directed forces are applied to the ends of a homogeneous member: $F_1 = 40$ H and $F_2 = 100$ H. Determine the tension force T of the member in the cross-section, which divides the member into two parts in a ratio of 1:2.



Solution. If the forces were equal to each other, then the tensional force in any section of the rod would be the same and equal to the forces applied

to the ends of the rod. The rod would be at rest in this case. But since the sum of the forces acting on the rod is different from zero, the rod will move with acceleration, the magnitude and direction of which are determined by Newton's second law: $\vec{F}_1 + \vec{F}_2 = m\vec{a}$, where m is the mass of the rod. Since both forces act along a straight line, the geometric sum can be replaced by an algebraic one:

$$a = \frac{F_1 + F_2}{m} \quad (1)$$

In the accelerated motion of the rod, the tension forces are different in different sections. To determine these forces, we use the following method: divide the rod into two parts in the section we are interested in and discard one of them, for example, the left one. The action of the left part on the right part is replaced by the tension force T (Fig. *b*). As a result of the action of the force difference, the remaining right part of the rod with mass m and $F_2 - T$ should move with an acceleration equal in magnitude and direction to the previous acceleration expressed by formula $a = \frac{F_2 - T}{m_1}$ (1). Since the rod is homogeneous, therefore, $m_1 = \frac{m}{3}$

$$a = \frac{F_2 - T}{\frac{m}{3}} \quad (2)$$

Equating the right-hand sides of equality (1) and (2) and expressing the tension force T from the resulting equality, we find: $T = F_2 - \frac{F_2 - F_1}{3}$

Substituting the values and F_1, F_2 , we get

$$T = 80 \text{ H.}$$

Problem 1. A boat with two passengers sails evenly on the lake at a speed of $v_l = 2 \text{ m/s}$. One person jumped from the stern of the boat so that his speed relative to the water was equal to zero. Then a similar jump was made by the 2nd person (and his speed relative to the water turned out to be equal to 0).

Task 2. A rocket with a mass without charge $M = 600 \text{ g}$, when burned $m = 80 \text{ g}$ of powder, takes off to a height of $h = 180 \text{ m}$. Assume that the powder burns instantly at the start

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Momentum of force is Formula and what is measured
2. What is an absolutely elastic blow?
3. Write down the law of conservation of momentum of a closed system in an absolutely inelastic impact
4. Power is Formula and how it is measured
5. Potential energy is...
6. How to determine the momentum of a system of bodies?
7. What is a completely inelastic impact?
8. What kind of motion is called reactive?
9. Write down the law of conservation of mechanical energy
10. Formulate Newton's Second Law
11. The direction of which vectors coincides with the direction of force and acceleration?

12. Write down the law of conservation of momentum of a closed system for an absolutely elastic impact

13. Mechanical work is... Formula and how it is measured

14. Kinetic energy is... Formula and what is measured

Task 1. A skater with a mass of $M=50$ kg throws a puck with a mass of $m=200$ g horizontally at a speed of $v=20$ m/s. How far will the skater roll back after throwing the puck? The coefficient of friction of the skates on the ice is $k=0.02$.

Task 2. A rope with a length of $L = 4$ m and a weight of $m = 0.5$ kg hangs vertically from the edge of the roof. What work does need to be done to lift the rope to the roof?

SECTION 2. MOLECULAR PHYSICS AND THERMODYNAMICS

TOPIC 6. BASIC CONCEPTS OF MOLECULAR-KINETIC THEORY

Goal

To consider the experimental substantiation of the molecular-kinetic theory of matter. To formulate the laws of behavior of rarefied gases. To define the concepts of "heat" and "work". To define the concept of "heat capacity"

Typical tasks for performing practical

Example. Find the molar mass M of a mixture of oxygen by mass and nitrogen by mass $m_1 = 25$ r $m_2 = 75$ r

Solution:. The molar mass of a mixture is the ratio of the mass of the mixture to the amount of the substance of the mixture, i.e.: $M_{CM} = \frac{m_{CM}}{\nu_{CM}}$

$$M_{CM} = \frac{m_{CM}}{\nu_{CM}} \quad (1)$$

The mass of the mixture is equal to the sum of the masses of the components of the mixture
The amount of the substance of the mixture is equal to the sum of the quantities of the substance of the components. $m_{CM} = m_1 + m_2$

Substituting the expressions and , we get $m_{CM} \nu_{CM}$

$$M_{CM} = \frac{m_1 + m_2}{\frac{m_1}{M_1} + \frac{m_2}{M_2}} \quad (2)$$

Let's find the molar masses of oxygen and $M_1 M_2$ nitrogen:

$M_1 = 32 \cdot 10^{-3} \text{ кг/моль}$ Let us substitute the values of the quantities in $M_2 = 28 \cdot 10^{-3} \text{ кг/моль}$ (2) and make the calculations: $M_{\text{CM}} = 28,9 \cdot 10^{-3} \text{ кг/моль}$

Task 1. In the vessel with a capacity there is a gas by the amount of substance . Determine the concentration of molecules in the vessel. $V = 20 \text{ л}$ $\nu = 1,5 \text{ кмоль}$

Task 2. An ideal gas is in a closed vessel under normal conditions. Determine the concentration of gas molecules. n

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What is particle concentration?
2. How to determine the concentration of particles in a given volume?
3. Write down the basic equation of the kinetic theory of gases. Give an explanation.
4. How do you determine the average kinetic energy of a molecule? Please explain.
5. How do you determine the total energy of a molecule? Please explain.
6. How to determine the energy of the translational motion of a molecule? Please explain.
7. How to determine the energy of the rotational motion of a molecule? Please explain.
8. How are pressure and molecular concentration related? Please explain.
9. Write down the standard speed. Give an explanation.
10. Write down the arithmetic mean speed. Give an explanation.
11. Write down the most likely speed. Give an explanation.

Task 1. Two vessels of the same capacity contain different gases: the first one contains hydrogen, the second one contains oxygen. Find the ratio of gas concentrations if the masses of gases are the same. n_1/n_2

Problem 2. To determine the average kinetic energy of translational motion and the average value of the total kinetic energy of the water vapor molecule at the temperature . Find also the kinetic energy W of the translational motion of all vapor molecules containing the amount of matter $T = 600 \text{ К}$ $\nu = 1 \text{ кмоль}$.

TOPIC 7. IDEAL GAS

Goal

To consider the model of an ideal gas. To study the equation of state of an ideal gas. To formulate Boltzmann's law. To study Maxwell's law of distribution. To define the concept of "degrees of freedom". To consider the "classical law of energy distribution by degrees of freedom". To define the concept of "heat capacity". To consider the features of heat transfer in gases.

Typical tasks for performing practical

Example. The cylinder contains helium under pressure at a temperature of . After the mass of helium has been consumed from the cylinder $V = 10 \text{ л}$, $p_1 = 1 \text{ МПа}$, $T_1 = 300 \text{ К}$, $m = 10 \text{ г}$, the temperature in the cylinder has dropped to . Determine the pressure of helium remaining in the cylinder. $T_2 = 290 \text{ К}$

Solution: To solve the problem, we will use the Clapeyron-Mendeleev equation, applying it twice to the initial and final states of the gas. For the initial state, the equation has the form:

$$p_1 V = \frac{m_1}{M} R T_1 \quad (1)$$

and for the final state:

$$p_2 V = \frac{m_2}{M} R T_2, \quad (2)$$

where m_1, m_2 are the masses of helium in the initial and final states.

Let us express the masses of helium from equations (1) and (2):

$$m_1 = \frac{M p_1 V}{R T_1} \quad (3)$$

$$m_2 = \frac{M p_2 V}{R T_2} \quad (4)$$

Subtracting equation (4) from (3), we get: $m = m_1 - m_2 = \frac{M p_1 V}{R T_1} - \frac{M p_2 V}{R T_2}$

From here we find the pressure we are looking for:

$$p_2 = \frac{R T_2}{M V} \left(\frac{M p_1 V}{R T_1} \right) = \frac{T_2}{T_1} p_1 - \frac{m}{M} \frac{R T_2}{V} \quad (5)$$

Let us check whether the right-hand side of formula (5) gives a unit of pressure. To do this, let us express all the quantities included in it in the corresponding units. The unit in which the first term is expressed is beyond doubt, since the ratio is a dimensionless quantity. $\frac{T_2}{T_1}$

Having made sure that the right side of the obtained calculation formula gives the unit of the desired value – pressure, we can substitute the values of all quantities in (5) and make calculations.

In formula (5), all quantities except the molar mass M of helium are known. For helium as a monatomic gas, the relative molecular mass is equal to its relative atomic mass A_r .

From the table of D. I. Mendeleev, we find . Therefore, the molar mass of helium By substituting the values of values in $A_r = 4$, $M = A_r \cdot 10^{-3} \frac{\text{кг}}{\text{моль}} = 4 \cdot \frac{10^{-3} \text{кг}}{\text{моль}}$. (5), we get:

$$p_2 = 364 \text{ кПа}$$

Problem 1. Into a cylinder with a length of $l = 1.6 \text{ m}$, filled with air at normal atmospheric pressure p_0 , a piston with an area of $S = 200 \text{ cm}^2$ that will act on the piston if it is stopped at a distance from the bottom of the cylinder $l_1 = 10 \text{ cm}$

Task 2. A flask with a capacity of $V = 300 \text{ cm}^3$, closed with a plug with a tap, contains rarefied air. To measure the pressure in the flask, the neck of the flask was immersed in water to a slight depth and the tap was opened, as a result of which water with a mass of $m = 292 \text{ g}$ entered the flask. $p_0 = 100 \text{ кПа}$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Write down the equation of state of ideal gases. Give an explanation.
2. Define the concept of "isoprocess".
3. What isoprocesses do you know? List
4. Write down the equation of the isothermal process. Explain
5. Write down the equation of the isochoric process. Explain
6. Write down the equation of the isobaric process. Explain
7. Write down the equation of the isothermal process. Explain
8. An adiabatic process is an isoprocess. Please explain.
9. Write down the equation of the adiabatic process. Give an explanation.
10. Define the concept of "entropy".
11. Define the concept of "enthalpy"
12. Define the concept of "partial pressure"?
13. Write down Dalton's law. Give an explanation.

Task 1. A hollow ball with a capacity filled with air at a temperature of $T_1 = 573 \text{ K}$, was connected by a tube to a cup filled with mercury. Determine the mass m of mercury that entered the ball when the air in it cooled down to temperature $T_2 = 293 \text{ K}$. $V = 10 \text{ cm}^3$

Task 2. Temperature. How much will the lifting force of the ball change when the temperature rises to $T_2 = 293 \text{ K}$? Consider the capacity V of the shell unchanged and the external pressure normal. In the lower part of the shell there is a hole through which hydrogen can escape into the surrounding space. $T_1 = 273 \text{ K}$

TOPIC 8. TRANSFERENCE PHENOMENA

Goal

To consider the collision of molecules with each other. To define the concept of scattering cross-section. To study the characteristics of collisions. To define the concept of diffusion. To define the concept of thermal conductivity. To define the concept of viscous

Typical tasks for performing practical

Example. Two thin-walled coaxial cylinders with a length can rotate freely around their common z-axis $l = 10$ cm. The radius R of the large cylinder is 5 cm. There is a gap between the cylinders of the size d . Both cylinders are in the air under normal conditions. The inner cylinder is rotated at a constant frequency n_1 . The outer cylinder is braked. Determine how long it takes from the moment the outer cylinder is released to acquire a rotational speed n_2 . Neglect the change in the relative speed of the cylinders in the calculations. The mass of the outer cylinder is equal to $m_1 = 20$ g, $m_2 = 100$ g.

Solution: When the inner cylinder rotates, the layer of air is carried away by it and begins to participate in the rotational motion. Near the surface of this cylinder, the layer of air acquires over time almost the same linear velocity as the velocity of the points on the surface of the cylinder, i.e. $v = 2\pi n_1(R - d)d \ll R$

$$v \approx 2\pi n_1 R$$

(1)

As a result of internal friction, the angular momentum is transmitted to the neighboring layers of the gas and ultimately to the outer cylinder. In the time interval Δt , the outer cylinder acquires angular momentum $L = pR$, where p is the momentum received behind the outer cylinder. Δt

$$p = L/R \quad (2)$$

On the other hand:

$$p = \eta \frac{dv}{dz} S \Delta t \quad (3)$$

where η is the dynamic viscosity; $\frac{dv}{dz}$ is the velocity gradient; S is the surface area of the cylinder

$$S = 2\pi Rl$$

By equating the right-hand sides of expressions (2) and (3) and expressing the desired interval t from the resulting equality Δ , we get: $\Delta t = \frac{L}{\eta R \frac{dv}{dz} S}$

We find the quantities included in this formula, and the angular momentum $L \frac{d\vartheta}{dz} S$. $L = J \omega_2$, where J is the moment of inertia of the cylinder (); $mJ = mR^2$ is its mass; ω_2 is the angular velocity of the outer cylinder). With this in mind, we write ($\omega_2 = 2\pi n_2$)

$$L = mR^2 \cdot 2\pi n_2 = 2\pi m n_2 R^2$$

The gradient of velocity $\frac{d\vartheta}{dz} = \frac{\vartheta}{z} = \frac{\vartheta}{d} \frac{dz}{dz} = \frac{\vartheta}{z} = \frac{\vartheta}{d}$. The area of the cylinder is $S = 2\pi Rl$.

Substituting the expressions, and, in $L \frac{d\vartheta}{dz} S$ (4) we get:

$$\Delta t = \frac{m d n_2}{\eta \vartheta l} \quad (4)$$

Replacing here by ϑ (1), we find

$$\Delta t = \frac{m d n_2}{2\pi \eta R l n_1} \quad (5)$$

Dynamic viscosity of air (see Table 1). $\eta = 17,2 \text{ мкПа} \cdot \text{с} = 1,72 \cdot 10^{-5} \text{ Па} \cdot \text{с}$ (14).

Substituting the values of the quantities included in it into (5) and making calculations, we get:

$$\Delta t = 18,5 \text{ с}$$

Task 1. Determine the dependence of dynamic viscosity on temperature T in the following processes: 1) isobaric; 2) isochoric. Plot these dependencies on graphs. η

Task 2. Determine the dependence of dynamic viscosity on pressure p in the following processes: 1) isothermal; 2) isochoric. Plot these dependencies on graphs. η

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Write down the barometric formula
2. How to determine the coefficient of thermal conductivity?
3. Formulate Fick's law. Explain
4. What is called thermal conductivity?
5. How to Determine the Momentum Transferred by Molecules from One Layer of Gas to Another
6. How to determine the diffusion coefficient?
7. Formulate Newton's law. Explain
8. What is called viscosity?
9. How to determine the average number of collisions of a molecule per unit time
10. How to determine the dynamic viscosity of a gas?
11. Formulate Fourier's law. Explain
12. What is called diffusion?

Problem 1. Two horizontal disks with radii $R = 20$ cm are located on top of each other so that their axes coincide. The distance d between the planes of the disks is 0.5 cm. The upper disk is stationary, the lower one rotates relative to the geometric axis with a frequency of $n = 10$ s⁻¹. Find the torque M acting on the upper disk. The dynamic viscosity of η the air in which the disks are located is equal to 17.2 μ Pa·s.

Task 2. Determine the dependence of dynamic viscosity on pressure in the following processes: 1) isothermal; 2) isohorn. Plot these dependencies on graphs. ηp

TOPIC 9. FUNDAMENTALS OF THERMODYNAMICS

Goal

To define the concept of "internal energy". To study the first law of thermodynamics. To consider the application of the first law of thermodynamics to isoprocesses. To consider micro- and macrostates of a thermodynamic system. To define the concept of "thermodynamic probability" of a macroscopic state. To define the concept of "entropy". To consider Boltzmann's formula. To study the second law of thermodynamics and its statistical meaning. To study the third law of thermodynamics.

Typical tasks for performing practical

Example. Calculate the specific heat capacity of neon and hydrogen at constant volume (c_v) and pressure (c_p), taking these gases as ideal.

Solution. Specific heat capacities of ideal gases are expressed by formulas

$$c_v = \frac{i}{2} \frac{R}{M} \quad (1)$$

$$c_p = \frac{i+2}{2} \frac{R}{M}. \quad (2)$$

For neon (monatomic gas), $i_1 = 3$, $M_1 = 20 \cdot 10^{-3}$ кг/моль

By substituting the values of i , and making calculations in formulas (1) and (2), we will find: $i_1 M_1 R$

$$c_{v1} = 624 \text{ Дж/(кг·К)}; c_{p1} = 1,04 \text{ кДж/(кг·К)}.$$

For hydrogen (diatomic gas), $i_2 = 5$, $M_2 = 2 \cdot 10^{-3}$ кг/моль

Calculation according to formulas (1) and (2) gives the following values of specific heat capacities of hydrogen:

$$c_{v2} = 10,4 \text{ кДж}/(\text{кг} \cdot \text{K}); c_{p2} = 14,6 \text{ кДж}/(\text{кг} \cdot \text{K}).$$

Task 1. The cylinder contains argon and nitrogen. Determine the specific heat capacity of a mixture of these gases if the mass fractions of argon () and nitrogen () are the same and equal to $c_v \omega_1 \omega_2 = 0.5$.

Problem 2. Hydrogen occupies volume at pressure . The gas is heated at a constant volume to pressure . Determine: 1) change in the internal energy of the gas; 2) the amount of heat $V_1 = 10^3 p_1 = 100 \text{ кПа}$ $p_2 = 300 \text{ кПа}$ ΔU Q imparted to the gas.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Write down the first law of thermodynamics in an isothermal process. Explain
2. How are molar and specific heat capacities related?
3. How to determine the work aimed at changing the volume? Give explanations.
4. Write down the first law of thermodynamics in the adiabatic process. Give explanations.
5. Write down the Boltzmann formula. Define the concept
6. Define the concept of "molar heat capacity"?
7. Write down the Mayr equation. What is its physical meaning? Give an explanation.
8. How to determine the operation of a gas in an isothermal process?
9. Write down the first law of thermodynamics in the isobaric process. Explain
10. How to determine molar heat capacities at constant volume and constant pressure?
11. How to determine the internal energy of a gas?
12. Write down the first law of thermodynamics. Give an explanation.
13. How to Determine Specific Heat Capacity at Constant Volume and Constant Pressure?
14. How to determine the work of a gas in an isobaric process?
15. Write down the Poisson equation. Give explanations.
16. How to determine thermal efficiency? Explain

Problem 1. The difference in specific heat capacity and $c_v c_p$, of a diatomic gas is equal to 260 J/(kg·K). Find the molar mass of M of the gas - its specific heat capacity and $c_v c_p$

Problem 2. With isochoric heating of oxygen by volume, the gas pressure changed by . Find the amount of heat imparted to the gas. $V = 50 \text{ л}$ $\Delta p = 0,5 \text{ МПа}$ Q

SECTION 3. ELECTRICITY AND MAGNETISM

TOPIC 11. ELECTROSTATICS

Goal

To define the concept of "electric charge". To formulate the law of conservation of charge. To formulate Coulomb's law. To define the concept of "electric field strength". To formulate the principle of superposition. To define the concept of "electric dipole". To consider the dipole field. To consider the work of electrostatic field forces. To define the concept of "potential" and "potential difference". To define the concept of "equipotential surfaces". To consider conductors and dielectrics. To consider polar and non-polar molecules in an electric field. To define the concept of "polarization of dielectrics". To consider the piezoelectric effect. To consider ferroelectrics and their properties. To define the concept of "electrostriction". To consider conductors in an electric field. To define the concept of "electric capacitance of conductors". To study the structure of capacitors. To consider the types of capacitor connections. To define the concept of "electric field energy".

Typical tasks for performing practical

Example. Positive charges and are in a vacuum at a distance from each other. Determine the work $Q_1 = 3 \text{ мкКл}$ $Q_2 = 20 \text{ нКл}$ $r_1 = 1,5 \text{ мА}$ that must be done to bring the charges closer together to a distance of $r_2 = 1 \text{ м}$

Solution: Suppose that the first charge remains stationary, and the second, under the influence of external forces, moves in the field created by the charge Q_1 Q_2 QI , approaching it from a distance of up to $r_1 = 1,5 \text{ м}$ $r_2 = 1 \text{ м}$.

The work of an external force to move a charge from one point of the field with a potential to another, the potential of which is equal in modulo and opposite in sign to the work $A' Q \varphi_1 \varphi_2 A$ of the field forces to move the charge between the same points:

$$A' = -A.$$

The work of the field forces to displace the charge . Then the work of external forces can be recorded in the form of $AA = Q(\varphi_1 - \varphi_2)A'$

$$A' = -Q(\varphi_1 - \varphi_2) = Q(\varphi_2 - \varphi_1) \quad (1)$$

The potentials of the points of the beginning and end of the path are expressed by formulas

$$\varphi_1 = \frac{Q_1}{4\pi\epsilon\epsilon_0 r_1}; \varphi_2 = \frac{Q_2}{4\pi\epsilon\epsilon_0 r_2}$$

Substituting $\varphi_{expressions 1}$ and φ_2 into formula (1) and taking into account that the charge to be carried for this case, we get: $Q = Q_2$

$$A' = \frac{Q_1 Q_2}{4\pi\epsilon_0} \left(\frac{1}{r_1} - \frac{1}{r_2} \right) \quad (2)$$

If we take into account that, then after substituting the values of the quantities in formula (2) and calculating the $\frac{1}{4\pi\epsilon_0} = 9 \cdot 10^9 \text{ M/}\Phi$

$$A' = 180 \text{ мкДж.}$$

Task 1. A flat air capacitor with an electric capacitance is charged to separate potentials. After disconnecting from the current source, the distance between the capacitor plates was increased by five times. To determine: 1) the potential difference on the capacitor plates after they are separated; 2) the work of external forces to move the plates apart. $C = 1,11 \text{ нФ}$ $U = 300 \text{ В}$

Problem 2. Perpendicular to the arm of the dipole with an electric moment, a homogeneous electric field with an intensity is excited. Under the influence of field forces, the dipole begins to rotate relative to the axis passing through its center. Find the angular velocity ω of the dipole at the moment of its passage of equilibrium. The moment of inertia $p = 12 \text{ пКл} \cdot \text{м}$ $E = 300 \text{ кВ/м}$ of the dipole with respect to the axis perpendicular to the arm and passing through its center is equal to $2 \cdot 10^{-11} \text{ кг} \cdot \text{м}^2$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Millikan's experiment. Elementary electric charge.
2. Formulate Coulomb's law. Write down the formula. Date of explanation.
3. Write down the law of conservation of charge. Give explanations.
4. Define the concept of "Electric field strength". Give an explanation.
5. How to determine the force acting on a point charge Q placed in an electric field. Write down the formula. Give an explanation.
6. Define the concept of "flux of the vector of intensity E of the electric field". Write down the formula. Give an explanation.
7. Formulate the Ostrogradsky-Gauss theorem. Write down the formula. Give an explanation.
8. Formulate the principle of superposition of electric fields.
9. How to determine the strength of the field created by an infinitely long uniformly charged filament? Write down the formula. Give an explanation.

10. How to determine the strength of the electric field created by a metal sphere? Write down the formula. Give an explanation.
11. How to determine the strength of the electric field created by a point charge? Write down the formula. Give an explanation.
12. Define the concept of "electrical displacement"
13. Formulate a theorem on the circulation of the electric field intensity vector. Write down the formula. Give an explanation.
14. Define the concept of "electric field potential"
15. How to determine the energy W of the interaction of a system of point charges?
16. Write down the relationship between the potential and the electric field strength.
17. How to determine the work performed by an electric field when moving a point charge?
18. Define the concept of "dipole". Write down the formula. Give an explanation.
19. Define the concept of "electric moment of the dipole". Write down the formula. Give an explanation.
20. Write down the Clausius-Mosotti equation. Give an explanation.
21. Write down the Lorentz-Lorentz formula. Give an explanation.
22. Write down the Debye-Langevin formula. Give an explanation.
23. Define the concept of "Electric capacitance".
24. How do you determine the electrical capacitance of a capacitor? Write down the formula. Give an explanation.
25. How to determine the electrical capacitance of capacitors connected in series? Write down the formula. Give an explanation.
26. How to determine the electrical capacitance of capacitors connected in parallel? Write down the formula. Give an explanation.
27. How to determine the energy of a charged conductor? Write down the formula. Give an explanation.
28. How do you determine the energy of a charged capacitor? Write down the formula. Give an explanation.
29. How to determine the bulk energy density? Write down the formula. Give an explanation.

Problem 1. Two balls of mass each are suspended at one point on threads each long. Having received the same charge, the balls diverge so that the threads form an angle between them. Find the charge of each ball. $m = 0,1 \text{ rL} = 20 \text{ cm}$ $\alpha = 60^\circ$

Problem 2. A straight metal rod with a diameter and length carries a charge evenly distributed over its surface. Determine the intensity of the field $d = 5 \text{ cm}$ $l = 4 \text{ м}$ $Q = 500 \text{ нКл}$ E at a point located opposite the middle of the rod at a distance from its surface $a = 1 \text{ cm}$

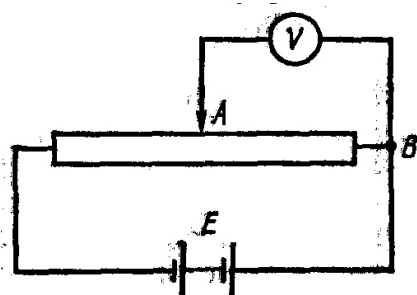
TOPIC 12. DIRECT ELECTRIC CURRENT

Goal

To define the concept of "electric current". To formulate Ohm's law for a section of the circuit. To formulate Ohm's law in differential form. To consider the resistance of a system of conductors in parallel and series connections. To define the concept of "extraneous forces". To formulate Ohm's law for a complete circuit. To formulate Joule-Lenz's law in integral and differential forms. To define the concepts of "work of electric current" and "power of electric current".

Typical tasks for performing practical

Example. A potentiometer with resistance is connected to a current source, the emf ε which is 150 V and the internal resistance. Determine the reading of a voltmeter with resistance connected



by a conductor to one of the terminals of the potentiometer and a movable contact with the middle of the potentiometer winding.

What is the potential difference between the same points of the potentiometer when the voltmeter is turned off? $R = 100 \text{ Ом}$ $r = 50 \text{ Ом}$ $R_v = 500 \text{ Ом}$

Solution: The reading of the voltmeter connected to points U_1 A and B is determined by the formula

$$U_1 = I_1 R_1 \quad (1)$$

where I_1 is the current in the unbranched part of the circuit; R_1 is the resistance of the voltmeter and half of the potentiometer connected in parallel.

We will find the current strength according to Ohm's law for the entire circuit: I_1

$$I_1 = \frac{\varepsilon}{R+r} \quad (2)$$

where R is the resistance of the external circuit.

The external resistance R is the sum of two resistances:

$$R = R/2 + R_1. \quad (3)$$

The resistance R_1 of a parallel connection can be found by the formula from $\frac{1}{R_1} = \frac{1}{R_B} + \frac{1}{R/2}$

$$R_1 = \frac{RR_B}{R + 2R_B}$$

By substituting numerical values of quantities into this formula and making calculations, we will find

$$R_1 = 45,5 \text{ Ом.}$$

By substituting the right side of equality (3) into expression (2), we determine the amperage:

$$I = \frac{\varepsilon}{\frac{R}{2} + R_1 + r} = 1,03 \text{ A}$$

If we substitute the values in formula (1), we will find the voltmeter reading: $I_1 R_1 U_1 = 46,9 \text{ В.}$

The potential difference between points A and B when the voltmeter is turned off is equal to the product of the current by half the resistance of the potentiometer, i.e. or $I_2 U_2 = \frac{I_2}{R_2} U_2 = \frac{\varepsilon}{R+r} \frac{R}{2}$

Substituting here the values of the values ε , r and R we get

$$U_2 = 50 \text{ В.}$$

Problem 1. Two groups of three cells connected in series are connected in parallel. The emf ε each cell is 1.2 V, the internal resistance is $r = 0.2 \text{ Ohm}$. The resulting battery is closed to the external resistance $R = 1.5 \text{ Ohm}$. Find the current I in the external circuit.

Problem 2. There are N identical galvanic cells with an emf ε and an internal resistance each. From these cells, it is necessary to assemble a battery consisting of several groups connected in parallel, containing $r_1 n$ cells connected in series. At what value of n will the current I in an external circuit with resistance R be maximum? What will be the internal resistance of the battery at this value nR_1 ?

QUESTIONS AND TASKS FOR SELF-CONTROL

1. How do you determine the DC amperage?
2. How to determine the resistance of a homogeneous conductor?
3. How to determine the connection resistance of conductors in series and parallel connection?
4. Write down Ohm's law for a heterogeneous section of the circuit. Explain
5. Kirchhoff's First Rule
6. How to determine the current capacity?

7. Formulate the Joule-Lenz law
8. Ohm's Law in Differential Form
9. What is called the density of electric current. Please explain
10. What is called conductivity? Specific conductivity? Please explain
- 11.
12. Write down Ohm's law for a homogeneous portion of the circuit. Explain
13. Kirchhoff's Second Rule
14. How to calculate the work of an electrostatic field from the movement of charge. Give an explanation.
15. Formulate the Joule-Lenz law
16. Joule-Lenz law in differential form

Task 1. The emf of ε battery is 20 V. Resistance R of the external circuit is 2 Ohm, current is $I=4$ A. Find the efficiency of the battery. At what value of the main resistance R will the efficiency be 99%?

Task 2. A heater is connected to the battery clamps. The EMF ε the battery is 24 V. Internal resistance is $r=1$ Ohm. The heater included in the circuit consumes power $P=80$ W. Calculate the current I in the circuit and the efficiency of the heater η .

TOPIC 13.ELECTRIC CURRENT IN VARIOUS MEDIA

Goal

To consider the classical theory of electrical conductivity of metals. To consider the features of the electrical conductivity of liquids. To consider the features of the electrical conductivity of gases and plasma. To consider the current in a vacuum. To consider the features of the electrical conductivity of semiconductors.

Typical tasks for performing practical

Example. A resistance resistor is included in the circuit of a DC source with an emf. Determine:

- 1) the current density in the connecting wires with a cross-sectional area
- 2) the number of $\varepsilon =$

$6 \text{ BR} = 80 \text{ Ом} S = 2 \text{ мм}^2$; N electrons passing through the cross-section of the wires during the time. $t = 1 \text{ c}$

Solution: 1. Current density by definition is the ratio of current strength I to the cross-sectional area of the wire:

$$j = I/S. \quad (1)$$

The current strength in this formula is expressed according to Ohm's law:

$$I = \frac{\varepsilon}{R+R_1+r_1} \quad (2)$$

where R is the resistance of the resistor; R_1 is the resistance of the connecting wires; r_1 is the internal resistance of the current source.

Ignoring the resistances and from (2), we get

$$I = \varepsilon/R.$$

Substituting this expression of the current in (1), we find

$$j = \varepsilon/(RS).$$

Having made calculations according to this formula, we get $j = 3.75 \cdot 10^4 \text{ A/мм}$

2. The number of electrons passing through the cross-section during time t is found by dividing the charge Q flowing through the cross-section during this time by the elementary charge:

$$N = Q/e,$$

or taking into account that $Q = It$ и $I = \varepsilon/R$,

$$N = \frac{\varepsilon t}{Re}$$

Let's insert the numerical values of the quantities here and calculate (we will take the elementary charge from Table 24.): $e = 1,60 \cdot 10^{-19} \text{ Кл}$

$$N = 4,69 \cdot 10^{17} \text{ electrons.}$$

Problem 1. Determine the average velocity of the ordered motion of electrons in a copper conductor with a current strength and a conductor cross-section $< v > 10 \text{ AS}$ equal to Assume that there are two conduction electrons for every copper atom. 1 мм^2

Problem 2. The current density j in the aluminum wire is equal to Find the average velocity of the ordered motion of the electron assuming that the number of free electrons in aluminum is equal to the number of atoms. 1 A/мм^2 . $< v > 1 \text{ см}^3$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Define the concept of "current density". Write down the formula. Give explanations.
2. Formulate Ohm's law. Write Ohm's law in differential form. Give explanations.

3. Formulate the Joule-Lenz law. Write the Joule-Lenz law in differential form. Give explanations.
4. Define the concept of "electrical conductivity". Write down the formula and give an explanation.
5. Formulate the Wiedemann-Franz law. Write down the formula and give explanations.
6. Define the concept of "thermo-EMF". How to define it? In which devices is the effect of thermo-EMF applied?
7. Formulate Faraday's first law of electrolysis. Write down the formula and give explanations.
8. Formulate the second Faraday Law of Electrolysis. Write down the formula and give explanations.
9. Formulate Faraday's unified law of electrolysis. Write down the formula and give explanations.
10. Write down Ohm's law in differential form for electrolytes. Give explanations.
11. Define the concept of "ion mobility". Write down the formula and give explanations.
12. Define the concept of "saturation current" and "saturation current density". Write down the formula and give explanations.

Task 1. An electrolytic bath with a solution of copper sulfate is connected to a battery of accumulators with EMF and internal resistance. Determine the mass $E = 4 \text{ Br} = 0,1 \text{ Ом} t$ of copper released during electrolysis during the time of , if the EMF of polarization and the resistance R of $t = 10 \text{ мин}$ $E_n = 1,5 \text{ В}$ the solution is equal to 0.5 Ом . Copper is divalent.

Task 2. To determine the amount of substance v and the number of atoms N of the divalent metal deposited on the cathode of the electrolytic bath, if a current of force $.t = 5 \text{ мин}$ $I = 2 \text{ А}$

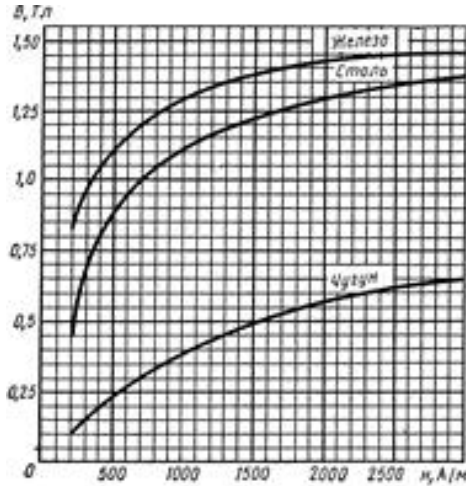
TOPIC 14. ELECTROMAGNETISM

Goal

To formulate Ampere's law. To define the concept of "magnetic field induction". To consider a circuit with a current in a magnetic field. To define the concept of "magnetic flux". To formulate the Biot-Savard-Laplace law. To define the concept of "magnetic field strength". To formulate the law of total current. To define the concept of "Lorentz force". To consider the structure and principle of operation of mass spectrometers. To consider the structure and principle of operation of charged particle accelerators. To consider the features of the movement of charged particles in a magnetic field. To define the concept of "magnetohydrodynamic effect" and "Hall effect".

Typical tasks for performing practical

Example. A cast-iron ring has an air gap with a length of . The length $l_0 = 5 \text{ mm}$ of the middle



line of the ring is 1 m. How many turns N does the winding on the ring contain, if at the current the induction $I = 4 \text{ AB}$ of the magnetic field in the air gap is 0.5 T ?

Solution: Ignoring the scattering of magnetic flux, we can assume that the field induction in the air gap is equal to the field induction in cast iron. Based on the law of total current, we write

$$IN = Hl + H_0I_0.$$

According to the graph, we find that when the magnetic field strength $B = 0,5 \text{ Тл}$ in cast iron is equal to $1,2 \text{ кА/м}$. Since for air $\mu = 1$, the field strength in the air gap

$$H_0 = B\mu_0 = 0,4 \text{ МА/м}.$$

Required number of turns:

$$N = \frac{l + H_0I_0}{I} = 800.$$

Problem 1. Determine the Lorentz force F acting on an electron that has flown into a homogeneous magnetic field at an angle to the induction lines. The magnetic induction $\nu = 4 \text{ мМ/с}$ $\alpha = 30^\circ$ of the field is equal to $0,2 \text{ Тл}$

Problem 2. A current flows along a ring with radius R . Magnetic induction is on the axis of the ring at a distance $d = 1 \text{ м}$ from its plane. Determine the magnetic moment of the ring with current. Consider $B = 10 \text{ нТл}$ $r_m R$ to be much less than d .

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Formulate Ampere's law. Write down the formula. Give an explanation.
2. Define the concept of "magnetic field induction".
3. How do you determine magnetic flux? Write down the formula. Define
4. Formulate the Bio-Savard-Laplace law. Write down the formula. Give an explanation.
5. How to determine the strength of the magnetic field? Write down the formula. Give an explanation.
6. Formulate the law of total current. Write down the formula. Give an explanation.

7. How to determine the magnetic moment of a circuit with current? Write down the formula. Give an explanation.
8. How do you determine the Lorentz force? Write down the formula. Give an explanation.
9. Formulate a theorem on the circulation of the magnetic induction vector. Write down the formula. Give an explanation.
10. How to determine the magnetic flux through a flat circuit? Write down the formula. Give an explanation.
11. Define the concept of "flow chaining". Write down the formula. Give an explanation.
12. Magnetic permeability is... Write down the formula. Give an explanation.
13. Magnetic resistance is... Write down the formula. Give an explanation.
14. Describe the structure and principle of operation of mass spectrometers.
15. Describe the structure and principle of operation of charged particle accelerators.
16. What are the features of the movement of charged particles in a magnetic field?
17. The magnetohydrodynamic effect is... Write down the formula. Give an explanation.
18. The Hall effect is.... Write down the formula. Give an explanation.

Problem 1. An electron in an unexcited hydrogen atom moves around the nucleus in a circle with a radius of $r = 53 \text{ nm}$. Calculate the strength of the equivalent circular current I and the strength of the field H in the center of the circle.

Problem 2. At a distance from the trajectory of a rectilinear electron, the maximum value of magnetic induction $B_{\text{max}} = 160 \text{ mT}$. Determine the electron's velocity v .

TOPIC 15.ELECTROMAGNETIC INDUCTION

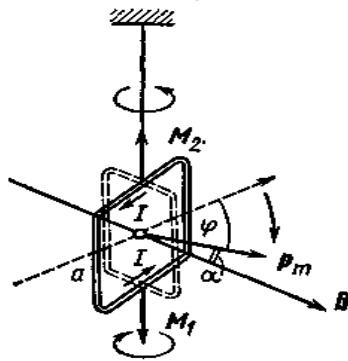
Goal

To define the concept of "magnetic field energy density". To define the concept of "inductance". To consider the phenomenon of mutual induction. To define the concept of "magnetic energy" of a circuit with current. To consider the phenomenon of EMF induction and induction current. To consider the possibilities of applying Faraday's law. To define the concept of "work of the Ampere force".

Typical tasks for performing practical

Example. A square frame with a side of length a , containing N turns of thin wire, is suspended on an elastic thread, the torsion constant $C = 2 \text{ cmN} = 100 \text{ C}$ of which is equal to C . The plane of the frame coincides with the direction of the line of induction of the external magnetic field. Determine the induction of the external magnetic field if, when passing a current through the frame, it has rotated by an angle $10 \text{ мкН} \cdot \text{м/град}$ $I = 1 \text{ A}$ $\alpha = 60^\circ$.

Solution: The induction B of the external field can be found from the equilibrium condition of the frame in the field. The frame will be in equilibrium if the sum of the mechanical moments acting on it is equal to zero:



$$\sum M = 0$$

In this case, two moments act on the frame: – the moment of forces with which the external magnetic field acts on the frame with the current, and – the moment of elastic forces arising when the thread on which the frame is suspended is twisted. Therefore, formula (1) can

be rewritten in the form $\vec{M}_1 \vec{M}_2$

$$\vec{M}_1 + \vec{M}_2 = 0 \quad (1)$$

Expressing this equality in terms of the magnitudes on which the moments of forces depend, we get: $M_1 M_2$

$$p_m B \sin \alpha - C \varphi = 0 \quad (2)$$

A minus sign is placed before a moment because this moment is opposite in the direction of the moment $M_2 M_1$

If we take into account that $p_m = ISN = Ia^2 N$ is the current in the frame; $S = a^2$ is the area of the frame; N is the number of its turns, we will rewrite equation (2) in the form:

$$NIa^2 B \sin \alpha - C \varphi = 0$$

From:

$$B = \frac{C \varphi}{NIa^2 \sin \varphi} \quad (3)$$

From it is obvious that $\sin \alpha = \cos \varphi$. Taking this into account, equation (3) will take the form $\alpha = \frac{\pi}{2} - \varphi$ $\alpha = \cos \varphi$

$$B = \frac{C \varphi}{NIa^2 \cos \varphi} \quad (4)$$

The value of the torsional constant calculated per degree (and not the radian, as it should be expressed in SI) is written as C

$$C = 10 \cdot 10^{-6} \text{ Н} \cdot \text{м/град}, \quad C = 10 \cdot 10^{-6} \text{ Н} \cdot \text{м/град}$$

Since the value of the angle is also given in degrees. φ

Let's substitute the data into formula (4) and make the calculations:

$$B = 0,03 \text{ Тл} = 30 \text{ мТл}$$

Problem 1. A long straight solenoid made of wire with a diameter is wound so that the turns fit tightly to each other. What is the intensity of $d = 0,5 \text{ мм}$ the magnetic field H inside the solenoid at the current strength? The thickness of the insulation should be neglected. $I = 4 \text{ A}$

Problem 2. A straight wire with a length of $l = 10 \text{ cm}$, through which a current of $I = 20 \text{ A}$ flows, is in a homogeneous magnetic field with an induction of $B = 0.01 \text{ T}$. Find the angle of α between the directions of the vector and the current, if the force is exerted on the wire $\vec{B}\vec{F} = 10 \text{ мН}$.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. The energy density of a magnetic field is... Write down the formula. Give explanations.
2. Inductance is... Write down the formula. Give explanations.
3. Mutual induction is.... Write down the formula. Give explanations.
4. The magnetic energy of a circuit with current is... Write down the formula. Give explanations.
5. EMF of induction is... Write down the formula. Give explanations.
6. Induction current is... Write down the formula. Give explanations.
7. Formulate Faraday's law. Write down the formula. Give explanations.
8. The Ampere force is... Write down the formula. Give explanations.
9. The work of the Ampere force is... Write down the formula. Explain

Problem 1. An electron in a hydrogen atom moves around the nucleus in a circular orbit of a certain radius. Find the ratio of the magnetic moment m of the equivalent circular current to the angular momentum L of the electron's orbital motion. Consider the charge of the electron and its mass known. Indicate the directions of the vectors and $\vec{p}_m, \vec{L}$

Problem 2. The magnetic field is created by an infinitely long conductor with a current I . At a distance $a = 10 \text{ cm}$ from the conductor, find a point dipole whose magnetic moment vector $\vec{p}_m = 100 \text{ A} \cdot (\text{p}_m 1 \text{ mA} \cdot \text{m}^2)$ lies in the same plane with the conductor and is perpendicular to it. Determine the force F acting on the magnetic dipole.

TOPIC 16. MAGNETIC PROPERTIES OF MATTER

Goal

To consider the magnetic field in matter. To define the concept of "magnetic permeability". To consider the elementary theory of diamagnetism. To consider the elementary theory of paramagnetism. To consider the nature of ferromagnetism.

Typical tasks for performing practical

Example. The NO molecule has a magnetic moment Determine the specific paramagnetic susceptibility of nitric oxide gas under normal conditions. $M_l = 1,8 \mu_B \cdot \chi_{yд}$

Solution. According to Langevin's theory, the magnetic susceptibility of a paramagnetic substance is determined by the expression

$$\chi = \mu_0 \frac{n M_l}{3kT} \quad (1)$$

where μ_0 is the magnetic constant ($\mu_0 = 4\pi \cdot 10^{-7} \text{ ГН/мн}$); n is the concentration of molecules (the number of molecules per unit volume); M_l is the magnetic moment of the atom; k is the Boltzmann constant; T is the thermodynamic temperature.

Specific magnetic susceptibility is related to magnetic susceptibility by the ratio $\chi_{yд} \chi$

$$\chi_{yд} = \frac{\chi}{\rho}$$

Replacing in this expression according to (1), we get χ

$$\chi_{yд} = \mu_0 \frac{M_l^2 n}{3kT \rho}.$$

Note that the concentration of molecules and the density of the gas can be expressed as follows:

$$n = N_A/V_m \text{ и } \rho = M/V_m$$

where N_A is Avogadro's constant; M is the molar mass; V_m is the molar volume. $N_A V_m$

$$\text{Then and } n/p = N_A/M \chi_{yд} = \mu_0 \frac{M_l^2 N_A}{3kTM}.$$

Let's make calculations (take into account that $1 \text{ и } \mu_B = 9,27 \cdot 10^{-24} \text{ А} \cdot \text{м}^2$ $M = 30 \cdot 10^{-3} \text{ кг/моль}$

Task 1. The magnetic susceptibility χ of aluminum is equal to Determine its specific magnetic and molar susceptibility. $2,1 \cdot 10^{-5} \cdot \chi_{yд} \chi_m$

Problem 2. Determine the largest value of the value a , at which the error caused by replacing the exact expression of the Langevin function with an approximate $L(a) \approx a/3$, does not exceed .1 %

QUESTIONS AND TASKS FOR SELF-CONTROL

1. How many types of magnets are there? List and explain each of them
2. Magnetization is... Write down the formula. Explain
3. Magnetic susceptibility is... Write down the formula. Explain
4. Bohr's magneton is.... Explain
5. Write down the relationship between magnetic induction, magnetic field strength, and magnetization.
6. Langevin's function is... Write down the formula. Explain
7. How do you determine the magnetic susceptibility of paramagnets? Write down the formula. Explain

Problem 1. Calculate the average number of Boron magnetons per iron atom if the magnetization of iron is equal to $\langle n \rangle = 1,84 \text{ MA/m}$.

Problem 2. For one iron atom in an empty 3 *d-shell*, *there are four unpaired electrons. To determine the theoretical value of the magnetization of iron J_{ns} at saturation.*

TOPIC 18. MAXWELL'S THEORY AND ELECTROMAGNETIC WAVES

Goal

To define the concept of "displacement current". To consider Maxwell's equations and the limits of their applicability. To consider the wave equation of an electromagnetic wave. To study the principle of operation of "dipole emitters". To consider the emission of waves by moving charges. To consider the speed of propagation of electromagnetic waves in media. To define the concept of the "Poynting vector".

Typical tasks for performing practical

Example. When an electromagnetic wave passes from a non-magnetic medium with a permittivity to a vacuum, the wavelength increased by . Determine the frequencies of oscillations. $\Delta\lambda = 48,8 \text{ м}$

Solution: When an electromagnetic wave passes from one medium to another, the frequency of oscillations does not change. Wavelength Increment

$$\Delta\lambda = \lambda_0 - \lambda.$$

Where is the wavelength in the vacuum, and is the wavelength in the medium $\lambda_0 = \frac{c}{\nu} \lambda = \frac{\vartheta}{\nu}$

Speed of propagation of electromagnetic waves in the medium:

$$\vartheta = \frac{c}{\sqrt{\varepsilon\mu}} = \frac{c}{\sqrt{\varepsilon}}$$

Since the medium is non-magnetic: $\mu = 1$

From the above it follows that:

$$\nu = \frac{c}{\Delta\lambda} \left(1 - \frac{1}{\sqrt{\varepsilon}} \right) = 2 \text{ МГц}$$

Task 1. To determine the average energy carried by an electromagnetic wave across the surface, the area of which for the time if the surface density of the radiation flux (radiation intensity) I in a vacuum, if the average volume energy density of the electromagnetic wave is equal to $S = 1,5 \text{ см}^2 \text{ т} = 5 \text{ с}, 3 \cdot 10^{-10} \text{ Дж/м}^3$

Problem 2. In a vacuum, a plane electromagnetic wave propagates along the x-axis. Determine the amplitude of the electric field intensity of an electromagnetic wave if the amplitude of magnetic field induction is 40 нТл $E_m B_m$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Displacement current is...
2. . Write down Maxwell's equations in differential and integral form. Give explanations.
3. Write down the material equation. Give an explanation.
4. Write down the wave equation of the electromagnetic wave.
5. What is the principle of operation of "dipole emitters"?
6. The Pointing Vector is... Explain

Task 1. The amplitude of the electric field intensity of an electromagnetic wave in a vacuum is . Determine the surface density of the radiation flux $E_m 10 \text{ В/м}$

Task 2. To determine the velocity of propagation of electromagnetic waves in a non-magnetic medium with a permittivity $\varepsilon = 2,2$

SECTION 4. OPTICS

TOPIC 19. LAWS OF GEOMETRIC OPTICS.

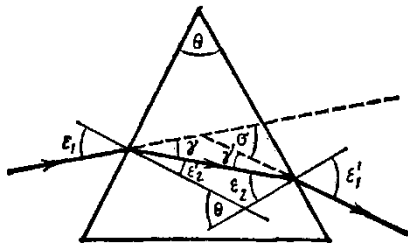
Goal

To define the concept of "light rays". To formulate the laws of ray optics. To consider the images obtained with the help of lenses. To consider the shortcomings of lenses. To consider the optical system of the eye.

Typical tasks for performing practical

Example. A ray of light falls on a glass prism with a refractive angle at an angle. Determine the angle of deflection σ the beam by the prism if the refractive index $\theta = 50^\circ$, $n = 1.56$.

Solution. It is advisable to solve this problem not in a general way, as is customary, but operationally, making all intermediate calculations. In this case, we lose somewhat in the accuracy of calculations, but win in clarity and simplicity of calculations. From the figure it can be seen that the angle of deviation



$$\sigma = \gamma + \gamma' \quad (1)$$

angles and are simply expressed in terms of angles γ, γ' , which we will calculate sequentially: $\gamma, \gamma', \varepsilon_1, \varepsilon_2, \varepsilon_2', \varepsilon_1'$

1) From the law of refraction we have $n = \frac{\sin \varepsilon_1}{\sin \varepsilon_2}$

$$\varepsilon_2 = \arcsin\left(\frac{\sin \varepsilon_1}{n}\right) = 18,7^\circ$$

2) from the figure, it follows that the angle of incidence on the second face of the prism is equal to ε_2

$$\varepsilon_2 = \theta - \varepsilon_2' = 31,3^\circ, \varepsilon_2 = \theta - \varepsilon_2' = 31,3^\circ$$

The angle is less than the limit, so on the second face the ray will be refracted and come out of the prism; $\varepsilon_2 \varepsilon_{2\text{пред}} = \arcsin\left(\frac{1}{n}\right) = 39,9^\circ$

$$3) \text{ since , then } \frac{\sin \varepsilon_2}{\sin \varepsilon_1} = \frac{1}{n} \varepsilon'_1 = \arcsin(n \sin \varepsilon_2) = 54,1^\circ$$

Now let's find the angles and : $\gamma\gamma'$

$$\gamma = \varepsilon_1 - \varepsilon'_2 = 11,3^\circ, \text{ and}$$

$$\gamma' = \varepsilon'_1 - \varepsilon_2 = 22,8^\circ,$$

Using formula (1) we find $\sigma = \gamma + \gamma' = 34,1^\circ$

Task 1. Two flat rectangular mirrors form a dihedral angle $\varphi=179^\circ$. At a distance of $l=10 \text{ cm}$ from the line of contact of the mirrors and at the same distance from each mirror there is a point light source. Determine the distance d between the imaginary images of the source in the mirrors.

Task 2. A concave spherical mirror gives an image of an object on the screen, magnified by $D = 4$ times. The distance a from the object to the mirror is 25 cm. Determine the radius R of the curvature of the mirror.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What types of images are there?
2. What types of lenses are there?
3. What is called focal length?
4. How do you determine the focal length of a spherical mirror? Explain the formula.
5. What is optical power?
6. How to determine the optical power of a spherical mirror? Give an explanation of the formula.
7. Formulate the law of refraction of light. Give an explanation.
8. What do I call the limiting angle of total reflection?
9. How to determine the limiting angle of total reflection? Explain the formula.
10. What is the optical power of a thin lens?
11. How to determine the optical power of a thin lens? Give an explanation of the formula.
12. How do you calculate the power of two thin lenses?
13. Write down the formula of the thin lens. Explain the formula.
14. What is called angular magnification?
15. How to determine the angular magnification of a magnifier? Give an explanation of the formula.

16. How to determine the angular magnification of a telescope? Give an explanation of the formula.
17. How to determine the angular magnification of a microscope? Give an explanation of the formula.
18. List the laws of geometric optics
19. Formulate the law of rectilinear propagation of light. Explain
20. Formulate the law of independent propagation of rays. Explain
21. Formulate the law of refraction of light. Explain
22. Formulate the law of light reflection. Give an explanation.

Problem 1. A biconvex lens has the same radii of curvature of surfaces. At what radius of curvature R of the surfaces of the lens will its principal focal length f be equal to 20 cm?

Problem 2. The refractive angle of the prism is θ . The angle of the smallest deviation of the beam from the original direction is $\sigma = 30^\circ$. Determine the refractive index n of the glass from which the prism is made.

TOPIC 21. BASIC LAWS OF LIGHT PROPAGATION

Goal

Study the spectrum of electromagnetic waves. Consider photometric quantities. Formulate Huygens' principle. Formulate Fermat's principle. Consider the basics of electromagnetic optics. Study Fresnel's formulas.

Typical tasks for performing practical

Example. A fluorescent cylindrical lamp with diameter $d = 2,5 \text{ cm}$ and length $l = 40 \text{ cm}$ creates illumination at a distance $r = 5 \text{ m}$ in the direction perpendicular to the axis of the lamp. Taking the lamp as a cosine emitter, determine: 1) luminous intensity I_v in this direction; 2) brightness L ; 3) luminosity M of the lamp.

Solution. 1. The larger of the two dimensions of the lamp – the length – is 12 times less than the distance at which the illumination is measured.

Therefore, to calculate the luminous intensity in a given direction, we can take the lamp as a point source and apply the formula , from which $E = \frac{I}{r^2} I = Er^2$

By substituting the values of quantities into this formula and making calculations, we get

$$I = 25 \text{ кД.}$$

2. To calculate the brightness, let's use the formula

$$L = I/\sigma,$$

where σ is the area of projection of an extended light source on a plane perpendicular to the direction of observation.

In the case of a cylindrical fluorescent lamp, the projection is in the shape of a rectangle with a length l and width d .

$$L = I/(ld).$$

Having made calculations according to this formula, we will find

$$L = 2,5 \text{ ккД/м}^2.$$

3. Since a fluorescent lamp can be considered a cosine emitter, its luminosity

$$M = \pi L = 7,9 \text{ клк.}$$

Task 1. What current I will be shown by a galvanometer connected to a selenium photocell if a lamp with a total luminous flux of ? The area of the working surface of a photocell is equal to , sensitivity $r = 75 \text{ см}\Phi_0 1,2 \text{ клм} 10 \text{ см}^2 i = 300 \text{ мкА/лм.}$

Task 2. At what height h above the center of the round table should a light bulb be hung with a radius so that the illumination on the edge of the table is maximum? $r = 1 \text{ м}$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. The spectrum of electromagnetic waves is...
2. List the types of electromagnetic radiation and their brief characteristics (wavelength range and sources)
3. List the main characteristics of electromagnetic radiation. Explain
4. Formulate Huygens' principle
5. Formulate the Fermat principle
6. The light flux is...
7. Surface illumination is
8. The brightness of the luminous surface is
9. Luminosity is

Task 1. When printing a photograph, the negative was illuminated for a period with a bulb with a luminous intensity from a distance of $r_1 = 50$ cm. Determine the time $t_1 = 3I_1 = 15$ кдр₁t₂, during which it is necessary to illuminate the negative with a bulb with the luminous intensity cd from a distance, in order to obtain an imprint with the same degree of blackening as in the first case? $I_2 = 60r_2 = 2$ м

Task 2. What current I will be shown by a galvanometer connected to a selenium photocell if a light bulb with a total luminous flux of Φ is placed at a distance from it? Working surface $S = 75$ см² $\Phi_0 = 1,2$ кл

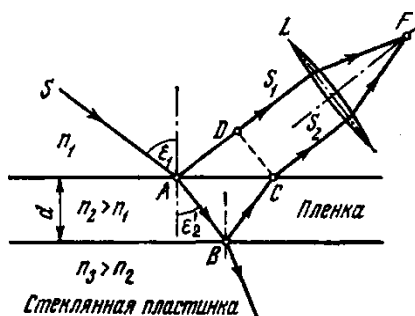
TOPIC 22. INTERFERENCE OF LIGHT

Goal

Consider the conditions for observing the interference pattern. Define the concept of "coherence". Consider interference in thin films. Consider the coating of optics.

Typical tasks for performing practical

Example. A thick glass plate covered with a very thin film with a refractive index of 1.4 is hit by a normally parallel beam of monochromatic light (λ). The reflected light is attenuated as much as possible due to interference. Determine the thickness d $n_2\lambda = 0,6$ мкм of the film.



Solution: From the light wave incident on the film, we extract a narrow beam SA . The stroke of this beam in the case when the angle of incidence $\epsilon_1 \neq 0$ is shown in the figure. At points A and B , the incident beam is partially reflected and partially refracted. The reflected light beams fall on the converging lens AS_1BCS_2L , intersect at its focus F and interfere with each other.

Since the refractive index of air (n_1) is less than the refractive index of the film substance (n_2), which, in turn, is less than the refractive index of glass (n_3), in both cases the reflection occurs from a medium optically denser than the medium in which the incident wave is traveling. Therefore, the phase of oscillation of a light beam during reflection at point A changes by π rads, and in the same way, the phase of oscillation of a light beam when reflected at point B changes by π rad BCS_2 .

As is known, the condition for the maximum attenuation of light during interference in thin films is that the optical difference in the path of the interfering waves must be equal to an odd number of half-waves; $\Delta\Delta = (2k + 1)(\lambda/2)$.

As you can see from the figure, the optical stroke difference

$$\Delta = l_2 n_2 - l_1 n_1 = (|AB| + |BC|)n_2 - |AD|n_1$$

Therefore, the condition of the minimum light intensity will take the form of

$$(|AB| + |BC|)n_2 - |AD|n_1 = (2k + 1)(\lambda/2).$$

If the angle of incidence decreases, tending to zero, then and $\varepsilon_1 AD \rightarrow 0 (|AB| + |BC| \rightarrow 2d$, where d is the thickness of the film. Within the limit at we will have $\varepsilon_1 = 0 \Delta = 2dn_2 = (2k + 1)(\lambda/2)$

Where does the desired film thickness come from?

$$d = \frac{(2k+1)\lambda}{4n}.$$

Assuming, we get a number of possible values of film thickness: $k = 0, 1, 2, 3, \dots$,

$$d_0 = \frac{\lambda}{4n_2} = 0,11 \text{ мкм}, \text{ etc. } d_1 = \frac{3\lambda}{4n_2} = 3d_0 = 0,33 \text{ мкм}$$

Problem 1. A thin glass wedge () is subjected to normally monochromatic light. The dihedral angle between the surfaces of the wedge is γ . Determine the wavelength of light if the distance between adjacent interference maxima in reflected light is $n = 1,55 \text{ мм}$.

Problem 2. On the screen, an interference pattern from two coherent light sources with a wavelength λ is observed. When a thin plate of fused quartz with a refractive index n , the interference pattern is shifted to stripes on the path of one of the beams. Determine the thickness of the quartz plate. $\lambda = 480 \text{ нм} = 1,46 \text{ м} = 69 \text{ д}$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What are the main provisions and conclusions of the corpuscular and wave theories of light?
2. Why did the idea of the dual wave-particle nature of light arise?
3. What is the main idea of Planck's theory?

Problem 1. How long l_1 will the wave front of monochromatic light travel in a vacuum in the same time as it travels the path of length $l_2 = 1 \text{ m}$ in water?

Problem 2. In Michelson's interferometer, in the path of one of the interfering light beams ($\lambda = 590 \text{ нм}$), a glass tube with a length of $l = 10 \text{ cm}$, closed on both sides, was placed and pumped

out to a high vacuum. When the tube was filled with hydrogen chloride, the interference pattern was displaced. When hydrogen chloride was replaced by hydrogen bromide, the displacement of the interference pattern increased by $\Delta m = 42$ bands.

TOPIC 24. POLARIZATION OF LIGHT

Goal

To give the concepts of the definitions of "polarized light" and "natural light". To consider the phenomenon of Brewster. To consider the structure and principle of operation of the analyzer. To formulate Malus's law. To consider the phenomenon of birefringence. To consider the phenomenon of dichroism. To consider the rotation of the plane of polarization. To consider optical activity in nature.

Typical tasks for performing practical

Example. A mm-thick plate of quartz, cut perpendicular to the optical axis of the crystal, rotates the plane of polarization of monochromatic light of a certain wavelength by an angle $d_1 = 1\varphi_1 = 20^\circ$. To determine: 1) what is the thickness of the quartz plate placed between two "parallel" nicols d_2 in order for the light to be completely extinguished; 2) how long should a tube with a solution of sugar of mass concentration be placed between the nicolas to obtain the same effect? The specific rotation of the sugar solution is equal to $[\alpha] = 0,4 \text{ кг/л}$ $[0,665 \text{ град}/(\text{м} \cdot \text{кг} \cdot \text{м}^{-3})]$

Solution. 1. The angle of rotation of the plane of polarization by a quartz plate is determined by the ratio $\varphi = \alpha \cdot d$.

Using this formula, let's express the desired thickness of the plate: d_2

$$d_2 = \frac{\varphi_2}{\alpha} \quad (1)$$

where is the angle of rotation of the polarization plane at which the light will be completely extinguished). φ_2 ($\varphi_2 = 90^\circ$)

We also find the rotation constant α for quartz from the formula , substituting the values given in the problem condition and : $\varphi = \alpha \cdot d d_1 \varphi_1$

$$\alpha = \frac{\varphi_1}{d_1}$$

Substituting this expression α in formula (1), we get

$$d_2 = \frac{\varphi_2}{\alpha} d_1$$

Having made calculations according to this formula, we find the thickness of the plate:

$$d_2 = 4,5 \text{ мм.}$$

2. The length of the tube with the sugar solution is found from the ratio , which expresses the angle of rotation of the plane of polarization by the sugar solution, where $d\varphi_2 = [\alpha]Cd$ is the thickness of the sugar solution (assumed to be equal to the length l трубки). Отсюда получим

$$l = \varphi_2 / ([\alpha]C).$$

By substituting the values of , and making calculations, we find $\varphi_2[\alpha], C = 0,4 \text{ кг/л} = 400 \text{ кг/м}^3$

$$l = 3,8 \text{ дм.}$$

Task 1. In partially polarized light, the amplitude of the light vector corresponding to the maximum light intensity is times greater than the amplitude corresponding to the minimum intensity. Determine the degree of polarization of light. $n = 2\vec{P}$

Problem 2. A mm-thick quartz plate, cut perpendicular to the optical axis, was placed between parallel nicolas, as a result of which the plane of light polarization rotated by an angle . Determine the thickness of the plate at which this monochromatic light does not pass through the analyzer. $d_1 = 2\varphi = 53^\circ d_2$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Polarized light is.... Explain
2. Natural light is.... Please explain

3. Formulate Brewster's law. Write down the formula. Give an explanation.
4. Formulate Malus's law. Write down the formula. Give an explanation
5. How to determine the degree of polarization of light? Write down the formula. Give an explanation.
6. How to determine the angle of rotation of the plane of polarization in solids? Write down the formula. Give an explanation.
7. How to determine the angle of rotation of the polarization plane in pure liquids? Write down the formula. Give an explanation.
8. How to determine the angle of rotation of the plane of polarization in solutions? Write down the formula. Give an explanation.

Task 1. A beam of natural light traveling in water is reflected from the face of a diamond immersed in water. At what angle of incidence is the reflected light fully polarized? ε_n

Task 2. Degree of polarization of partially polarized light $\vec{P}$ is equal to 0.5. How many times does the maximum intensity of light transmitted through the analyzer differ from the minimum?

27. EMISSION OF LIGHT BY MATTER

Goal

To consider thermal radiation and its characteristics. To define the concept of "blackbody". To formulate the laws of thermal radiation (Kirchhoff, Stefan-Boltzmann, Wien). To consider Planck's formula. To study the derivation of the laws of thermal radiation of a blackbody from Planck's formula.

Typical tasks for performing practical

Example. The study of the Sun's radiation spectrum shows that the maximum spectral density of energy luminosity corresponds to the wavelength Taking the Sun as a black body, to determine. 1) the energy luminosity of the Sun's M_e ; 2) the energy flux $\lambda = 500 \text{ nm}$ $\vec{\Phi}_e$ emitted by the Sun; 3) the mass of electromagnetic waves (of

all lengths) emitted by the Sun in 1 s. τ

Solution 1. The energy luminosity of a blackbody is expressed by the Stefan–Boltzmann formula M_e

$$M_e = \sigma T^4 \quad (1)$$

The temperature of the radiating surface can be determined from Wien's displacement law. $\lambda_m = b/T$. Expressing the temperature T from here and substituting it in formula (1), we get

$$M_e = \sigma (b\lambda_m)^4, \quad (2)$$

Having made calculations according to formula (2), we find

$$M_e = 64 \text{ MBT/M}^2$$

2. The energy flux emitted by the Sun is equal to the product of the Sun's energy luminosity by the area S of its surface. Φ_e

$$\Phi_e = 4\pi r^2 M_e \quad (3)$$

where r is the radius of the Sun r —

By substituting the values of r and M_e in formula (3), we get $\pi r M_e$

$$\Phi_e = 3,9 \cdot 10^{26} \text{ BT.}$$

3. The mass of electromagnetic waves (of all lengths) emitted by the Sun during time t , we will determine by applying the law of proportionality of mass and energy $E = mc^2$. The energy of electromagnetic waves emitted during time t is equal to the product of the flux of energy F (radiation power) by time $E = \Phi t$. Therefore, from where $\Phi_e = mc^2 \tau = \Phi_e / c^2$

Having made calculations according to this formula, we will find

$$m = 4,3 \cdot 10^9 \text{ кг.}$$

Task 1. Determine the temperature T , at which the energy luminosity of the blackbody is equal to $M_e 10 \text{ kBT/M}^2$

Task 2. What wavelength is the maximum spectral density of blackbody energy luminosity at a temperature $\lambda_m (M_\lambda, T)_{\max} t = 0^\circ\text{C}$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What is called a blackbody?

2. Formulate the Stefan-Boltzmann law of displacement. Write down the formula. Explain
3. Energy luminosity is...
4. Formulate Wien's law of displacement. Write down the formula. Explain
5. Write down Planck's formula. Give explanations.
6. Write down the dependence of the maximum spectral density of energy luminosity on temperature. Give an explanation.
7. Formulate Kirchhoff's law of displacement. Write down the formula. Explain

Task 1. Determine the energy W radiated during the time of min from the inspection window by the area of the melting furnace, if its temperature is $t = 15 = 8 \text{ cm}^2 T = 1,2 \text{ K}$

Problem 2. The temperature of the upper layers of the Sun is equal to . Considering the Sun to be a black body, determine the wavelength , which corresponds to the maximum spectral density of the Sun's energy luminosity. $5,3 \text{ K } \lambda_m(M_\lambda, T)_{max}$

TOPIC 28. WAVE PROPERTIES OF MATTER

Goal

To consider the wave-particle dualism of matter. To formulate the de Broglie hypothesis. To consider the uncertainty relation. To consider the wave function and its statistical meaning. To consider the temporal and stationary Schrödinger equations. To consider the physical foundations of electron microscopy.

Typical tasks for performing practical

Example. What accelerating potential difference U must an electron travel for the de Broglie wavelength λ to be equal to 0.1 nm ?

Solution: The de Broglie wavelength is related to the momentum of the particle p , which in turn is related to the kinetic energy E :

$$\lambda = \frac{h}{p}; p = \sqrt{2mE} \lambda = \frac{h}{\sqrt{2mE}}$$

In turn, the electron acquired kinetic energy by accelerating in an electric field, having passed the potential difference, then this energy is equal to the work of the field, i.e.

$$E = eU$$

Let's substitute for the wavelength in the expression and express the desired voltage:

$$\lambda = \frac{h}{\sqrt{2meU}}; \lambda^2 = \frac{h^2}{2meU} \Rightarrow U = \frac{h^2}{2me\lambda^2}$$

$$U = 150,8 \text{ B}$$

Problem 1. Determine the de Broglie wavelength λ , which characterizes the wave properties of the electron, if its velocity $v = 1 \text{ Mm/s}$. Make the same calculation for the proton.

Problem 2. The electron is moving at a speed of $v = 200 \text{ Mm/s}$. Determine the de Broglie wavelength λ , taking into account the change in the mass of the electron as a function of the velocity.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Wave dualism is...
2. Formulate the de Broglie hypothesis.
3. Formulate the uncertainty ratio. Explain
4. The wave function is.... Please explain.
5. Write down Schrödinger's time equations.
6. Write down the stationary Schrödinger equation as well
7. What are the phase and group velocities of a photon?
8. How, based on the uncertainty relation, can the presence of the natural width of spectral lines be explained?
9. What determines the square of the modulus of the wave function?
10. Why is quantum mechanics a statistical theory?
11. What is the difference between the understanding of causality in classical and quantum mechanics?
12. How will the transparency coefficient of a potential barrier change with a doubling of its width?
13. Can a particle be at the bottom of a "potential well"?
14. Is this determined by the shape of the "pit"?
15. What is the difference between the quantum mechanical and classical descriptions of a harmonic oscillator? In the conclusions of these descriptions?

Problem 1. Determine the de Broglie wavelength λ of an electron if its kinetic energy is $T = 1 \text{ eV}$.

Problem 2. Find the de Broglie wavelength λ of a proton that has passed the accelerating potential difference U : 1) ; 2) 1 κ B1 MB

SECTION 5. PHYSICS OF THE ATOM AND NUCLEUS

TOPIC 29. MODELS OF THE STRUCTURE OF THE ATOM

Goal

To introduce the concepts of "atomic units of energy" and "atomic units of mass". To consider Thomson's model of the atom. To consider Rutherford's model of the atom. To consider Bohr's model of the atom. To formulate Bohr's postulates. To consider the spectrum of hydrogen. To study the development of Bohr's theory.

Typical tasks for performing practical

Example. Calculate the radius of the first orbit of the hydrogen atom (Bohr radius) and the velocity of the electron in this orbit.

Solution. According to Bohr's theory, the radius r of the electron orbit and the velocity v of the electron on it are related by the equation Since the problem requires the determination of the quantities related to the first orbit, the principal quantum number and the above equation will take the form $mvr = n\hbar$. $n = 1$

$$mvr = \hbar \quad (1)$$

To determine two unknown quantities, one more equation is needed. As the second equation, we will use the equation of motion of the electron. According to Bohr's theory, the electron revolves around the nucleus. At the same time, the force of interaction between the electric charges of the nucleus and the electron gives the electron centripetal acceleration. Based on Newton's second law, we can write:

$$\frac{m\vartheta^2}{r} = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r^2} \quad (2)$$

(and m – charge and mass of the electron), or

$$m\vartheta^2 = \frac{1}{4\pi\epsilon_0} \frac{e^2}{r}$$

The joint solution of equations (1) and (2) with respect to r

$$r = \frac{4\pi\epsilon_0\hbar}{(me)^2}$$

By substituting the values of $\hbar$, e , and making calculations, we find the Bohr radius: $\hbar e, m$

$$r = a = 5,29 \cdot 10^{-11} \text{M}$$

From equation (1), we obtain the expression of the electron's velocity in the first orbit:

$$\vartheta = \frac{\hbar}{mr}$$

Having made calculations according to this formula, we will find

$$\vartheta = 2,18 \text{ Mm}/c$$

Task 1. To determine the potential P , kinetic T , and total E of the energy of an electron in the first orbit of a hydrogen atom.

Problem 2. Determine the wavelength λ corresponding to the third spectral line in the Balmer series.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Why did the nuclear model of the atom turn out to be untenable?
2. Why, of the various series of spectral lines of the hydrogen atom, was the Balmer series the first to be studied?
3. What is the meaning of the numbers m and n in Balmer's generalized formula?
4. What is the radiation frequency of a hydrogen atom corresponding to the short-wave boundary of the Bracket series?
5. Explain the meaning of Bohr's postulates.
6. How do Bohr's postulates explain the linear spectrum of an atom?

7. What are the main inputs that can be made on the basis of the experiments of Frank and Hertz?
8. Using Bohr's model, indicate the spectral lines that can arise when a hydrogen atom transitions to states $n = 3$ and $n = 4$.
9. Plot the wavelength scale with three lines of each of the first two spectral series of the hydrogen atom.
10. Why does the absorption spectrum of a hydrogen atom contain only the Lyman series?

Problem 1. Atomic hydrogen excited by light of a certain wavelength emits only three spectral lines when it transitions to the ground state. Determine the wavelengths of these lines and indicate which series they belong to.

Problem 2. A photon with energy knocked an electron out of an unexcited hydrogen atom. What velocity v will an electron have far from the nucleus of an atom? $\varepsilon = 16,5 \text{ eV}$

TOPIC 30. STRUCTURE AND SPECTRA OF ATOMS

Goal

To consider a hydrogen-like atom. To consider the spectra of hydrogen and alkali metals. To define the concept of "electron spin". To consider multielectron atoms. To formulate the postulates of Mendeleev's periodic law. To consider the spectra of multielectron atoms. To study the basics of spectral analysis.

Typical tasks for performing practical

Example. Find the possible values of the total mechanical moments of atoms in the states ^4P and ^5D

Solution: State ^4P : quantum numbers ; ; $L = 12S + 1 = 4S = 1\frac{1}{2}$

The internal quantum number can take the following values:

$$J = L + S, L + S - 1, |L - S|$$

$$J = 2\frac{1}{2}, 1\frac{1}{2}, \frac{1}{2}$$

Total Mechanical Moment of Atom:

$$M = \frac{h}{2\pi} \sqrt{J(J-1)}$$

$$M = \frac{h}{2\pi} \sqrt{\frac{35}{4}}, M = \frac{h}{2\pi} \sqrt{\frac{15}{4}} \quad M = \frac{h}{2\pi} \sqrt{\frac{3}{4}}$$

State : ^5D quantum numbers ; $L = 22S + 1 = 5$; $S = 2$

The internal quantum number can take the following values:

$$J = L + S, L + S - 1, |L - S|$$

$$J = 4, 3, 2, 1, 0$$

Total Mechanical Moment of Atom:

$$M = \frac{h}{2\pi} \sqrt{J(J-1)}$$

$$M = \frac{h}{2\pi} \sqrt{20}, ; ; 0 \quad M = \frac{h}{2\pi} \sqrt{12} \quad M = \frac{h}{2\pi} \sqrt{6} \quad M = \frac{h}{2\pi} \sqrt{2}$$

Problem 1. Determine how many different wave functions correspond to the main quantum number $n = 5$.

Task 2. Construct and explain a diagram illustrating the splitting of energy levels and spectral lines (taking into account the rules of selection) during transitions between states c and $.$ ($-$ transition). $l = 2l = 1d \rightarrow p$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What do quantum numbers characterize: the main one, orbital and magnetic?
What values can they take?

2. What are the possible values for the main quantum number as well? $lm ln =$

3. How many different states correspond? $n = 4$
4. Compare the probability densities of detecting an electron in the ground state of a hydrogen atom according to Bohr's theory and quantum mechanics.
5. Why can a hydrogen atom have the same energy value when in different states?

Problem 1. To determine the wavelengths of spectral lines arising during the transition of excited lithium atoms from the state to the ground state . The Rydberg corrections for S- and P-terms are equal to -0.41 and -0.043525

Problem 2. The binding energy of the valence electron of the lithium atom in the 2S and 2P states is 5.39 and 3.54 eV, respectively. Calculate the Rydberg corrections for the S- and P-terms of this atom

TOPIC 31. LASERS

Goal

To consider the structure and principle of laser operation. To study the properties of laser radiation. To consider the use of laser radiation in medicine and industry.

Typical tasks for performing practical

Example. A 1 mW laser emits light with a wavelength of 632.8 nm. Calculate the flux of radiation quanta.

Solution: Energy of one photon: , then: $E_0 = h\nu = h \frac{c}{\lambda}$

$$E = N \cdot E_0$$

$$E = P \cdot t$$

$$N \cdot E_0 = P \cdot t$$

Photon flux:

$$\Pi = \frac{N}{t} = \frac{P}{E_0}$$

Therefore:

$$\Pi = \frac{P\lambda}{hc} = 31,8 \text{ БТ}$$

Task 1. The laser emits radiation with a wavelength of 330 nm. Determine the energy of one quantum of light emitted by the laser.

Task 2. Determine the Q-factor of the helium-neon laser resonator from the first task in relation to radiation losses, if the core length is 40 cm and the mirror reflectance is 0.9.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What kind of radiation is called spontaneous?
2. What kind of radiation is called induced?
3. Explain the structure and principle of operation of the laser.
4. List and explain the properties of laser radiation.

Task 1. A laser amplifier is a cell filled with a light-amplifying medium (such a medium is said to have an inverse population). Laser radiation falls on the input of the laser amplifier from . The power of laser radiation at the output of the amplifier is equal to . Find the force that should be applied to the amplifier in order to keep it in a stationary position. $P_1 = 1 \text{ кВт}$ $P_2 = 10 \text{ МВт}$

Problem 2. A beam of laser radiation with power falls on an opaque plate at an angle of $\alpha = 30^\circ$. The plate absorbs 60% of the incident energy, and the rest of the energy is mirrored. Find the absolute value of the force acting on the plate from the direction of light. Speed of light $c = 3 \cdot 10^8 \text{ м/с}$.

TOPIC 32. NATURAL RADIOACTIVITY

Goal

To study the composition of the atomic nucleus. To consider the binding energy of atomic nuclei. To define the concept of "radioactive radiation". To consider the types of radioactive radiation. To formulate the laws of radioactive decay. To consider the physical basis of the effect of ionizing radiation on the body.

Typical tasks for performing practical

Example. Determine the half-life of a radioactive isotope if $2/3$ of the initial number of nuclei of this isotope decayed during $t = 10$ мин

Solution: Half-life of a radioactive isotope

$$T = \frac{\ln 2}{\lambda} \quad (1)$$

Where λ is the constant of the radioactive isotope

Number of decayed nuclei:

$$\Delta N = N_0 - N \quad (2)$$

Where N_0 is the initial number of non-decayed nuclei; N is the number of non-decayed nuclei at time t , which, according to the law of radioactive decay:

$$N = N_0 e^{-\lambda t} \quad (3)$$

Taking into account (2) and (3), we will find the fraction of decayed nuclei during the t

$$\frac{\Delta N}{N_0} = \frac{N_0 - N}{N_0} = 1 - e^{-\lambda t}$$

According to the problem condition:

$$\frac{\Delta N}{N_0} = 1 - e^{-\lambda t} = \frac{2}{3}$$

$$e^{-\lambda t} = \frac{1}{3}; -\lambda t = \ln \frac{1}{3}$$

$$\text{From } \lambda = \frac{\ln 3}{t}$$

Therefore:

$$T = \frac{\ln 2}{\lambda} = \frac{\ln 2}{\ln 3} t = 6,31 \text{ мин}$$

Problem 1. Chlorine is a mixture of two isotopes with relative atomic masses A_1 and A_2 . Calculate the relative atomic mass of chlorine if the mass fractions of both the first and second isotopes are w_1 and w_2 , respectively. $A_1 = 34,969$, $A_2 = 36,966$

Task 2. What part of the mass of a neutral plutonium atom is the mass of its electron shell?

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What particles form the nucleus of a zinc atom? How many are there?
2. The atomic nucleus was "composed" of N free nucleons (the mass of each nucleon is equal to m).
3. What are the mass and specific energy of the binding of this nucleus?
4. What is the difference between isobars and isotopes?
5. Why does the strength of nuclei decrease when switching to heavy elements?
6. How is the ultrafine structure of spectral lines explained?
7. How and how many times will the number of nuclei of a radioactive substance change in a time equal to three half-lives?
8. How (according to what law) does the activity of a nuclide change over time?
9. How will the position of a chemical element in the periodic table change after two α decays of the nuclei of its atoms? After successive one α decay and two β decays?
10. How is α decay explained on the basis of quantum theory?
11. How to explain the continuity of the energy spectrum of β particles

Problem 1. What is the probability W that a given atom in the isotope of radioactive iodine will decay within the next second? ^{131}I

Task 2. What part of the initial number of radioactive actinium atoms will remain in 5 days? in 15 days? ^{225}Ac

TOPIC 33. ARTIFICIAL RADIOACTIVITY

Goal

To consider artificial transformations of nuclei. To consider nuclear reactions. To consider the theory of alpha decay. To consider the theory of beta decay. To consider models of the nucleus. To consider the Mössbauer effect. To consider the use of nuclear energy in the modern world.

Typical tasks for performing practical

Example. Determine what part of the initial amount of a radioactive nuclide decays in time t equal to the average lifetime of this nuclide.

Solution:

According to the law of radioactive decay and the conditions of the problem: $N = N_0 e^{-\lambda t}$

$$\frac{N_0 - N}{N_0} = 1 - e^{-\lambda t}$$

Because. $\lambda = \frac{1}{\tau}$

$$\frac{N_0 - N}{N_0} = 1 - e^{-\frac{1}{\tau} t} = 1 - e^{-\frac{t}{\tau}}$$

Considering that: $t = \tau$

$$\frac{N_0 - N}{N_0} = 1 - e^{-\frac{t}{\tau}} = 1 - e^{-1} = 1 - \frac{1}{e} = 0,632$$

Task 1. How many uranium-235 nuclei must fission in the time $t = 1$ s for the thermal power P of a nuclear reactor to be equal to 1 W?

Task 2. Find the electric power P of a nuclear power plant that consumes 0.1 kg of uranium-235 per day, if the efficiency of η station is 16%.

QUESTIONS AND TASKS FOR SELF-CONTROL

1. How is α decay explained on the basis of quantum theory?
2. How is the continuity of the energy spectrum of β particles explained?
3. Will the chemical nature of the element change when its nucleus emits a γ quantum?
4. What phenomena accompany the passage of γ radiation through matter and what is their essence?
5. What is the essence of the Mössbauer effect? What are its possible applications?
6. Write down the e-capture scheme. What accompanies e-capture? How is it different from $\beta^\pm$ decays?
7. How to explain the release of neutrinos (antineutrinos) during $\beta^\pm$ decays?
8. What are the characteristics of nuclear reactions?
9. What is the nuclear fission reaction? Give examples.

10. As a result of what reaction does the transformation of nuclei into nuclei occur? What are its prospects? ${}^{238}_{92}\text{U}$ ${}^{239}_{94}\text{U}$

Task 1. How many uranium-235 nuclei must fission in the time $t = 1$ s for the thermal power P of a nuclear reactor to be equal to 1 W?

Task 2. Find the electric power P of a nuclear power plant that consumes 0.1 kg of uranium-235 per day, if the efficiency of η station is 16%.

TOPIC 34. ELEMENTS OF DOSIMETRY

Goal

To define the concepts of "radiation dose" and "exposure dose". To define the concept of "dose rate". To consider the quantitative assessment of the biological effect of ionizing radiation. To define the concept of equivalent dose. To consider the structure and principle of operation of dosimetric devices. To study the methods of protection against ionizing radiation.

Typical tasks for performing practical

Example. At what depth should the source of a narrow beam of γ radiation (the energy of gamma photons is equal to 1.6 MeV) be immersed in water so that the intensity of the first beam coming out of the water is reduced by a factor of $k = 1000$?

Solution: , according to the condition . Then we get: $I = I_0 e^{-\mu x} \frac{I_0}{I} = k \Rightarrow I = \frac{I_0}{k}$

$$\frac{I_0}{k} = I_0 e^{-\mu x} \Rightarrow \frac{1}{k} = e^{-\mu x}$$

$$-\ln k = -\mu x \Rightarrow x = \frac{\ln k}{\mu}$$

Because : $\mu = 0,06 \text{ cm}^{-1}$

$$x = 115 \text{ cm} = 1,15 \text{ m}$$

Problem 1. The intensity of the I narrow beam of γ radiation decreased after passing through a layer of lead with a thickness of . To determine the energy ε gamma photons and the thickness of the half-attenuation layer. $x = 4 \text{ cm}$ $k = 8 \text{ паз}$ $x_{\frac{1}{2}}$

Task 2. A narrow beam of γ radiation passes through lead. At what value of the energy ε gamma photons will the thickness of the half-attenuation layer be maximum? Determine the maximum thickness of the half-attenuation layer for lead.

$x_{\frac{1}{2}} x_{max}$

QUESTIONS AND TASKS FOR SELF-CONTROL

1. Interaction of ionizing radiation with matter.
2. Linear ionization density, linear energy transfer, average path of ionizing particle.
3. Features of interaction with matter of alpha, beta, gamma radiation and neutrons.
4. Physical principles of protection against ionizing radiation.
5. The concept of the main biological effects of ionizing radiation.
6. The principle of operation of the ionization chamber.
7. The principle of operation of the track detector
8. Geiger-Müller counter diagram

Task 1. A narrow beam of γ radiation (the energy of ε gamma photons is 2.4 MeV) passes through a concrete slab with a thickness of 2.4 MeV. How thick does a cast iron slab give the same attenuation of this beam of γ radiation? $x_1 = 1 \text{ м}$ x_2

Problem 2. A cast-iron plate reduces the intensity of the I narrow beam of γ radiation (the energy of ε gamma photons is 2.8 MeV). How many times will a lead plate of the same thickness reduce the intensity of this beam? $k = 10 \text{ паз}$

TOPIC 35. ELEMENTARY PARTICLES

Goal

To consider such particles as electron, photon, proton. To consider the structure of the neutron. To study the properties of the neutron. To consider fundamental interactions. To consider the muon. To consider antiparticles. To consider neutrinos. To consider methods of neutrino registration. To consider unsolved problems of elementary particle physics.

Typical tasks for performing practical

Example. It is known that in the carbon-nitrogen, or carbon, cycle, the number of carbon nuclei remains unchanged. As a result of this cycle, four hydrogen nuclei (protons) are converted into a helium nucleus, and three ${}^1_1H {}^4_2He \gamma$ quanta, two positrons, and two neutrinos are formed. After recording this reaction, determine the energy released in this process

Solution: $4 {}^1_1H \rightarrow {}^4_2He + 2 {}^0_{+1}e + 2 {}^0_0\nu_e + 3\gamma + Q$

$$\Delta m = 4m_{{}^1_1H} - (m_{{}^4_2He} + 2m_e)$$

$$Q = \Delta mc^2 = 25,8 \text{ МэВ}$$

Problem 1. Taking into account that the energy of relativistic muons in cosmic radiation is 3 GeV, determine the distance traveled by muons during their lifetime, if the proper lifetime of the muon is 2.2 μs , and the rest energy is 100 MeV.

Problem 2. A neutral pion decays into two γ -quanta: . Taking the rest mass of the pion equal to , determine the energy of each of the resulting γ -quanta. $\pi_0 \rightarrow 2\gamma$ 264,1me

QUESTIONS AND TASKS FOR SELF-CONTROL

1. What is the nature of primary and secondary cosmic radiation? Name their properties.

2. Give diagrams of muon decay. What explains the emission of muon neutrinos (antineutrinos)?
3. Give diagrams of the decay of π -mesons. Characterize π -mesons.
4. What fundamental types of interactions are carried out in nature and how can they be characterized? Which of them is universal?
5. What conservation laws hold for all types of interactions of elementary particles?
6. What is the fundamental property of all elementary particles?
7. What are the properties of neutrinos and antineutrinos? What are their similarities and differences?
8. Which characteristics are the same for particles and antiparticles? Which are different?
9. What are the strangeness and parity of elementary particles? Why are they introduced? Do the laws of their conservation always hold?
10. What are the groups of elementary particles? What are the criteria by which elementary particles belong to a particular group?

Problem 1. When a neutron and an antineutron collide, their annihilation occurs, as a result of which two γ -quanta appear, and the energy of the particles is converted into the energy of γ -quanta. Determine the energy of each of the resulting γ -quanta, assuming that the kinetic energy of the neutron and positron before their collision is negligible

Task 2. Determine which of the following processes are allowed by the law of conservation of lepton number: 1) $p \rightarrow n + e^+ + \nu_e$; ; $K^- \rightarrow \mu^- + \bar{\nu}_\mu \pi^+ \rightarrow \mu^+ + e^- + e^+ K^+ \rightarrow e^+ + \pi^0 + \nu_e$

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2. List of educational and methodological support for students' independent work in the discipline

1. Methodical recommendations for laboratory classes in the discipline "Physics"
2. Methodical recommendations for independent work in the discipline "Physics".

3. List of resources of the information and telecommunication network "Internet" necessary for the development of the discipline

- 1 <http://demo.home.nov.ru> – The World of Physics: A Physical Experiment;
- 2 <http://experiment.edu.ru> – Natural Science Experiments – Physics: Collection of the Russian General Education Portal;
- 3 <http://fizkaf.narod.ru> – Department and Laboratory of Physics of the Moscow Institute of Open Education;
- 4 <http://genphys.phys.msu.ru> is the website of the Department of General Physics of the Faculty of Physics of Moscow State University.
- 5 <http://www.edu.delfa.net> – Physics Room of the St. Petersburg Academy of Postgraduate Pedagogical Education;
- 6 <http://www.phys.spb.ru> – website of the Faculty of Physics of St. Petersburg State University;
- 7 <http://genphys.phys.msu.ru/rus/edu/mech.php>
- 8 <https://ocw.mit.edu/courses/physics/8-01-classical-mechanics-fall-2016/>

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INSTITUTION OF HIGHER EDUCATION
"NORTH CAUCASUS FEDERAL UNIVERSITY"

SUGGESTIONS FOR TEACHING

on the organization and conduct of independent work
in the discipline "Physics I/College Physics I"
for students of the field of study

11.03.02 Infocommunication Technologies and Communication Systems
Profile
"Intelligent Data Processing in Infocommunication
Systems and Networks"

Stavropol 2026

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INTRODUCTION

SCHEDULE FOR INDEPENDENT WORK

METHODICAL RECOMMENDATIONS FOR THE STUDY OF THEORETICAL
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INTRODUCTION

Independent work is the planned educational, research, research work of students, carried out in extracurricular (classroom) time on the assignment and under the methodological guidance of the teacher, but without his direct participation (with the partial direct participation of the teacher, leaving the leading role behind the student's work).

Independent work of a student is an important type of educational and scientific activity of a student. The Federal State Educational Standard provides for a significant amount of time from the total labor intensity of the discipline for independent work. In this regard, training includes two parts that are almost the same in volume and mutual influence - the process of learning and the process of self-study. Therefore, independent work should become effective and purposeful work of the student.

The concept of modernization of Russian education defines the main tasks of vocational education - the training of a qualified worker of the appropriate level and profile, competitive in the labor market, competent, responsible, fluent in his profession and oriented in related fields of activity, capable of effective work in the specialty at the level of world standards, ready for constant professional growth, social and professional mobility.

The solution of these problems is impossible without increasing the role of students' independent work on educational material, increasing the responsibility of teachers for the development of independent work skills, for stimulating the professional growth of students, fostering creative activity and initiative.

Independent work of a student presupposes, first of all, his research and practical activities, since it is these types of educational work that are primarily prepared for the independent performance of professional tasks. The ultimate goal of independent work is the organization of independent cognitive activity, the formation of the ability to independently analyze information, to distinguish the main and secondary.

The main forms of independent work of students in the discipline "Physics" are:

- preparation for a practical lesson
- independent study of literature;
- preparation for the exam.

Practical classes are conducted in order to consolidate the information learned, to acquire the skills of its application in solving practical problems in the relevant subject area. As a result of studying the discipline, students form the following competencies (in accordance with the educational standard):

ID-1OPK-1 Understands the fundamental laws of nature and the basic physical mathematical laws

ID-2OPK-1 Applies physical laws and mathematical methods to solve problems of theoretical and

applied nature

ID-3OPK-1 Uses knowledge of physics and mathematics to solve practical problems

ID-1OPK-2 Finds and critically analyzes the information necessary to solve the problem.

ID-2OPK-2 develops a solution to a specific problem, choosing the best option, evaluating its advantages and disadvantages.

ID-3OPK-2 Understands the basic methods and means of conducting experimental research, standardization and certification systems.

ID-4OPK-2 selects methods and means of measurement and conducts experimental research.

ID-5OPK-2 is proficient in the methods of processing and presenting the data obtained and assessing the error of measurement results.

SCHEDULE FOR INDEPENDENT WORK

Type of student activity	Final product of independent work	Assessment Tools and Technologies	Delivery time
Semester 2			
Preparation for the topic: Kinematics and dynamics of a material point	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 1
Preparation for the topic: Laws of conservation	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 2
Preparation for the topic: Non-inertial frames of reference.	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Solid Mechanics	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Relativistic mechanics	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Gravity	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Oscillatory motion	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 18 Practical lesson No 3
Preparation for the topic: Preliminary information	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 4 Practical lesson No 18
Preparation for the topic: Statistical Physics	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Thermodynamics	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 5 Practical lesson No 18
Preparation for the topic: Crystalline state	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Liquid state	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Phase equilibria and transformations	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Physical Kinetics	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Electric field in a vacuum	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 6

Type of student activity	Final product of independent work	Assessment Tools and Technologies	Delivery time
Semester 2			
Preparation for the topic: Electric Field in Dielectrics	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 18 Practical lesson No 6
Preparation for the topic: Conductors in an electric field	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Electric Field Energy	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Direct electric current	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 7 Practical lesson No 18
Preparation for the topic: Magnetic field in a vacuum	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 18
Preparation for the topic: Magnetic field in matter	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Electromagnetic induction	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 8 Practical lesson No 18
Physics I/College Physics IMaxwell's equations	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Motion of charged particles in electric and magnetic fields	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Classical theory of electrical conductivity of metals	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Electric current in gases	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Electrical oscillations	Prepared Practice Report	List of practical works	Practical lesson No 18
Semester 3			
Preparation for the topic: Geometric Optics	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 1
Preparation for the topic: Photometry	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 18 Practical lesson No 2
Preparation for the topic: Light interference	Interview Solving typical tasks	Interview Questions	Practical lesson No 18

Type of student activity	Final product of independent work	Assessment Tools and Technologies	Delivery time
Semester 2			
	Prepared Practice Report	Examples of typical tasks List of practical works	Practical lesson No 3
Preparation for the topic: Light diffraction	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 4
Preparation for the topic: Light Polarization	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Optics of moving media	Interview Solving typical tasks	Interview Questions Examples of typical tasks	Practical lesson No 18 Practical lesson No 4
Preparation for the topic: Interaction of electromagnetic waves with matter	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Thermal radiation	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 6
Preparation for the topic: Bohr's theory of the atom	Interview Solving typical tasks	Interview Questions Examples of typical tasks	
Preparation for the topic: The Quantum Mechanical Theory of the Hydrogen-Like Atom	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 7
Preparation for the topic: Multielectron atoms	Interview Prepared Practice Report	Interview Questions List of practical works	Practical lesson No 18
Preparation for the topic: Molecules and crystals	Interview	Interview Questions	Practical lesson No 18
Preparation for the topic: Atomic nucleus	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 8
Preparation for the topic: Elementary particles	Interview Solving typical tasks Prepared Practice Report	Interview Questions Examples of typical tasks List of practical works	Practical lesson No 18 Practical lesson No 9

METHODICAL RECOMMENDATIONS FOR THE STUDY OF THEORETICAL MATERIAL, PREPARATION FOR PRACTICAL CLASSES

When preparing for practical classes, it is necessary:

- to repeat the material of the corresponding lectures;
- carefully study the description of the practical lesson set out in the workshop;
- answer questions on the content of a practical or laboratory lesson asked by the teacher at a preliminary survey before completing tasks.

As a result of completing the tasks, the following learning results are achieved:

- development of thinking and creative abilities of the student,
- acquisition and consolidation of independent work skills,
- acquisition and consolidation of skills in the design and compilation of written tasks.

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 - 2 <http://experiment.edu.ru> – Natural Science Experiments – Physics: Collection of the Russian General Education Portal;
 - 3 <http://fizkaf.narod.ru> – Department and Laboratory of Physics of the Moscow Institute of Open Education;
 - 4 <http://genphys.phys.msu.ru> is the website of the Department of General Physics of the Faculty of Physics of Moscow State University.
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