Syllabus
Course Program

Physics

Specialty
141 - Electricity, electrical engineering and electromechanics

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Electric power engineering
Electromechanics
Electric drive, mechatronics and robotics

Department
Physics (168)

Level of education
Bachelor's level

Course type
General, Mandatory

Semester
1, 2, 3

Language of instruction
English

Lecturers and course developers

Olena Lyubchenko
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Cand. Sc. Physics and Mathematics, Professor, Head of the Department of Physics, NTU "KhPI".

Author of more than 100 scientific and educational publications.
Lecturer in the "Physics" courses
More about the lecturer on the department's website

General information

Summary

The course of physics acquaints with the fundamental concepts, laws and theories of classical and modern physics, the basic methods of solving physical problems, and the features of physical processes. This will ensure the effective mastery of special disciplines and further possibility of using physical principles in professional activity. The course covers all sections of physics as a fundamental discipline that forms a holistic picture of the modern world. During the study of basic laws and phenomena, students acquire skills of learning the laws of physics in practice, summarize and analyze the results of physical experiments to apply in the field of software engineering

Course objectives and goals

The aim of the course is to provide future software engineers with a base knowledge of physics; to form students' skill of understanding the physical content of problems; to develop students' ability to practically apply fundamental knowledge of physics in the field of software engineering.

Format of classes

Lectures, practical classes, labs, self-study, consultations. Final assessment is an exam..

Competencies

К01. Ability to think abstractly, analyses and synthesis.
К02. Ability to apply knowledge in practical situations.
К03. Ability to communicate in the state language both orally and in writing.
К05. Ability to search, process and analyses information from various sources.
К06. Ability to identify, pose and solve problems.
К07. Ability to work in a team.
К08. Ability to work autonomously.
К12. Ability to solve practical problems using the methods of mathematics, physics and electrical engineering.

Learning outcomes

PLO 10. Find the necessary information in scientific and technical literature, databases and other sources of information, assess its relevance and reliability.
PLO 11. To communicate freely on professional issues in the state and foreign languages orally and in writing, to discuss the results of professional activities with specialists and non-specialists, to argue their position on controversial issues.
PLO 15. To understand and demonstrate good professional, social and emotional behaviour, to adhere to a healthy lifestyle.
PLO 18. To be able to learn independently, acquire new knowledge and improve skills in working with modern equipment, measuring equipment and applied software.
PLO 19. To apply suitable empirical and theoretical methods to reduce electricity losses during its production, transportation, distribution and use.

Student workload

The total volume of the discipline is 390 hours (13 ECTS credits):
Semester 1 (5 ECTS credits):
Lectures - 32 hours, laboratory work - 16 hours, practical classes - 16 hours, independent work - 86 hours.
Semester 2 (4 ECTS credits):
lectures - 32 hours, laboratory work - 16 hours, practical classes - 16 hours, independent work - 56 hours.
Semester 3 (4 ECTS credits):
lectures - 32 hours, laboratory work - 16 hours, practical classes - 16 hours, independent work - 56 hours..

Course prerequisites

To successfully learn the course, you must have knowledge and practical skills from the courses "Physics", "Algebra and the beginnings of analysis" in the scope provided by the programs of general secondary schools.

Features of the course, teaching and learning methods, and technologies

Lectures are conducted interactively using multimedia technologies. Practical classes use problem-based learning, teamwork, case method, feedback method from students.

Program of the course

Topics of the lectures

Semester 1

Content module 1. Physical foundations of mechanics

Topic 1.1. Elements of kinematics

Mechanical motion. Material point, system of material points, absolutely solid body, continuous medium. Systems of reference. The principle of independence of movements. Kinematic description of motion. Trajectory, path, displacement. Velocity and acceleration in the general case of curvilinear motion. Normal and tangential acceleration. Angular velocity and angular acceleration of a point moving in a circle and their relation to linear velocities and accelerations.

Topic 1.2. Dynamics of a material point

The concept of state in classical mechanics. The main problem of dynamics. Newton's first law (law of inertia). The concept of inertial reference systems. The concept of force. The second law of Newton. Forces in mechanics. The momentum of a particle. The impulse of a force. Force as a derivative of momentum. Newton's third law. The law of motion of the center of inertia. The law of conservation of momentum.

Topic 1.3. Solid body in mechanics and laws of its motion

Moment of force (rotational moment). Moment of inertia of a material point and a solid relative to the axis. Calculation of moments of inertia of solids. Steiner's theorem. Equation of dynamics of rotational motion. Moment of momentum. Equation of moments. Law of conservation of momentum.

Topic 1.4. Work and energy

Energy. Work. Power. Kinetic energy. Work, power and kinetic energy in the rotational motion of a body. Field as a form of matter. Conservative and non-conservative forces. Dissipation of energy. Potential energy of a particle. The law of conservation of mechanical energy.

Topic 1.5. The principle of relativity in mechanics

Galileo's transformations. Invariants of Galileo's transformations. Non-inertial reference systems. The forces of inertia. Newton's second law in non-inertial reference frames. Dependence of the acceleration of gravity on latitude.

Topic 1.6. Elements of relativistic mechanics

Postulates of special relativity. Lorentz transformations. Invariants of Lorentz transformations. Consequences of Lorentz transformations: reduction of moving length scales, slowing down of moving clocks. Relativity of simultaneity. Interval in four-dimensional space. Relative impulse. The basic equation of relativistic dynamics. Total energy of a relativistic particle. Energy of rest. Kinetic energy. Conservation of energy-momentum in relativistic mechanics.

Content module 2. Mechanical vibrations and waves

Topic 2.1. Harmonic vibrations

Classification of oscillations. Characteristics of harmonic oscillations: displacement from the equilibrium position, amplitude, period, linear and cyclic frequency, phase, initial phase. Harmonic oscillations. Energy relations for an oscillator. Physical, mathematical and spring pendulums. The phase plane of the oscillator. Graphical representation of harmonic oscillations using a rotating vector. Addition of harmonic oscillations of the same direction. Beating. Addition of mutually perpendicular oscillations. Lissajous figures.

Topic 2.2. Damped and forced oscillations

Free damped oscillations. Damping coefficient, decrement, logarithmic decrement, quality factor, relaxation time. Forced mechanical oscillations. The process of establishing oscillations. Amplitude and phase at forced oscillations. Resonance.

Topic 2.3: Wave processes
Mechanism of formation of mechanical waves. Transverse and longitudinal waves. The plane waves. Equation of a travelling wave (plane, spherical and cylindrical). Phase velocity, wavelength, wavenumber and wave vector. Energy of waves. The condition vector. Standing waves. Nodes and voids.

Content module 3: Fundamentals of molecular physics and thermodynamics
Topic 3.1: Fundamentals of molecular kinetic theory of gases
Thermodynamic parameters. Equilibrium state. Basic principles of the molecular kinetic theory of gases. Equation of state of an ideal gas. Dalton's law. The basic equation of the molecular kinetic theory of ideal gas. Average kinetic energy of molecules. The molecular kinetic meaning of temperature.

Topic 3.2. Classical statistical distributions
Maxwell's distribution of molecules of an ideal gas by thermal motion velocity. Arithmetic mean, root mean square and most probable velocity of gas molecules. Barometric formula. The Boltzmann distribution. Maxwell-Boltzmann distribution.

Topic 3.3: Fundamentals of thermodynamics
Internal energy of a thermodynamic system. Work and heat. The first law of thermodynamics. Heat capacity of gases. Number of degrees of freedom of a molecule. Law of uniform distribution of energy by degrees of freedom. Polytropic processes. Isoprocesses. Adiabatic process. Poisson's equation. Application of the first law of thermodynamics to polytropic processes. Circular process (cycle). Thermal engines and cooling machines. Carnot cycle. Thermodynamic temperature scale. The second law of thermodynamics. Entropy. The third law of thermodynamics - Nernst's theorem.

Topic 3.4: Phenomena of transfer
Average free path length of molecules, effective diameter of molecules, average number of collisions. The phenomenon of diffusion. Diffusion coefficient. Diffusion in gases and solids. The phenomenon of thermal conductivity. The phenomenon of thermal conductivity. The phenomenon of viscosity. Viscosity coefficient of gases and liquids. Dynamic and kinematic viscosity.

Semester 2

Content module 4. Electricity
Topic 4.1: Electrostatics in a vacuum
Discreteness of electric charge. The law of conservation of charge. Coulomb's law. The intensity of the electric field of a point charge. The principle of superposition. Flow of electric field intensity. Gauss's theorem for the electric field and its application: the field of uniformly charged bodies: an infinite plane, a thread (cylinder), a ball. Work of field forces in the movement of charges. Circulation of electrostatic field intensity. Field potential of a point charge, system of charges. Equipotential surfaces. Potential energy.

Topic 4.2. Conductors and dielectrics in an electrostatic field
Conductor in an electric field. The phenomenon of electrostatic induction. Electrostatic protection. Dielectrics. Dipole in an external electric field. Polar and non-polar molecules. Polarisation of dielectrics in an electric field. Dielectric constant and dielectric constant. Electrical displacement. Gauss's theorem for the field in dielectrics.

Topic 4.3. Direct electric current
Direct electric current, its characteristics and conditions of existence. The strength of the electric current. Current density vector. Electromotive force. Difference of electric potentials, electric voltage. Electrical resistance of conductors. Ohm's and Lenz-Joule's laws in integral and differential forms. Kirchhoff's rules.

Content module 5: Magnetism

Topic 5. 1. Magnetostatics in a vacuum
The magnetic field. The vector of magnetic induction. Magnetic moment of a circuit with electric current. Moment of force acting on the circuit. Bio-Savar-Laplace law. The principle of superposition of magnetic fields. Magnetic field of the simplest systems: a straight conductor with current, circular current. The law

of total current for a magnetic field in a vacuum. Ampere's law. Lorentz's force. Magnetic flux. Gauss's theorem for magnetic flux. Work on moving a conductor and a circuit with a current in a magnetic field.

Topic 5. 2. Magnetic field in matter

Magnetic field in matter. Magnetic field of a moving charge. Molecular currents. Magnetic moments of atoms. Magnetization. Magnetic permeability and magnetic susceptibility. The intensity of the magnetic field. The law of total current for a magnetic field in matter. Conditions at the interface of two media. Types of magnets: paramagnets, diamagnets, ferromagnets.

Topic 5.3. Electromagnetic induction

The phenomenon of electromagnetic induction. Faraday's law of electromagnetic induction. Lenz's rule. Phenomena of self-induction and mutual induction. Inductance. Self-inductance of a long solenoid. The establishment and disappearance of current in an electric circuit. Mutual inductance. Practical applications of electromagnetic induction. The energy of the magnetic field.

Topic 5.4. Fundamentals of Maxwell's theory of the electromagnetic field

Maxwell's explanation of the emergence of electromagnetic induction. Vortex electric field. Displacement currents. The electromagnetic field. Foucault currents, skin effect. Maxwell's system of equations in integral and differential forms. Speed of propagation of electromagnetic excitations.

Topic 5.5. Electromagnetic oscillations and waves

Harmonic electromagnetic oscillations. Thomson oscillating circuit. Free damped electromagnetic oscillations. Damping coefficient, damping decrement, logarithmic damping decrement, quality factor, relaxation time of the oscillatory system. Forced electromagnetic oscillations. Impedance. Alternating current generator. Resonance of voltages. Alternating current power. Electromagnetic waves. Wave equations for electromagnetic waves. The speed of propagation of electromagnetic waves in media. Energy of electromagnetic waves. The flow of energy. Condition-Pointing vector.

Content module 6: Optics

Topic 6.1. Geometric optics

The nature of light. Laws of light propagation, reflection and refraction. Absolute and relative refractive indices. The phenomenon of total internal reflection, light guides and their use. Optical systems.

Topic 6.2. Interference of light

Interference of monochromatic waves. Quasi-monochromatic waves. Coherence. Temporal and spatial coherence. Time of coherence. Coherence length. Calculation of the interference pattern from two sources. Interference of light in thin films, strips of equal thickness and equal slope. Newton's rings. Enlightenment of optical systems.

Topic 6.3. Diffraction of light

Huygens-Fresnel principle. Fresnel diffraction. Fresnel zone method. Fresnel diffraction on a round hole and a disc. Poisson's spot. Fraunhofer diffraction. Diffraction on one and many slits. Diffraction grating. Fraunhofer diffraction and spectral decomposition. Resolution and dispersion of spectral instruments.

Topic 6.4. Electromagnetic waves in matter

Light propagation in matter. The phenomenon of light dispersion. The concept of the mechanism of light dispersion. Absorption of light. The Bouguer-Lambert law. The relationship between dispersion and absorption. Spectral analysis, its scientific and practical application. Polarization of waves. Polarization of waves by reflection and refraction. Brewster and Malus laws. Double refraction in uniaxial crystals and its explanation. Polarizing devices. Nicol's prism. Rotation of the polarization plane.

Semester 3

Content module 7: Basic concepts of quantum physics

Topic 7.1. Elements of quantum optics
Thermal equilibrium radiation of a black body, its laws: Kirchhoff, Stefan-Boltzmann, Wien. Quantum hypothesis and Planck's formula. Photons. Energy, momentum and mass of a photon. External photoelectric effect. Quantum and wave explanations of light pressure. Lebedev's experiments. Corpuscular-wave duality of light.

Topic 7.2. Basic concepts of quantum physics
Rutherford's model of the atom. Linear spectra of hydrogen-like atoms. Discreteness of energy levels of atoms. Bohr's postulates.

Topic 7.3. Quantum mechanics
The de Broglie hypothesis. Experimental confirmation of the wave properties of matter particles. Diffraction of electrons (experiments of Davisson and Germer, Thomson and Tartakovsky, Biberman, Sushkin and Fabrikant). Practical applications of particle diffraction. Electronography, neutronography. Heisenberg uncertainty ratio.

Topic 7.4. Quantum state. Schrödinger's equation.
Wave function and its statistical meaning. Schrödinger's time equation. Schrödinger's equation for stationary states. A free particle. A particle in a one-dimensional rectangular "potential well" (quantization of energy and momentum of a particle). Harmonic oscillator. Zero oscillations. Passage of a particle through a potential barrier. Tunnel effect.

Content module 8: Physics of atoms and molecules

Topic 8.1. The atom
Schrödinger's equation for a particle (electron) in a spherically symmetric field - hydrogen atom, type of wave functions and probability density distribution, physical meaning of quantum numbers. Quantization of energy, momentum and projection of electron momentum. The ground state of the hydrogen atom. Experiment of Stern and Gerlach. Spin of an electron. Spin quantum number. Orbital and spin magnetic moments. Complex atoms. Fermions and bosons. Pauli's principle. Distribution of electrons in the atom by states. Mendeleev's periodic table of elements.

Topic 8.2. Molecule
The nature of chemical bonding. Ionic and covalent types of bonding. The hydrogen molecule. Exchange interaction. Energy structure of molecules. Electronic, vibrational and rotational energy levels of two-nuclear molecules. Molecular spectra.

Content module 9. Physics of the atomic nucleus

Topic 9. 1. The atomic nucleus
Composition of atomic nuclei. Mass and charge numbers. Characteristics of nuclei: charge, size and mass of the nucleus. Interaction of nucleons in the nucleus and the concept of properties and nature of nuclear forces. Mass defect and binding energy of nuclei. Nuclear reactions. The law of radioactive decay. Activity of a radionuclide. Patterns of alpha, beta, and gamma decay of nuclei. Chain reaction of nuclear fission. Nuclear reactor. Thermonuclear reactions.

Content module 10: Elements of condensed matter physics

Topic 10.1. Crystals
Structure of crystals. The nature of chemical bonds in solids. The concept of phonons. Heat capacity of crystals.

Topic 10.2. The concept of the zone theory of solids
Energy bands in crystals. The valence band, the band gap and the conduction band. Filling of bands: metals, dielectrics, semiconductors.

Topic 10.3. Elements of quantum statistics
Statistical description of a quantum system. Quantum ideal gases. Bose-Einstein and Fermi-Dirac distributions.

Topic 10.4. Electrical conductivity of matter

Classical and quantum nature of electrical conductivity of metals. Superconductivity. The Meissner effect. High temperature superconductivity. Intrinsic and impurity electrical conductivity of semiconductors. Electronic and hole semiconductors, p-n junction. Photoelectric phenomena in semiconductors: photoconductivity, photoelectromotive force. Principle of operation of a solar cell.

Topics of practical classes

Semester 1.
Topic 1: Physical foundations of mechanics
Kinematics of translational and rotational movements. Dynamics of translational and rotational movements. Conservation laws in classical mechanics.

Topic 2. Mechanical vibrations and waves
Harmonic vibrations. Damped and forced oscillations. Wave processes.

Topic 3. Molecular physics and thermodynamics
Fundamentals of molecular kinetic theory of gases. Classical statistical distributions. Fundamentals of thermodynamics.

Semester 2.
Topic 4. Electricity
Electrostatics in a vacuum. Direct electric current.

Topic 5. Magnetism
Magnetostatics in a vacuum. Electromagnetism.
Topic 6: Optics
Interference of light. Diffraction of light. Electromagnetic waves in matter.

Semester 3.
Topic 7. Basic concepts of quantum physics
Quantum optics. Quantum mechanics. Schrödinger's equation.

Topic 8: Physics of atoms and molecules
The atom. The molecule.
Topic 9: Atomic nucleus.
Mass defect and binding energy of nuclei. Nuclear reactions. The law of radioactive decay. Activity.
Topic 10. Elements of condensed matter physics
Crystals. Quantum statistics. Electrical conductivity.

Topics of laboratory works

Semester 1.
Topic 1: Physical foundations of mechanics

LW Determination of the acceleration of free fall using a mathematical pendulum.
LW Checking the basic law of the dynamics of rotational motion
LW Study of the laws of elastic and inelastic impact of balls

Topic 2. Mechanical vibrations and waves
LW Determination of the speed of sound in air by the method of adding mutually perpendicular vibrations.
LW Determination of the acoustic parameters of a tuning fork.
LW Determination of the speed of sound in solids by the method of acoustic resonance.

Topic 3. Molecular physics and thermodynamics
LW Determination of the dynamic viscosity of a liquid by the Stokes method.
LW Determination of the ratio of molar heat capacities.

Semester 2.
Topic 4. Electricity
LW Calibration of a galvanometer and determination of its internal resistance.
LW Experimental verification of Kirchhoff's rules.
LW Determination of characteristics and conditions for the economic use of direct current sources.

Topic 5. Magnetism
LW Determination of the magnetic field intensity of an electromagnet
LW Determination of the horizontal component of the Earth's magnetic field strength.
LW Determination of the angle of magnetic inclination.

Topic 6: Optics
LW Determination of the radius of curvature of a lens using Newton's apparatus.
LW Determination of the slit width and period of a diffraction grating using diffraction.

Semester 3.
Topic 7. Basic concepts of quantum physics
LW Study of the laws of thermal radiation.
LW Determination of the de Broglie wavelength of electrons.
LW The Ramsauer effect.

Topic 8: Physics of atoms and molecules
LW Determination of the Rydberg constant.
LW Study of the discreteness of energy levels of atoms using the Frank-Hertz effect.

Topic 9: Physics of the atomic nucleus
LW Study of statistical regularities of the natural background radiation.
Topic 10. Elements of condensed matter physics
LW Determination of the width of the band gap of a semiconductor.
LW Study of the kinetics of photoconductivity.

Self-study

The course requirements involve fulfilment of individual calculation and graphic assignment. Results must be represented as a written report. Students are also recommended educational material (lecture notes; problem solving guide) for self-study..

Course materials and recommended reading

Compulsory materials

1. Lyubchenko O. A. Mechanics : [study guide] = Механіка : навч.-метод. посібник / O. A. Lyubchenko. – Kharkiv : NTU "KhPI", 2016. – 324 p. – Engl. lang. URI: https://repository.kpi.kharkov.ua/handle/KhPI-Press/26411

2. Lyubchenko O. A. Mechanics. Oscillations and waves : Конспект лекций по курсу "Физика" на англ. яз. / Е. А. Любченко, А. Ю. Гребенник ; Нац. техн. ун-т "Харьк. политехн. ин-т". - Х. : НТУ "ХПИ", 2006. - 51 p. URL: http://web.kpi.kharkov.ua/tef/educational-material-in-english-ua/
3. Lyubchenko O. A. Electricity and magnetism: Конспект лекций по курсу "Физика" на англ. яз.; - Х. : НТУ "ХПИ", 2006. - 71 с. URL: http://web.kpi.kharkov.ua/tef/educational-material-in-english-ua/
4. Lyubchenko O. A. Optics. Atomic and Nuclear Physics: Конспект лекций по курсу "Физика" на англ. яз. НТУ "ХПИ", 2006. - 122 с.
5. Lyubchenko O. A. Magnetism: [problem solving guide – Kharkiv : NTU "KhPI", 2012. - 39 p. http://web.kpi.kharkov.ua/tef/wp-content/uploads/sites/114/2020/03/Magnetism_problems.pdf
6. Lyubchenko O. A. Electricity: [problem solving guide – Kharkiv : NTU "KhPI", 2015. - 42 p. http://web.kpi.kharkov.ua/tef/wp-content/uploads/sites/114/2020/03/Magnetism_problems.pdf

Additional materials

1. D.C.Giancoli. Physics for scientists and engineers with modern Physics. 4th ed., Pearson Educatioon, Inc., USA, 2009.
2. N.J.Giordano. College Physics. Reasoning and Relationships. 2 ed., V1 and 2, Brooks/Cole, Cengage Learning, USA, 2010
3. Physics. Principles and Problems. Glencoe Science Program. Interactive Students Edition., 2005 URL: http://physicspp.com
4. J. Walker. Fundamentals of physics /J.Walker, D. Halliday, R. Resnick - 10th extended ed., USA, 2014
R.A.Serway, C.Vuille, J.S.Faughn. College Physics. Brooks/Cole, Cengage Learning, USA, 2009

Assessment and grading

Criteria for assessment of student performance, and the final score structure

100% of the final grade consists of assessment results in the form of an exam (40%) and current assessment (60%).
Exam: written assignment (2 theory questions + problem solving) and oral presentation.
Current assessment: oral answers during practical classes, homework, individual calculation and graphic assignment (20% each).

Grading scale

Total points	National	ECTS
90–100	Excellent	A
82–89	Good	B
75–81	Good	C
64–74	Satisfactory	D
60–63	Satisfactory	E
35–59	Unsatisfactory (requires additional learning)	FX
1–34	Unsatisfactory (requires repetition of the course)	F

Norms of academic integrity and course policy

The student must adhere to the Code of Ethics of Academic Relations and Integrity of NTU "KhPI": to demonstrate discipline, good manners, kindness, honesty, and responsibility. Conflict situations should be openly discussed in academic groups with a lecturer, and if it is impossible to resolve the conflict, they should be brought to the attention of the Institute's management.
Regulatory and legal documents related to the implementation of the principles of academic integrity at NTU "KhPI" are available on the website: http://blogs.kpi.kharkov.ua/v2/nv/akademichna-dobrochesnist/

Approval

Approved by	30.08.2023	Head of the department Olena LYUBCHENKO
	31.08.2023	Guarantor of the educational program Galina OMELIANENKO
	30.08.2023	Guarantor of the educational program Elena YURIEVA
	31.08.2023	Guarantor of the educational program Mykola ANISHCHENKO