Syllabus
Course Program

Physics

Specialty
133 – Industrial Engineering

Institute
Institute of Computer Modeling, Applied Physics and Mathematics

Educational program
Industrial Engineering

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

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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 engineering

Course objectives and goals

The aim of the course is to provide future 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, calculation tasks, self-study, consultations. Final assessment is an exam.

Competencies

3К2. Ability to apply knowledge in practical situations.
3К3. Ability to plan and manage time.
3К6. Ability to conduct research at a certain level.

Learning outcomes

РНО1. Knowledge and understanding of the principles of technological, fundamental and engineering sciences underlying the branch engineering of the relevant industry.
РНО4. Perform engineering calculations to solve complex problems and practical problems in industrial engineering

Student workload

The total volume of the discipline is 390 hours (13 ECTS credits): lectures - 80 hours, laboratory classes - 48 hours, practical classes - 32 hours, self-study - 230 hours

Course prerequisites

To complete the course, you must have knowledge and practical skills in Physics, Algebra, and Calculus to the extent required by the secondary school curriculum

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

1 semester "Classical Mechanics and Thermodynamics"

Topic 1: Introduction to the course

Principles of the scientific method. Empirical and theoretical methods of physical knowledge. Physics as a science. Subject, purpose, and task of physics. The cube of physical theories. The modern physical picture of the world. The concepts of space, time, and matter. Physics as a fundamental basis of technology and the training of engineering personnel. Elements of the theory of dimensions of physical quantities. Units of physical quantities in the SI.

Topic 2. Elements of kinematics

The subject of mechanics. The main tasks of mechanics. Kinematics, statics and dynamics. The main task of kinematics. The reference system. Kinematic characteristics. The principle of independence of movements. Relative velocity. Velocity and acceleration in the general case of curvilinear motion.

Topic 3. Dynamics of translational motion of a material point

The concept of state in classical mechanics. The main task of dynamics. Newton's first law (law of inertia). Newton's second law as an equation of motion. The main forces considered in mechanics. Newton's third law. The limit of applicability of classical mechanics. Inertial and non-inertial reference systems. Galileo's transformation. The forces of inertia. Newton's second law in non-inertial reference frames.

Topic 4. Work and energy

Energy. Work. Power. Kinetic and potential energy. Field as a form of matter that carries out force interactions between bodies. Conservative and non-conservative forces. Potential energy of a particle in an external force field and its relationship with the force acting on the particle.

Topic 5. Momentum. Conservation laws in classical mechanics

Momentum of a particle. Momentum of a force. Force as a derivative of momentum. Isolated system as a physical model. Internal and external forces. Centre of inertia (centre of mass) of the system. The law of

motion of the center of inertia. Laws of conservation of mechanical energy and momentum as a fundamental law of nature. Collision of bodies. Central impact. Absolutely elastic and inelastic impacts.

Topic 6. Kinematics of rotational motion of a material point

The kinematic equation for the rotational motion of a material point. The angular velocity and angular acceleration of a point moving in a circle, their relationship to linear velocities and accelerations.

Topic 7. Dynamics of rotational motion of a material point

Moment of force (rotational moment). Moment of inertia of a material point relative to the axis. Equation of dynamics of rotational motion of a point relative to the axis. Moment of momentum. The equation of moments. Law of conservation of momentum.

Topic 8: Dynamics of a solid body

Moment of inertia of a solid relative to the axis. Calculation of moments of inertia of solids. Steiner's theorem. Equations of dynamics of rotational motion of a solid relative to the axis. Equations of motion and equilibrium of a solid. Work, power and kinetic energy in the rotational motion of a body.

Topic 9: Free mechanical oscillations

Characteristics of harmonic oscillations. Differential equation of harmonic oscillations. Energy relations for an oscillator. Physical, mathematical and spring pendulums. The phase plane of the oscillator.

Topic 10. Addition of oscillations

Graphical representation of harmonic oscillations using a rotating vector. Adding harmonic oscillations of the same direction. Beating. Adding mutually perpendicular oscillations. Lissajous figures. Practical applications of oscillation addition. Fourier decomposition

Topic 11. Damped and forced oscillations

Free damped oscillations, their differential equation. Damping coefficient, damping decrement, logarithmic damping decrement, quality factor, relaxation time of an oscillatory system.
Forced mechanical oscillations, their differential equation. The process of establishing oscillations. Amplitude and phase at forced oscillations. The resonance.

Topic 12: Wave processes

Mechanism of formation of mechanical waves. Elastic waves in solids, gases and liquids. Transverse and longitudinal waves. Equation of a travelling plane wave. Phase velocity, wavelength, wavenumber and wave vector. Energy of waves. The flow of energy. The condition vector.

Topic 13. Fundamentals of molecular kinetic theory. Classical statistical distributions.

Molecular physics and thermodynamics, their tasks and methods. Thermodynamic parameters. Temperature scales. Equilibrium state. Basic principles of the molecular kinetic theory of gases. Mass of atoms and molecules. The amount of substance. The basic equation of the molecular kinetic theory of ideal gas. Molecular kinetic interpretation of pressure and temperature. Dalton's law. Equation of state of an ideal gas. Classical statistical distributions. Maxwell's distribution of ideal gas molecules by thermal velocity. Barometric formula. Boltzmann distribution. Maxwell-Boltzmann distribution.

Topic 14: Fundamentals of thermodynamics

Internal energy of a thermodynamic system. Work and heat are two forms of energy transfer to a thermodynamic system. The first law of thermodynamics. Heat capacity of gases. Mayer's equation. Number of degrees of freedom of a molecule. The law of uniform distribution of energy by degrees of freedom. Isoprocesses. Adiabatic process. Circular process (cycle). Thermal engines and cooling machines. Reversible and irreversible processes. Carnot cycle. Efficiency of a thermal machine. The second law of thermodynamics. Entropy. Determination of the entropy of a system through the statistical weight of its macrostate. The third law of thermodynamics - Nernst's theorem and its consequences.

Topic 15: Phenomena of transfer

Average free path length of molecules, effective diameter of molecules, average number of collisions. The phenomenon of diffusion. Diffusion coefficient. The phenomenon of thermal conductivity. The phenomenon of thermal conductivity. The phenomenon of viscosity. Dynamic and kinematic viscosity.

Topic 16. Summary

2 semester "Electrodynamics and Optics"

Topic 17. Electrostatics in vacuum

Electric charge, electric field. Discreteness of electric charge. Law of charge conservation. Coulomb's law. Electric field intensity vector, lines of force. Electric field strength of point charge. The principle of superposition. Flow of electric field strength. Gauss's theorem for the electric field. Field of uniformly charged bodies (infinite plane, thread, ball).

Topic 18. The work of the forces of the field. Potential

Operation of field forces when moving charges. Electrostatic field strength circulation. Electric potential, potential difference. Potential of the point charge field, charge system. Equipotential surfaces. Connection of electric potential with electrostatic field strength. The potential nature of the electric field. Potential energy.

Topic 19. Conductors and dielectrics in electrostatic field

Conductor in an electric field. Electrostatic induction phenomenon. Electrostatic protection. Dielectrics. Electric dipole. Polarization of dielectrics in an electric field. Dielectric constant and dielectric susceptibility. Electrical displacement. Gauss's theorem for the field in dielectrics. Electrostatic capacitance. Capacitors. Series and parallel connection of capacitors. Energy of interaction of electric charges. Energy of the charged capacitor. Energy of the electric field. The bulk energy density of an electric field in a dielectric.

Topic 20. Direct electric current

Direct electric current, its characteristics and conditions of existence. The strength of the electric current. Current density vector. Extraneous forces. Electromotive force. Electric potential difference, electric voltage. Electrical resistance of conductors. Ohm and Lenz-Joule laws in integral and differential form. Ohm's law for a section of a circle containing EMF. Ohm's law for a closed circle. Rules of Kirchhoff.

Topic 21. Magnetostatics in vacuum. Movement of charged particles in a magnetic field

Magnetic field. Magnetic induction vector. Magnetic field lines of force. Ampere's law. The force of interaction of parallel currents. Bio-Savard-Laplace law. The principle of superposition of magnetic fields. The magnetic field of the simplest systems. Vortex nature of the magnetic field. The law of total current for a magnetic field in a vacuum. The Lorentz Force. The motion of a charged particle in an electric and magnetic field. Practical application in accelerators, MHD generators, mass spectrometers, electron beam devices.

Topic 22. Gauss's theorem for magnetic flux

Magnetic moment of circuit with electric current. Circuit with current in magnetic field. The moment of force acting on the contour. Potential energy of the circuit with current in the external magnetic field. Magnetic flux. Gauss's theorem for magnetic flux. Work to move the conductor and circuit with current in a magnetic field.

Topic 23. Magnetic field in matter

Magnetic field in matter. The magnetic field of the charge that moves. Molecular currents. Magnetic moments of atoms. Magnetization. Magnetic permeability and magnetic susceptibility. Magnetic field strength. The law of total current for the magnetic field in matter. Types of magnets: paramagnets, diamagnets, ferromagnets.

Topic 24. Electromagnetic induction

The phenomenon of electromagnetic induction. Faraday's law of electromagnetic induction. Lenz's rule. Phenomena of self-induction and mutual induction. Inductance. Intrinsic inductance of a long solenoid. Mutual inductance. Energy of the magnetic field.

Topic 25. Foundations of Maxwell's theory for the electromagnetic field

Faradean and Maxwell interpretation of the phenomenon of electromagnetic induction. Maxwell's explanation of the occurrence of e. g. c. induction. Vortex electric field. Bias currents. The Eichenwald experiment. The connection between electric and magnetic fields, as one of the manifestations of the general connection in nature. Electromagnetic field. Foucault currents, skin effect. Maxwell's system of equations in integral and differential forms. Propagation rate of electromagnetic excitations.

Topic 26. Electromagnetic oscillations

Harmonic electromagnetic oscillations. Thomson oscillatory circuit. Free attenuating electromagnetic oscillations, their differential equation. Quality. Forced electromagnetic oscillations. Impedance. Alternator. Resonance of stresses. Resonance of currents. AC power.

Topic 27. Electromagnetic waves

Prediction of the existence of waves in Maxwell's theory. Wave equation for electromagnetic waves. Differential equation of a flat monochromatic electromagnetic wave. Propagation rate of electromagnetic waves in media. Maxwell's Law. Experiments Hertz, Lebedev and Glagoleva-Arkadyeva. Dipole radiation (Hertz vibrator).

Topic 28. Geometric optics

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

Topic 29. Interference of light

Interference of monochromatic waves. Coherence. Calculation of 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 30. Light diffraction

The Huygens-Fresnel principle. Fresnel diffraction. Fresnel zones method. Fresnel diffraction on round hole and disk. Fraunhofer diffraction. Diffraction on one and many slits. Diffraction grating. Fraunhofer diffraction and spectral decomposition. Resolution and dispersion of spectral devices.

Topic 31. Electromagnetic waves in matter

Propagation of light in matter. The phenomenon of light dispersion. Absorption of light. The Booger-Lambert law. Relation of dispersion to absorption. Spectral analysis, its scientific and practical application. Polarization of waves. Polarization of waves during reflection and refraction. Laws of Brewster and Males. Polarization devices. Prism Nicolas. Rotation of the polarization plane.

Topic 32. Summary

3rd semester "Modern Physics"

Topic 33. Elements of Relational Mechanics

Relational kinematics. The problem of space and time. Postulates of the special theory of relativity. Lorentz transformation. Law of addition of velocities. Relativity of simultaneity. An interval in a four-dimensional space. Relational momentum. The basic equation of relational dynamics. The total energy of the relational particle. Energy of rest. The relationship between energy and momentum, between mass and energy in relational mechanics. Conservation of energy-momentum in relational mechanics.

Topic 34. Elements of quantum optics

Thermal equilibrium radiation of the black body, its laws: Kirchhoff, Stefan-Boltzmann, Win. Fundamental difficulties and contradictions in explaining these laws within the framework of classical physics (Rayleigh-Jeans formula and "ultraviolet catastrophe"). Quantum hypothesis and Planck's formula. Photons. Energy, momentum and mass of the photon. External photo effect. Quantum and wave explanations of light pressure. Lebedev's experiments. Corpuscular-wave dualism of light.

Topic 35. Quantum mechanics and corpuscular-wave dualism of matter

Rutherford atom model. The difficulties of classical physics in explaining the structure and stability of an atom. Postulates of Bohr. Spectral series in the emission spectrum of a hydrogen atom and hydrogen-like ions. Excitation and ionization potentials of atoms. Experimental justification of the idea of quantization (discreteness) of the state of an atom (experiments of Frank and Hertz). De Broglie hypothesis. Experimental confirmation of the wave properties of matter particles. Diffraction of electrons, neutrons, atoms, molecules. Practical applications of particle diffraction (electronography, neutronography). Heisenberg uncertainty ratio.

Topic 36. Quantum state. Schrödinger equation

State problem of microparticles: classical and quantum. Wave function and its statistical meaning. Amplitude of probabilities. Explanation of microparticle behavior in a two-density interferometer. Superposition of states in quantum theory. Probability in quantum theory. The principle of causality in quantum mechanics. Principle of conformity. Operators of physical quantities in quantum mechanics. Schrödinger's time equation. Stationary states.

Topic 37. Physics of Atoms and Molecules

Solving the Schrödinger equation for an electron in a spherically symmetric field - a hydrogen atom. Quantization of energy, momentum, and electron momentum projection. The ground state of a hydrogen atom. Stern and Gerlach's experiment. Spin the electron. Total momentum of a quantum particle. Orbital and spin magnetic moments. Complex atoms. Zeeman effect. Selection rules. Width of energy levels and spectral lines. The principle of identity. Fermions and bosons. Pauli principle. Distribution of electrons in an atom by states. Filling of electronic shells. Periodic system of elements by D. I. Mendeleev. Nature of chemical bonding. Ionic and covalent types of bond. A hydrogen molecule. Exchange interaction. Energy structure of molecules.

Topic 38. Crystals. The concept of the zone theory of solids. Elements of quantum statistics

Structure of crystals. Defects of crystals. The concept of phonons. Heat capacity of crystals.
Zone structure of the electron energy spectrum. Energy zones in crystals. Filling zones: metals, dielectrics,

semiconductors. Quasiparticles are conduction electrons and holes. The concept of effective mass. Statistical description of a quantum system. Phase space. Bose-Einstein and Fermi-Dirac distributions.

Topic 39. Electrical conductivity of the substance

The nature of current carriers in metals and semiconductors. Dependence of electrical conductivity of metals and semiconductors on temperature. Understanding the quantum nature of the electrical conductivity of metals.

Classification of semiconductor materials. Intrinsic and impurity electrical conductivity of semiconductors and their temperature dependence. Electronic and hole semiconductors, p-n junction. Photoelectric phenomena in semiconductors. The principle of operation of the solar battery.

Topic 40. Physics of the atomic nucleus. Nuclear reactions. Modern physical picture of the world

Composition of atomic nuclei. Nucleons. Characteristics of nuclei: charge, size and mass of the nucleus. Properties and nature of nuclear forces. Mass defect and binding energy of nuclei.

The main types of nuclear reactions. Reaction threshold. The law of radioactive decay. Radionuclide activity. The origin and patterns of alpha, beta, and gamma decay of nuclei. Neutrinos and antineutrinos. Artificial nuclear reactions. Nuclear fission reactions and their energy balance. Nuclear fission chain reaction. Nuclear reactor. Thermonuclear reactions. Controlled fusion. Substance and field. Elementary particles. Classification of elementary particles. Particle interaction. Particles and antiparticles. The birth and annihilation of the electron and positron. Quarks. Laws of conservation during the interaction of elementary particles.

Topics of practical classes

1 semester

Topic 1. Kinematics of translational motion
Topic 2. Dynamics of translational movement
Topic 3. Conservation laws in mechanics
Topic 4. Kinematics and dynamics of rotational motion
Topic 5. Harmonic oscillations
Topic 6. Mechanical waves
Topic 7. Fundamentals of molecular kinetic theory
Topic 8. Fundamentals of thermodynamics

2nd semester

Topic 9. Electrostatics in vacuum
Topic 10. Electric field in matter
Topic 11. Direct current
Topic 12. Magnetostatics in vacuum
Topic 13. Electromagnetic induction
Topic 14. AC circuits
Topic 15. Geometric optics
Topic 16. Wave optics

3semester

no practical training

Topics of laboratory work

1 semester

Topic 1. Introductory lesson on "Processing the results of a physical experiment"
Topic 2. Laboratory work on kinematics
Topic 3. Laboratory work on conservation laws in mechanics
Topic 4. Laboratory work on solid dynamics
Topic 5. Laboratory work on harmonic vibrations
Topic 6. Laboratory work on mechanical waves
Topic 7. Laboratory work on thermodynamics
Topic 8. Final lesson on laboratory work

2 semester

Topic 9. Introductory lesson on "Working with electrical instruments"
Topic 10. Laboratory work on DC
Topic 11. Laboratory work on the rules of Kirchhoff
Topic 12. Laboratory work on magnetostatics
Topic 13. Laboratory work on electromagnetic induction
Topic 14. Laboratory work on light interference
Topic 15. Laboratory work on light diffraction
Topic 16. Final lesson

3 semester

Topic 17. Laboratory work on quantum optics
Topic 18. Laboratory work on the study of spectra of hydrogen-like atoms
Topic 19. Laboratory work "Experiment of Frank and Hertz"
Topic 20. Laboratory work "Electron diffraction"
Topic 21. Final lesson in quantum physics
Topic 22. Laboratory work on electrical conductivity of semiconductors
Topic 23. Laboratory work on the study of the natural radiation background of the Earth
Topic 24. Final lesson

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
	30.08.2023	Guarantor of the educational program Iryna Tynianova