GENERAL PHYSICS COURSE

Total credit number – 25 (37.5 ECTS credits)

(lectures, practical, laboratory classes, individual work – 1350 hours)

1. MECHANICS – 4.5 credits (6.75 ECTS credits)

Introduction

Subject of physics. Role of physics in the process of cognition of the material world. Evolution of physical ideas. Modern physics and scientific and technological advance. Mechanics. Chief task of mechanics. Main sections of mechanics. Modern concepts of space and time. Material particle, perfectly rigid body and continuum as models used in classical mechanics. Mathematical instruments of physics.

Particle and perfectly rigid body kinematics

Relativity of mechanical motion. Reference system. Description of material particle motion in the vector and reference form: position vector of the material particle, trajectory, displacement vector of the material particle, path length, average and instantaneous velocity, average and instantaneous acceleration. Transformation of Galilean coordinates. Rule of velocity addition in classical mechanics. Normal and tangential acceleration of the material particle in curvilinear motion. Elementary rotation angle. Angular velocity and acceleration vector. Rotation frequency and period. Relation between angular and linear kinematic values. Translational and rotational motion of the rigid body. Free motion of the rigid body as the superposition of its translational and rotational motion. Instantaneous axis of rotation.

Classical dynamics of the material particle and of the system of material points

Interaction between bodies. Types of interaction in existence. Force and mechanical motion. Newton's first law. Inertial reference frames. Inertia. Concept of inertial mass. Basic forces in mechanics. Newton’s second law. Impulse. Impulse of force. Integral form of the fundamental law of dynamics. Newton’s third law. Application of Newton’s laws to solve physical problems. Impulse. Moment of momentum of the material particle. Moment of force. Momental equation for material particles. System of material points. System centre of mass. Law of centre of mass motion. Impulse of the system of material points. Isolated system. Laws of variation and of conservation of momentum of the system of material points. Momental equation for the system of material points.

Mechanical work and energy

Work of force. Power. Kinetic energy. Potential energy. Potential and non-potential force fields. Conservative and non-conservative forces. Relation between conservative force and potential energy. Potential energy of the body lifted above the Earth surface. Potential energy of the elastically deformed body. Full mechanical energy of the body, of the system of bodies. Principle of conservation of energy. Relation between conservation principle and space-time symmetry.

Motion of bodies with varying mass

Examples and characteristics of motion of bodies with varying mass. Jet propulsion. Reactive force. Meshchersky equation. Tsiolkovsky formula. Information on jet engines. Ukrainian scientists' contribution to the progress of cosmonautics.

Collision of bodies

General characteristics of the mechanical processes which take place during the collision of bodies. Impact. Central impact. Perfectly elastic and perfectly inelastic impact. Collision principles and modern methods of studying elementary particles.

Universal gravitation

Kepler laws and the law of gravity. Concept of gravitational mass. Equivalency of gravitational and inertial masses. Gravitation constant and ways of its determination. Determination of the Earth's mass. Gravity. Zero-gravity. Work in the gravitational field. Potential energy of the body in the gravitational field. Gravitational filed potential. Relation between gravitational field potential and its tension. Motion in the gravitational field. Cosmic velocities. Motion of artificial satellites of the Earth. Dependence of the gravity acceleration of the Earth from latitude. Explanation of causes of high and low tide. Energy of gravitational interaction of two particle masses. Gravitational energy of the homogeneous sphere.

Non-inertial frames of reference in classical mechanics

Non-inertial frames of reference. Interrelation between velocities and accelerations in different frames of reference. Forces of inertia and their manifestations. Forces of inertia at the accelerated translational motion of the frame of reference. Forces of inertia influencing the body in the rotating frame of reference: centrifugal force of inertia, Coriolis force. Equivalence principle. Influence of the Earth's daily rotation on the motion of bodies at its surface and on their weight.

Elements of rigid body mechanics

Model concepts of a perfectly rigid body as a system of rigidly bound material particles. Rigid body mass centre. Particle and body moments of inertia relative to the rotation axis. Examples of analytical calculations of moments of inertia of some homogeneous bodies. Huygens-Steiner theorem. Equation of the dynamics of the rotational motion of the rigid body. Plane motion of the rigid body. Kinetic energy of the rotational motion. Total kinetic energy at the plane motion of the rigid body. Conservation laws al translational and rotational motion of the rigid body. Free rotation axes. Gyroscopes and particularities of their motion. Precession and nutation of gyroscopes. Gyroscopic forces. Examples of using gyroscopes.

Elements of rigid body statics

Conditions of rigid body equilibrium. Methods of mass centers determinations. Force couple. Principle of potential energy minimum in the stable position of the rigid body.

Deformations and tensions in rigid bodies

Mechanical tensions. Deformation. Relative deformation. Elastic and plastic deformation. Hooke's law. Young modulus. Shear and torsion. Shear modulus. Deformation and uniform compression modulus. Poisson ratio. Mechanical tension diagram.

Elements of liquid and gas mechanics

Properties of liquids and gases. Pressure in liquids and gases. Laws of hydrostatics (Archimedean, Pascal). Perfect liquid. Perfect liquid stationary motion. Lines and tubes of current. Equation of continuity. Bernoulli equation and physical content of its constituents. Torricelli formula. Viscosity (internal friction) of liquids and gases. Internal friction force. Laminar and turbulent flow. Reynolds number. Flow of liquid in a horizontal cylindrical tube. Poiseuille formula. Movement of bodies in liquids and gases. Similarity method. Stokes formula. Lifting force and frontal resistance. Magnus effect.

Mechanical vibration and mechanical waves in an elastic medium

Periodic processes. Mechanical harmonic oscillation and their kinematical characteristics: amplitude, phase, initial phase, period, frequency, circular frequency. Harmonic oscillation equation. Vectoral model of harmonic oscillation. Mathematical and physical pendulum. Harmonic oscillator energy. Composition of unidirectional harmonic vibrations. Beating. Composition of inter-perpendicular oscillations. Lissajous figures. Free damped mechanical vibration, its differential equation and its solution. Damping coefficient, damping constant, logarithmic decrement, Q factor of oscillatory system. Forced mechanical oscillation, its differential equation and its solution. Mechanical resonance. Parametric resonance. Propagation of oscillation in elastic medium. Elastic harmonic wave and its characteristics: wave-length, frequency, wave front, wave surface, wave number, wave phase. Progressive plane, spherical and cylindrical waves. Wave equation describing propagation of elastic waves in homogeneous isotropic medium. Wave motion energy. Flux and energy flux density. Umov vector. Superposition principle. Elastic wave interference. Stationary wave. Wave diffraction. Huygens principle. Sound. Sound intensity and timbre. Sources of sound. Doppler effect in acoustics.

Elements of relativistic mechanics

Deviations from Newton's laws of mechanics. Michelson experiment. Special relativity theory postulates. Laurence's transformation. Consequences of Laurence's transformation. Relativity of simultaneousness of events in different frames of reference, body length in different frames of reference, proper length. Relativity of time interval between events, proper time. Interval. Interval invariance. Types of intervals and their particularities. Relativist law of velocity composition. Relativist impulse. Basic equation of relativist dynamics. Total energy of the relativist particle. Rest energy. Kinetic energy. Interrelation between energy and impulse, mass and energy in relativist mechanics. Conservation of energy, impulse and moment of momentum in relativist mechanics.

2. MOLECULAR PHYSICS AND THERMODYNAMICS – 4.5 credits (6.75 ECTS credits)

Introduction

Subject and tasks of molecular physics and thermodynamics. Concept of thermodynamic system and basic methods of its description. Micro- and macro-parameters of the system. Volume, pressure, temperature and their measurement. Thermometric body. Empiric temperature scales. Concept of state equation. Thermodynamic equilibrium of the system. Concept of process. Equilibrium and non-equilibrium processes.

Elements of the molecular-kinetic theory. Perfect gas

Basic theses and experimental verification of the molecular-kinetic theory. Molecule mass and size. Relative atomic and molecular weight. Atomic mass unit. Mole. Molar mass. Avogadro number. Gaseous, liquid and solid states of a substance from the point of view of the molecular-kinetic theory basic theses. Experimental gas laws: Boyle-Mariotte law, Gay-Lussac law, Charles law, Dalton law, Avogadro law. Perfect gas as a model of the simplest statistical system. Perfect gas state equation: Clapeyron, Mendeleyev-Clapeyron equation. Universal gas constant. Loschmidt number. Basic equation of the perfect gas kinetic theory. Molecular-kinetic interpretation of pressure and temperature. Boltzmann constant. Perfect gas temperature scale. Concept of absolute zero. Perfect gas in the Earth's attractive field. Barometric height formula. Macro- and microstates of the statistical system and relations between them. Statistical laws. Average values (time and ensemble). Fluctuations. Ergodic hypothesis. Statistical ensembles. Basic concepts of the probability theory. Probability summation and product probability theorems. Probability distribution function, probability density. Calculation of average values with the use of distribution functions. Concept of phase space. Maxwellian distribution by constituents and velocity module. Most probable, arithmetic mean, quadratic mean velocity. Maxwellian distribution of molecules by energies. Experimental verification of Maxwellian distribution. Boltzmann distribution. Perren's experiments to determine the Avogadro number. Maxwell-Boltzmann distribution. Influence of fluctuations on the receptiveness of measuring instruments.

Fundamental thermodynamics

Basic definitions and the scope of application of thermodynamics laws. Internal energy. Work and heat. Physical meaning, analytical notation and different formulations of the first law of thermodynamics. Thermodynamic system heat capacity. Mayer equation. DOF and internal energy of perfect gas molecules. Boltzmann-Maxwell theorem on the uniform distribution of energy according to the DOF of translational and rotational motion of molecules. Disagreement between the classical theory of perfect gas heat capacity and experiment. Adiabatic process. Poisson equation. Polytropic process. Work done by perfect gas in isoprocesses, adiabatic and polytropic processes. Cyclic processes. Reversible and irreversible processes. Work in the cyclic process. Heat-engines and refrigerators. Carnot cycle of perfect gas and its coefficient of efficiency. Carnot theorem. Clausius equation and inequality. Different formulations of the second law of thermodynamics and their equivalency. Absolute thermodynamic temperature scale. Entropy. Thermodynamic probability. Statistical weight. Connection between entropy and the state probability of the system. Boltzmann formula. Statistical character of the second law of thermodynamics. Le Chatelier-Broun principle. Nernst heat theorem as the third law of thermodynamics. Unattainability of the absolute zero of temperature. Cycle and thermodynamic function (potentials) methods. Internal energy, free energy, enthalpy, Gibbs thermodynamic potential and their differentials. Physical meaning of thermodynamic functions. Maxwell relation, Gibbs-Helmholtz equation. Chemical potential. Thermodynamic equilibrium conditions. Elements of irreversible processes thermodynamics.

Transport phenomena in perfect gases

General characteristics of transport phenomena. Collision between molecules. Effective molecule collision cross-section. Effective molecule diameter. Average length of free path of molecules. Diffusion in gases. Fick diffusion laws. Viscosity (internal friction) in gases. Heat conduction in gases. Dependence of diffusion, viscosity, heat conduction coefficients from pressure and temperature. Relation between transport coefficients. Vacuum. Generation and measurement of low pressures. Effusion.

Real gases

General characteristics of real gases. Deviation of real gas behaviour from ideal gas laws. Forces and potential energy of intermolecular interaction. Van der Waals equation of state and isotherm of gas. Physical meaning of constants of Van der Waals equation. Critical state of substance. Law of corresponding states. Comparative characteristics of Andrews experimental gas isotherms and theoretically calculated Van der Waals gas isotherms. Metastable state. Superheated liquid and supercooled gas. Saturated vapour. Internal energy of real gas. Heat capacity and entropy of real gas. Joule-Thomson effect. Inversion temperature. Gas liquefaction and low temperatures generation.

Elements of physics of liquids

General properties and structure of liquids. Viscosity (internal friction) of liquids. Diffusion in liquids. Superficial layer of liquids. Surface tension. Surface curvature and bubble pressure. Laplace formula. Interaction of liquids with rigid body surface. Wetting. Capillary phenomena. Height of lift of liquids in cylindrical capillary vessels. Influence of curved surface on the saturated vapour pressure. Wetting and capillary phenomena in nature and technology. Surface-active substances. Adsorption. Flotation. Thermodynamics of surface phenomena.

Elements of solid-state physics

General properties of crystalline and amorphous solids. Basic characteristics of crystals. Short-range and long-range order. Polycrystals. Monocrystals. Closely packed crystal lattices. Ionic crystals. Metallic crystals. Covalent crystals. Molecular crystals. Quasi-crystals. Liquid crystals. General information on fullerenes. Defects in real crystals. Mechanism of point defect formation. Diffusion in solids. Linear defects: edge and screw dislocations. Concept of dislocation mechanism of plastic deformation. Character of thermal motion in crystals. Thermal expansion of solids. Heat capacity of solids. Dulong-Petit law. Concept of quantum theory of heat capacity of solids. Phonons. Debye temperature. Debye law. Heat conduction in solids.

Phase transitions. Solutions and alloys.

Concept of phases. Phase equilibrium. Phase transitions of the first and the second order. Gibbs phase rule. Clausius-Clapeyron equation. Evaporation and boiling. Dependence of saturated vapour pressure from temperature. Phase diagrams. Triple point. Erenfest relation. Polymorphic transformations. Superfluidity. Sublimation, fusion, and crystallization of solids. General characteristics of solutions. Solubility. Liquid solutions. Henry law. Boiling of mixture of liquids. Raoult laws. Osmosis and osmotic pressure. Vant Hoff law. Alloys. Hard alloys. Eutectic. Chemical compounds. Binary state diagrams with varying character of mutual solubility of constituents.

3. ELECTRICITY AND MAGNETISM – 4,5 of credit (6,75 ECTS credits)

Introduction

Electromagnetic phenomenon in nature. Electric charge and its discreteness. Charge invariance. Charge conservation law. Idea development of electromagnetism nature. System of units in electrodynamics

Constant electric field in vacuum

Electrostatics subject. Coulomb's law. Intensity vector of electric field and force line. Intensity of point charge field in vacuum. Superposition principle. The use of superposition principle in solving electrostatic tasks. Gauss' law of flux in integral and differential form. The Gauss' law of flux application to intensity calculations of electrostatic fields: field of uniformly charged sphere, cylinder, spherical and cylindrical shells, unending straight thread.
Activity on charge displacement in electrostatic field. Circulation of intensity vector. Electrostatic field potential, potential difference. Potential coherence with field intensity. Equipotential surfaces. Potential of point charge field, systems of point charges and uninterruptedly charged bodies. Laplace and Poisson’s equations, their solution in elementary cases: uniformly charged space, sphere, cylinder, unending straight thread.
Electric dipole, dipole moment. Dipole field potential and intensity. Dipole energy in exterior field. Power and moment of forces, influencing dipole in exterior homogeneous and heterogeneous fields. Earnshow theorem. Electric field of optional system of charges at a great distance from it. Charge system dipole moment. Quadrupole. Octopole.

Electric field in physical medium

Conductors in electrostatic field. Charge division on conductor surface. Field intensity near conductor surface. Force lines and equipotential surfaces in the presence of conductors. Method of images. Condensers. Capacity of plane, spherical and cylindrical condensers. Parallel and series connection of condensers.
Electrostatic field in dielectrics. Micro- and macro field. Molecular mechanism of polarization, polar and nonpolar molecules. Volume and surface connected charges. Field intensity in dielectric. Polarization vector. Description of connected charge division using polarization vector.
Electric induction vector (displacement vector). Permittivity. Gauss' law of flux for intensity, induction and polarization vectors. Extreme conditions on surface of dielectric division, force lines refraction. Condenser and dielectric capacity.
Electrostatic field energy. Interaction energy of point charges. Self-energy of charged bodies. Volume density of electric field energy.

Constant electric current

Free charge current, current force, current density. Continuity equation integral and differential form. Specific resistance and conductivity. Ohm’s law in differential form. Specific resistance and specific conductivity. Ohm’s law for subcircuit, thin conductor resistance. Outside forces, electromotive force, Ohm’s law for closed circle. Joule and Lenz’s law. Line circuits. Kirchhoff rules.

Constant magnetic field in vacuum

Magnetic field, Oersted experiment. Magnetic induction vector. Magnetic field of charge, moving uniformly. Magnetic field force lines. Magnetic field of linear and volume current elements, Biot-Savart-Laplace law. Superposition principle for magnetic field. Theorem of induction circulation of magnetic field. Gauss' law of flux for magnetic field induction. The use of Gauss' law of flux, circulation theorems, superposition principle in calculations of magnetic fields of elementary systems: unending straight current, space with exterior current, magnetic field of circular turn on its axis, magnetic field in massive cylindrical conductor with coaxial cable current, solenoid and toroid field. Conductor interaction with current, Ampere force. Lorenz force. Charged particle motion in magnetic and electric fields. Magnetic moment of isolated plane turn with current. Forces and moment of forces, operating on magnetic moment in exterior homogeneous and heterogeneous fields. Magnetic moment energy in exterior field.

Electromagnetic induction

Electromagnetic induction phenomenon. Faraday's law of electromagnetic induction, induction electromotive force. Lenz's rule. Foucault currents. Self-induction phenomenon, inductance. Mutual induction. Inductances of elementary systems: cylindrical conductor, solenoid. Energy inductance coil with current. Magnetic field energy. Volume density of magnetic field energy.

Magnetic field in substances

Molecular current model. Magnetization vector. Micro- and macro field in magnetic. Magnetic induction vector and magnetic field intensity vector in magnetic. Magnetic susceptibility and permeability. Paramagnetic, diamagnetic, ferromagnetic. Permanent magnet. Circulation theorems and Gauss' theorems for field vectors in magnetics. Extreme conditions for magnetic field vectors on the surface of magnetic division. Microscopical magnetization mechanisms. Magnetic properties of atoms and molecules. Spin and magnetic intrinsic moment. Orbital, spin and gyromagnetic ratio. Diamagnetism nature, Larmor precession. Diamagnetic susceptibility. Paramagnetism nature, paramagnetic atoms. Paramagnetic susceptibility and its dependence on temperature, Curie’s law. The main information about Langevin theory. Ferromagnetism, antiferromagnetism and their nature. Transfer curve of ferromagnetic, hysteresis loop. Residual magnetization, coercive force. Saturation. Ferromagnetic property dependence on temperature, Curie-Weiss law. Curie point. Domains and domain frames, remagnetization mechanisms. Remagnetization operation. Einstein-de Haas effect. Barnett effect. Magnetic field energy in magnetics.

Electroconductivity in different mediums

Nature of current curriers in metals and semi-conductors, experimental detections of free charges. Dependence of metal electroconductivity and semi-conductors on temperature. Residual resistivity. Heating capacity of metals, Wiedemann-Frantz law. Classic theory of electroconductivity and its deficiency. Hall effect. Band theory conception of solids. Collective electrons. Fermi distribution, fermi energy and impulse. Electronic and p-type conductivity, donors and acceptors. Conception of microscopical metal conductivity and semi-conductor mechanisms. Phonons. Resistivity mechanism. Kinetic nature of Ohm’s law. Contact potential difference. Seebeck effect, thermoelectromotive force. Peltier effect, Peltier heat. Thomson effect. Work function, thermo- and field-emission. Electrolyte electroconductivity and its dependence on temperature. Faraday electrolysis law. Gas electroconductivity, ionization and recombination. Ionic avalanche, types of gas charges. Plasma conception. Plasma frequency.

Superconducting conversion, critical temperature, critical field. Superconductors of first and second type. High-temperature superconductivity. Ideal diamagnetism, flux jumping. Microscopical mechanism of superconductivity. Superconductivity application in science and technology.

Maxwell equations and electromagnetic waves

Displacement current. Maxwell equations in integrated and differential form. Physical meaning of some Maxwell system equations. Material correlations. Energy conservation law of electromagnetic field. Flow of electromagnetic field energy, Pointing vector. Electromagnetic field impulse.
Electromagnetic waves. Wave equation. Wave surface. Wave front. Plane and spherical electromagnetic waves: amplitude, wave phase, frequency, wavelength, wave vector, phase velocity. Plane electromagnetic waves. Converging and divergent waves. Cylindrical waves. Standing waves. Transverse electromagnetic wave. Electromagnetic wave polarization: linear, elliptic, circular. Energy flow in electromagnetic waves. Electromagnetic wave study, Hertz experiments. Electromagnetic wave radiation and its intensity. Dipole radiation. Antennas. Half-wave vibrator. Reception and transmission of modulated radio signals. Invariance of electromagnetic field equations in regard to Lorenz transformations. Transformations of electromagnetic field vectors when turning from one inertial system to another. Electromagnetic field invariants.

Quasistationary electromagnetic field

Quasistationary changeable current, quasistationary field. Circuits with sources of changeable electromotive forces, pure, inductive and capacitive reactance, impedance. Sinusoidal current. Operation and power in changeable current circuit. Oscillatory circuit, resonance curve, decrement, tuned-circuit Q-factor, bandpass. Inductively coupled circuits. Transformers and autotransformers. Scin-effect, penetration depth. Three-phase current and its application in technics.

4. OPTICS – 4.5 credits (6.75 ECTS credits)

Introduction

The subject of optics. The nature of light. The evolution of the concept of light. Electromagnetic wave scale, optical range. Light pressure. Experimental methods of the light speed measurement. The reflection and deflection of a plane electromagnetic wave on the verge of dielectric allocation. Absolute and relative refractive index.

Photometry elements and geometrical optics

Light flux. Eye spectral response. Main photometric values and units. Connection between energetic and light characteristics of emission. Geometrical optics as a role case of wave optics. Eikonal equation. Phereme principle. The geometrical optics canons. The effect of complete interior reflection, optical conductors and their application. Flat and spherical mirror. A spherical mirror formula . The formula of a fine lens. The image tracing in mirrors and lenses. General information on thick lenses. Centered optical system, its cardinal elements. Centered optical system formula. Optical systems aberrations. Optical devices.

Light interference

Two-ray interference. Fluctuation tracing vector diagram. Light intensity in superposition of two light waves. Geometrical and optical motion differences. The conditions of maximum and minimum illumination creation. The width of interference zone and the distance between the zones. Classical experimental methods of light interference observation. Coherence. Time coherence. Physical causes of time coherence. Coherence time. Coherence length.

The role of the light source in interference pattern observation. Spatial coherence. Coherence radius.

Double-reflecting interferometers: Michelson interferometer, Relley interferometer, stellar interferometer. The use of interferometers in different fields of science and technology. Multibeam interference and its features. Fabry-Perot interferometer. Interference filters. Lyummer-Gerke plate. Michelson echelon. Multibeam interference application. Interference in thin layers. The lines of the same grade and thickness. Newton rings. Non-expendable reflections application. Layers with null and high reflectance.. Dielectric mirrors. The optical systems antireflection.

Light diffraction

Gyuigens-Fresnel principle. Fresnel diffraction. Fresnel zone method, Fresnel zones. Analytical and graphical amplitude measurement. Zone plate and retarder. Fresnel diffraction from a round hole and a disk. Fresnel diffraction from a rectilinear border of a half-plane. The Cornu spiral. Fresnel diffraction from a split. Zone plate as a lens. Fresnel zone method difficulties. Fraunhofer diffraction. Fraunhofer diffraction from a split. Analytical and graphical methods of amplitude measurement, the location of minimum and maximum. Fraunhofer diffraction from the holes of different shape.

Diffracting screen. The diffraction maximum location and intensity. Oblique incidence of light at the screen. Reflecting screen. Diffraction of white light at the screen. Diffracting screen application in spectral devices. The main characteristics of spectral devices(free spectral range, angular and linear dispersion). X-ray diffraction. Laue and Wulf-Breg's equation. The main notions of Fourier optics. Fourier transform lens. Diffracting creation of an image by means of a lens.

Holography physical foundation. Basic schemes of recording and representation of thin-layer holograms. Thick-layer holograms. The obtaining of color image. The features of the hologram 2 as a data carrier. The application of the holography.

Light polarization

Natural and polarized light. Linear, circular and elliptic polarization. Partly polarized light. Polarization degree. Malus' law. Methods of obtaining polarized light. Polarization in reflection and deflection. Fresnel's formula. Bruster's angle. Double refraction phenomenon. Usual and unusual rays and their polarization. Monaxial and double-axis crystals. Optical axis of a crystal. Dichroism. Polarizers. Polarized prisms. Physical cause of double refraction. Transmission of electromagnetic wave in anisotropic medium. Anisotropy of deflection coefficient and the relation of radial velocity to the direction. Radial velocity ellipsoid. Positive and negative monaxial crystals. The Gujgen's constructions in different cases of deflection on a crystal surface.

Polarized light interference. The passage of linearly polarized light through a crystal wafer. Fourth wave wafer, half-wave wafer, one wave wafer. A crystal wafer between two polarizers. An assumed double refraction. Rotational displacement of polarization space in crystal and

amorphous medium. Optical isomerism. Rotational displacement of polarization space in magnetic field. Polarized light application in different fields of science and engineering.

Electromagnetic wave and substance interaction

Dispersion of light. Normal and anomalous dispersion. Dispersion simple theory. Complex dielectric constant. The physical content of imaginary part of effective dielectric constant. Wave packet. Envelope velocity. The phase velocity and envelope velocity connection. Light absorption. Buger's law. The nature of absorption. The features of the light absorption by metals. Complex wave vector and complex index of refraction. Penetration depth of electromagnetic wave in metal. Light reflection from a metal surface. Optical dispersion. The nature of dispersion processes. Relley's dispersion. Relley's law. Mee's dispersion. Scattered radiation polarization. Combination scattering. Mandelshtam-Brilluen's dispersion. Vavilov-Cherenkov's effect and its application for the registration high-velocity charged particles. Luminescence. Types of luminescence. Scintillations.

Elements of nonlinear optics

Main nonlinear effects. Nonlinear medium polarization and its nature. Harmonic generation. Space synchronism condition. Sum frequency generation. Light parametric amplification. The light in nonlinear medium: self-focusing and self-defocusing of the ray. Self-focusing length. Main physical causes of refractive exponent nonlinear nature. Lasers as the sources of induced emission. The passage of light through medium subject to induced emission. Optical intensifications. Intensification condition. Luminous flux influence on levels occupancy. Depth conditions. Population inversion creation. Laser principle circuit. Threshold of generation. Stationary generation condition. Pulsed lasers and CW lasers. Laser emission. Beam resonators. Cross and feathering modes in resonators. Mode synchronization. Short-range impulse generation. Laser spectrums. Characteristics of some lasers. Application of lasers in some fields of science and engineering.

Moving medium optics

Cross and feathering Doppler's effects. Red displacement in galaxy spectrum. Doppler line width. Optical phenomena in noninertial systems (The Sunyak effect).

5. ATOM AND NUCLEAR PHENOMENON PHYSICS – 4 credits (6 ECTS credits)

Introduction

Short historical background of modern ideas as to the structure of atom. Subject and objectives of the course «Atom and Nuclear Phenomenon Physics». Distance and energy values in atomic molecular and nuclear processes. Spectroscopy of masses. Limitation of the usage of classical mechanics concepts. Specific character of the microcosm laws. Quantum concepts. Relativity.

Quantum hypothesis

Radiation and atom absorption of light. Kirchhoff's law. Blackbody. Stefan-Boltzmann law. Wien displacement law. Function of state density of electromagnetic waves in the vacuum. Rayleigh-Jeans law. Ultraviolet catastrophe. Planck hypothesis. Planck's formula (derivation).

Planck's constant. Photons. Photon energy and impulse. Compton effect. Compton's formula derivation.

Bohr-Sommerfeld theory of atom of hydrogen

Determination of atom masses. Mass spectrograph and mass spectrometer. Discovery of electron. Electron classic radius. Thomson's static model of atom. Nucleus scattering of alpha particles, Rutherford's research. Effective dissipation cutover. Derivation of Rutherford's formula. Consequences of Rutherford's research. Atom planetary model. Impossibility of existence of a steady atom in fundamental physics. Quantizing of the energy of atoms, molecules, and radiation. Franck and Hertz research. Bohr's postulates. Bohr-Sommerfeld theory of atom of hydrogen, circular and elliptical orbits. Spectral series of atom of hydrogen. Spectral formulas. Rydberg's constant. Spectral terms. Ritz combined principle. Considering nucleus mass. Positronium and meson. Spectra of fire-like ions. Applicating the principle of relativity to atom of hydrogen. Highly activated atoms. Difficulties in the Bohr's theory.

Corpuscular wave dualism

Louis de Broille hypothesis. Broille's waves. Experimental confirmation of Broille's hypothesis. Diffraction of electrons, neutrons, atoms and molecules. Davidson and Germer, Thomson and Tartakovskyi researches. Electron and neutron diffraction investigations. Properties of Broille's waves, their group and phase velocities. Concept of a quantum state and its characteristics with the help of a wave function. Probable (static) interpretation of the wave function. Difference between quantum mechanical and fundamental description of movement of a particle. Superposition of a plane wave. Wavepacket. Correlation of uncertainty of Heisenberg and the theory of radiation. Physical content of correlation of uncertainty. Breadth of the energy level and the period of time of the active state.

Basics of the quantum physics

Schrödinger's stationary and non-stationary equation. Requirements for its solution. Conditions for regulation of the wave function. Static interpretation of the wave function. Principle of superposition. Interference of probabilities. Operators in the quantum mechanics. Equation for proper values and eigenfunctions. Othogonality of eigenfunctions. Average values of physical magnitudes. Operators of physical magnitudes. Operators of impulse and the coordinates. Inverted delta. Operator of the moment of impulse. Operator of projecting the moment of impulse into the decided direction. Proper values of square of the moment of impulse and of the projection of the moment of impulse. Space quantization. Addition of moments, vectoral model. Solution of the Schrödinger's equation for a particle in 1-D rectangular potential well. Harmonious oscillator. Solution of the Schrödinger's equation for a particle (electron) in a spherical symmetric field – atom of hydrogen, type of the wave functions and distribution of the density of probability, energy quantization, and orbital moment of impulse; physical content of quantum numbers. Response ratio of degeneration of energy. Fundamental state of the atom of hydrogen. Particle's passing through a potential barrier (Tunnel effect). Invention of a formula of transparency of a potential barrier. Cold emission. Tunnel diode. Macroscopic quantum tunneling. Optic analogue of the Tunnel effect.

Spin

Stern and Gerlah research. Spin properties of particles. Spin operator. Full moment of impulse. Orbital and spin magnetic moments. Experimental proof of spin existence. Spin – orbital interaction. Fine structure of energy levels according to the example of energy levels of tinned metals. Tinned metals' spectra. Experimental determination of the constant of fine structure with the help of quantum effect of Hall.

Quantum mechanics of the system of identical particles

Minimal value of volume in a coordinate impulse space. Principle of particles' non-fragmentation. Dependence of wave function from spin. Symmetrical and antisymmetrical wave functions. Quantum statistics (of Bose-Einstein and Fermi-Dirac). Relation between statistics and spin. Pauli principle.

Many-electron atoms

Electron in the central field. Approximate characteristics of certain electrons with the help of quantum numbers *n* and *l*. Conception of electronic configuration. Maximum quantity of electrons that has given values of quantum numbers (different cases). Electron shell. Properties of shells completely filled. Filling of electron shells considering the Pauli principle. Interaction of electrons in many-electron atoms. Conception of method of self-consistent field. Energy levels and atom spectra of tinned metals. Vectored addition of moments of impulse and types of bonds. Russel-Saunders and j-j bonds. Atom terms (symbolism). Gund law. General characteristics of energy levels and spectra of many-electron atoms. Explanation of the Mendeleev's periodic law. X-ray and X-ray photoelectron characteristic spectra and their nature. Moseley law.

Atoms in external fields

Magnetic properties of atoms. Hydromagnetic relation between orbital motion of electron and spin of electron. Bohr magneton. Calculation of Lande factor for the case of Russel-Saunders bond. Atom energy in magnetic field. Zeemann effect. Rule of selection. Determination of concepts of high and low magnetic fields. Paschen-Back effect, energy level formulas in low and high magnetic fields. Determination of number of spectral components considering selection. Phenomena of electron paramagnetic resonance (EPR) and nuclear magnetic resonance (NMR), theory and methodology of observation. Polarization of atoms and molecules. Stark effect. Electric resonance. Spontaneous and induced radiation. Absorption. Derivation of Planck's formula according to Einstein. Three-level quantum-mechanical amplifier and generator.

Molecules

Diatomic molecules. Polar and homopolar atomic bonds in molecules. Molecule of hydrogen. Types of molecular motion. Potential energy curves. Vibrational and rotational energy levels of diatomic molecules. Molecular spectrum. Rules of selection. Combinatorial dispersal of light. Anharmonicity of vibrations and dissociation. Nature of chemical bond. Directional valence.

Quantum properties of rigid bodies

Periodicity of potential and single-electron wave functions for crystal lattice. Forming of bands. Crystal states of activated electrons and conception of excitons. Crystal vibrational states and

conception of photons. Einstein and Debye theory of heat capacity. Interaction of electron and vibrational motions in crystal. Occupation of energy bands. Band models of metals, semiconductors, dielectrics. Rigid bodies conduction. Elements of theory of superfluidity and superconductivity. Josephson effect. Hall's quantum effect. Bose-Einstein condensates of rarefied gases of tinned metals.

6. NUCLEAR AND ELEMENTARY-PARTICLE PHYSICS – 3 credits (4.5 ECTS credits)

Introduction

Fundamental stages of the development of the conceptions on the atomic nucleus and elementary particles. The discovery of the natural radioactivity of the uranium, polonium and radium. The discovery and research of the α, β and γ radioactivity. The discovery of the atomic nucleus. The first artificial nuclear reaction (transformation of nitrogen into oxygen). The discovery of the proton. The first models of the atomic nucleus structure, atomic nucleus inability. The discovery of the neutron.

General characteristics of atomic nuclei

Proton and neutron composition of atomic nuclei. Characteristics of proton and neutron. Nucleus charge. Mass number and nuclear mass. Isotopes, isobars, isomers. Nuclei binding energy. Stable and unstable nuclei. Nuclei sizes. Nucleus models. Drop model and Veizsecker formula. Magic numbers. Shell model (oscillating model and role of spin-orbit interaction). Spins and nuclei magnetic moments. Determination of spins and nuclei magnetic moments. Quadrupole electric moment of nucleus as an extent of its non-sphericity.

Nuclear powers and their characteristics

Action radius and nuclear powers intensity. Dependence on spin and non-centralization. Characteristics of nuclear powers saturation. Interchange character. Charge independence and isotropic invariance of nuclear powers. Deutron and its characteristics (binding energy, spin and magnetic moments, quadrupole electric moment). Rectangular potential pit model and wave function of deuteron basic state. Scattering of slow neutrons by protons.

Radioactivity

Natural radioactivity. Radioactive-decay law, α- and β-decay and radioactive series, α-decay and Geyger-Nettole law, α-decay as tunneling through a potential barrier. Determination of nucleus dimensions using the data of α-decay. Types of β-decay. Continuity of energy spectrum of electrons. Neutrino. Non-preservation of evenness at β-decay. Woo's researches. Spirality of neutrino and antineutrino. β-decay of neutron, nuclei γ-emission and its characteristics. Nuclear isomers. Resonance emission and absorption of γ-quantums by atomic nuclei without repulse (Messbayer effect). Examples for the Messbayer effect application: measurement of gravitational red shifting within the Earth conditions. Artificial radioactivity. Trans-uranium elements.

Nuclear reactions

Classification and examples for nuclear reactions. Law of conservation of energy, law of conservation of pulse, law of conservation of pulse moment, law of conservation of evenness in nuclear reactions. Compound nucleus. Resonance nuclear reactions. Brate-Vigner formula.

Interaction of particles and emission with substances. Registration and observation of charged particles and photons.

Physics of neutrons

Nuclear fission and fusion. Neutron sources. Classification of neutrons and their characteristics. Interaction of neutrons with nuclei. The theory of moderation. Heavy nuclei fission. Analysis of fission process on the basis of the drop nucleus model. Chain nuclear reactions. Nuclear reactors using thermal neutrons. Graphite-uranium and water-cooled reactor. Defects of graphite-uranium reactors. Natural nuclear reactor in Ocklo. Thermonuclear reactions. Fusion of helium from hydrogen as a source of stars energy. Proton-proton and carbon-nitrogen chains. Prospectives for conducting of thermonuclear reactions within the Earth conditions.

Relativistic wave equations. Electromagnetic interaction

The equation of Clein-Gordon. Negative energy and antiparticles. The discovery of positron. Annihilation and formation of pairs of particles and antiparticles. Photons as carriers of electromagnetic interaction.

Strong interaction

Mesons of Jukava. π-mesons, their spin, evenness and decay. Isotopic spin of π-mesons. Baryon resonance. Strange particles. Hyperons and K-mesons. First complex models of elementary particles. Unitary multiplets of mesons and baryons. Prevision and discovery of Ω-baryon. Quarks. Quark structure of adrons. Quark and other heavy quarks. Colour of quarks and gluons. Transformation of elementary particles. Preservation of isotopic spin and strangeness. Examples for the creation and decay of particles caused by strong interaction.

Contemporary astrophysical conceptions

The Big Bang the theory of the hot Universe. The discovery of the relic radiation. Origin of chemical elements in the Universe. Connection of the fact of the life existence in the Universe and certain limitations on the laws of the microworld. Anthropical principle.