Ministry of Education and Science of Ukraine

PHYSICS

Curriculum for high (comprehensive) schools

Grades 10-11
STANDARD LEVEL

Standard level programme

Grade 10 (3 hours per week; 105 hours in total)

Expected outcomes of learning and cognitive activities	Guidelines for the content of the learning material
Introduction	
The knowledgeable component Operates concepts and definitions of the main stages of the development of physics, distinguishes between units of measurement, knows the principles of measurement. ***The activity component*** Skills in assessing the errors (uncertainties) of direct and indirect measurements Can estimate errors (uncertainties) of direct and indirect measurements, apply vector quantities, check the units in derived formulas.	The natural sciences and the contemporary human worldview. The origin and development of physics as a science. The role of physical knowledge in human life and social development. Theory and experience, role of basic physical theories. The physical model. Units of physical values, the SI international system of units. Direct and indirect measurements and errors (uncertainties) of measurements. Relations between mathematics and physics. Scalar and vector quantities, vector projections.
Section 1. Mechanics	
The knowledgeable component Operates basic concepts of mechanics, characteristics of different types of motion and interaction of bodies, the concept of a material point as a model of a real body, the terms: mechanical motion, reference frame, trajectory, movement, path, speed of uniform rectilinear motion, instantaneous speed, average speed, acceleration, accelerated motion in the field of gravity, period, frequency, angular speed, centripetal acceleration, relativity of mechanical motion, elastic force, sliding and rest friction forces, drag force in the motion of a body in a continuous medium, gravity, momentum of force, equilibrium conditions, mechanical work of different forces, momentum, conservative (potential) forces, kinetic and potential energy, zero level of potential energy. Defines the conditions under which the laws of conservation in mechanics are satisfied. Distinguishes between types of oscillation (free, extinction, forced, auto-) in different oscillation systems. **The activity component** Solves problems using formulas for rectilinear uniform and uniformly accelerated motion, uniform circular motion, motion of a body under the action of a constant force of gravity. Can analyse and graph rectilinear uniform acceleration motion. Selects the optimal frame of reference for solving specific problems, is able to make the transition from one frame of reference to another. Possesses the simplest methods of experimental	Basic principles of kinematics: space and time, mechanical motion, its relativity, reference frame, ways of describing motion, trajectory, path, displacement. The basic task of mechanics. Average speed and average velocity of a path. The concept of instantaneous velocity of motion. The law of addition of velocities. Straight-line uniform motion as the most ordinary type of motion. Acceleration, motion with constant acceleration. Equation of uniform rectilinear motion. Plots of dependence of kinematic quantities on time for uniformly accelerated rectilinear motion. Free fall and curvilinear motion under the constant force of gravity. Uniform motion of a material point in a circle. Angular velocity. Period of rotation and frequency of rotation. Central (normal) acceleration. Types of forces in mechanics. Measurement of forces, addition of forces. Equipotential. Inertial reference systems. Galileo's principle of relativity. Inertia and mass. Newton's laws of motion and the limits of their implementation. Gravitational interaction and gravitational field, gravity. Weight and weightlessness. First space velocity. Development of astronautics, contribution of Ukrainian scientists to space exploration. The forces of friction. Coefficient of sliding friction. Resistance forces in motion of a body in a liquid or gas. The motion of the body under the action of several forces. Algorithm for solving problems of dynamics. Equilibrium of bodies. Moment of force, centre of gravity of the body. Stability of equilibrium. Conservative (potential) forces. Using the laws of conservation of energy and momentum in mechanical phenomena. Reactive motion in nature and technology. Second space velocity. Elastic and inelastic collisions. Equilibrium and motion of liquid and gas. Lift-off force of an airfoil. Application of laws of mechanics to rocking motion. Harmonic oscillations. Equation of harmonic oscillations. Conditions for free vibrations. Elementary vibrating systems (mathematical pendulum, spring pendulum). Energy of vibrations.

investigation of the motion of bodies. Can apply Newton's laws of dynamics, force formulas, the algorithm for solving problems of dynamics, laws of conservation in mechanics, equilibrium conditions of bodies, find the characteristics of oscillations of the simplest oscillating systems and establish the relationship between them. Understands the physical nature of the origin and spread of waves.	Forced vibrations. Resonance. Action of pendulum clock as an example of self-oscillation. Propagation of mechanical vibrations in elastic media. Planar and spherical, transverse and longitudinal waves. Interference and diffraction of waves. Sound phenomena. Speed of sound. Classification of sounds, their properties. Acoustic resonance. **Suggested demonstrations** 1 Relativity of motion. 2 Application of the stroboscopic effect to study the motion of bodies. 3 Direction of velocity in circular motion. 4 Circular motion of bodies with different frequencies. 5 Dependence of the trajectory of body movement on the chosen frame of reference. 6 Measurement of forces. 7 Adding forces. 8 Newton's tube. 9 Inertia of bodies. 10 Weightlessness and the weight of a moving body with acceleration. 11 Types of deformation of bodies. 12 Types of equilibrium. 13 Stability of equilibrium of a body having an area of support. 14 Comparison of masses of bodies in interaction. 15 Reciprocal transformations of potential and kinetic energy. 16 Free vibrations of thread and spring pendulums
Educational projects	
Section 2. Elements of the special theory of relativity	
The knowledgeable component Operates the basic concepts of SRT, the relativity of length and intervals of time, understands the limits of application of the laws of classical and relativistic mechanics. ***The active component*** Applies the postulates of SST, relativistic law of addition of velocities. Determination of total and kinetic energy of a body within the framework of SRT.	The prerequisites for the emergence of the special theory of relativity (SRT). A. Einstein's principle of relativity. The basic principles of the special theory of relativity. Relativity of simultaneity of events. Relativity of intervals of length and time. Relativistic law of velocity addition. Total and kinetic energy of a moving body, rest energy. Main consequences of SRT and their experimental proves.
Educational projects	
Section 3. Molecular physics and thermodynamics	
The knowledgeable component Operates the concepts and definitions: Basic principles of MKT; ideal gas, gas pressure, gas laws, basic equation of MST, equation of state of ideal gas, isoprocesses, saturated and unsaturated steam, absolute and relative humidity, surface tension of liquid, wetting, capillary phenomena, mechanical stress, Hooke's law, Young's module, phase equilibrium and phase transitions, triple point, internal energy, gas work, first law of thermodynamics, adiabatic process, principle of heat machines, efficiency of heat engine. ***The activity component*** Solves problems on application of the basic equation of the MKT of gases, equation of	The main points of the molecular-kinetic theory (MKT) of the structure of matter. Masses and dimensions of atoms and molecules became Avogadro. Ideal gas as a physical model. Pressure of gases. Basic equation of MKT of gases. Temperature. Brownian motion, diffusion. Equation of state of ideal gas. Isoprocesses. Velocities of gas molecules and their (velocity) measurements. Stern experiment. Properties of saturated and unsaturated vapour. Humidity of air, its measurement. The dew point. Equilibrium of phases and phase transitions. Structure of liquids. Surface tension of liquids. Wetting. Capillary phenomena. Rigid bodies (crystalline and amorphous). Monocrystals, polycrystals. Anisotropy of crystals. Types of deformation of rigid bodies. Mechanical strain of rigid bodies. Hooke's law, Young's modulus. Mechanical properties of rigid bodies, thermal expansion. Liquid crystals and their properties.

state of gas and gas laws, properties of saturated steam and determination of air humidity; on surface tension of liquids, capillary phenomena; on application of Hooke's law, first law of thermodynamics and formulae of heat machine efficiency. Applies the first law of thermodynamics to isoprocesses in an ideal gas, to the adiabatic process. Experimentally measures air humidity, surface tension, Young's modulus, checks gas laws.	Basic concepts of thermodynamics. Internal energy. First law of thermodynamics. Quantity of heat and work in thermodynamics. Application of the first law of thermodynamics to isoprocesses in an ideal gas. The adiabatic process. Heat engines. Reversible and irreversible processes. Second law of thermodynamics. Cycles of heat machines. Efficiency of heat machines. The Carnot cycle. Principle of operation of a refrigeration machine. **Suggested demonstrations.** 1 The Brownian motion model. 2 Iso-processes in gases. 3 Properties of saturated steam. 4 Design of a psychrometer. 5 Boiling of water at reduced pressure. 6 Reduction of soap film area. 7 Capillary phenomena. 8 Types of deformation of rigid bodies. 9 Thermal expansion of rigid bodies. 10 Change in the temperature of a gas during an adiabatic process. 11 Models of different types of heat engines.
Educational projects	
Section 4. Electric field	
The knowledgeable component Operates the basic definitions: electric field, intensity, superposition principle, lines of force, dipole, dielectric permittivity, potential, electrical capacitance of a capacitor, energy of an electric field. ***The active component*** Solves problems on the application of the superposition principle, force lines; finds the strength and potential of the electrostatic field of several charges, and of charged conductors of symmetrical shape. Determines the capacitance of a capacitor and batteries of capacitors with different types of capacitor connections; energy of a charged capacitor; energy of an electric field..	Electric field. Electric field strength. Lines of force of the electric field. Point charge as the electrical analogue of a material point. Electric field of point charges. The principle of superposition, the electric field of a system of charges. Conductors and dielectrics in an electrostatic field. Concept of the dipole. Dielectric permittivity of matter. Work in moving a charge in a homogeneous electrostatic field. potential nature of electrostatic field. potential. Potential difference. Equipotential surfaces. Relation between the strength of a homogeneous electric field and the potential difference. Measurement of elementary electric charge. Experiment of Milliken. Electric capacitance. Capacitors and their use in engineering. Types of capacitors. Capacitance of a flat capacitor. Connection of capacitors. Energy of a charged capacitor. Energy of an electric field. **Suggested demonstrations.** 1 Interaction of charged bodies. 2 Electric field lines of force. 3 Electrostatic shielding. 4 The construction and functioning of different types of condenser. 5 Energy of a charged condenser
Educational projects	
General lessons	
RESERVE	

Grade 11 (3 hours per week; total 105 hours)

Expected outcomes of learning and cognitive activities	Guidelines for the content of the learning material
Section 1. Electrodynamics	
The knowledgeable component Operates concepts and definitions: electric current, current source, Ohm's law, shunt, additional resistance, current work and power, free charge carriers, superconductivity, electrolysis, laws of electrolysis, thermionic emission, electron-hole transition, magnetic field, magnetic field induction, Ampere force, Lorentz force; dia-, para- and ferromagnetics; electromagnetic induction, Lenz rule, self-induction, inductance, electromagnetic induction law, eddy electric field, eddy currents, magnetic field energy. ***The activity component*** Solves problems on application of knowledge of direct current, electric and magnetic field, Ohm's law for a complete circle, Joule-Lenz law, formulae for Ampere force and Lorentz force, Lenz rule, electromagnetic induction law, on application of inductance, on calculation of magnetic field energy, on movement of charged particles in uniform magnetic field Makes simple electric circuits; measures current, voltage, resistance, EMF. Observes the safety rules for the use of electrical devices***.***	Electric current, electrical circuit. Direct current. Sources of current. Electromotive force (EMF). Ohm's law for a complete circle. Short circuit. Determination of electrical resistance of a circuit with series and parallel connection of conductors. Measurement in electrical circuits, shunts and auxiliary supports. Work and power of electric current, thermal effects of current. Safety in use of electrical devices. Comparative characterisation of different media through which electric current can flow (metals, electrolyte solutions and melts, gases, plasma, semiconductors) free charge carriers, dependence of resistivity on temperature. Superconductivity. Electrolysis, laws of electrolysis. Types of independent discharge in gases. Application of electric current in different media. Thermoelectronic emission and current in vacuum, its application. Operation principle of electron-vacuum devices on the example of vacuum diode. Integral and impurity conductivity of semiconductors, electron-hole transition and its properties. Semiconductor diode. Semiconductor technologies and the element base of modern computer engineering. V.E. Lashkarev - the first researcher of p-n junction. Magnetic interaction and magnetic field. Induction of magnetic field. Magnetic moment of frames with current. The action of a magnetic field on a current frame. Magnetic field of solenoids. Ampere force and Lorentz force. Interaction of currents. Applications of the action of the magnetic field on the frame with current in electrical measuring instruments and electric motors. motion of a charged particle in a uniform magnetic field. Magnetic properties of matter. Dia-, para- and ferromagnetics. Dependence of magnetic parameters of substances on temperature. Use of magnetic materials. Experiments of M. Faraday. Electromagnetic induction. Lenz's rule. The law of electromagnetic induction. Self-induction. self-induction EMF, inductance. Vortex (induction) electric field. Eddy currents. The energy of the magnetic field of a coil with current. D. Maxwell's hypothesis. Interrelation of electric and magnetic fields as a manifestation of the existence of the magnetic field. and magnetic fields as a manifestation of the existence of an electromagnetic field. **Suggested demonstrations.** 1 Electric current as a function of source electromotive force and circuit impedance. 2 Effect of a magnetic field on a current. 3 Coils interacting with a current. 4 Electromagnetic induction, Lenz's rule. 5 Law of electromagnetic induction. 6 Self-induction phenomenon. 7 Dependence of coil inductance on core material. 8 Eddy currents. 9 Magnetic field energy
Section 2. Electromagnetic oscillations and waves	
The knowledgeable component Uses basic concepts and definitions: oscillating circuit, free and forced electromagnetic oscillations, Thomson formula, effective values of voltage and current; active, capacitive,	An oscillating circuit. The occurrence of free electromagnetic oscillations. Harmonic electromagnetic oscillations. Thomson formula. Energy conversion during free electromagnetic oscillations. Alternating current as forced electromagnetic oscillations. Capacitor and coil in an alternating current circuit. Active, capacitive and inductive supports. Operation and power of alternating current. Effective values of voltage and current. Transformers. Generation, transmission and use of alternating current energy.

inductive supports; operation and power of alternating current, transformer, modulation, principles of radiotelephone communication. ***The activity component*** Solves problems by applying Thomson's formula, effective values of current and voltage, transformation ratio. Explains the formation of electromagnetic waves and the principles of radiotelephone communication.	Electromagnetic waves, their formation and propagation. Conclusions from Maxwell's theory, experiments of Hertz. Rapidity of propagation of electromagnetic waves. Principles of radio telephone communication. Radio broadcasting and television. **Suggested demonstrations**. 1 Low frequency free electromagnetic oscillations in an oscillating circuit. 2 Principle of operation of an alternator. 3 Oscillogram of an alternating current. 4 Emission and reception of electromagnetic waves and their properties.
Section 3. Optics	
The knowledgeable component Operates the basic concepts of geometric optics: light beam, reflection and refraction laws, refractive index, total reflection, refraction, image, lenses. Operates the concepts of wave and quantum optics: coherence, interference and diffraction of light, Huygens-Fresnel principle, diffraction grating, spectroscope, quantum, photon, Planck constant, photo effect, photo effect laws, Einstein equation for photo effect, X-ray wave duality of light. ***The activity component*** Solves problems to apply the laws of geometric optics, to calculate optical systems, to relate the length and frequency of light waves, conditions for interference maxima and minima, to apply the diffraction grating formula, Einstein's equation for the photoelectric effect. Uses optical instruments, measures light wavelengths.	The development of ideas about the nature of light. Light as an electromagnetic wave. Propagation, absorption and scattering of light. Geometric optics as a limiting case wave optics. Laws of geometrical optics. Refractive index, its relation to the speed of light in a medium. Refraction and mirages. Imaging. Lenses, optical systems and optical instruments. Coherence of light waves. Peculiarities of laser radiation. Interference of light. Huygens-Fresnel principle. Diffraction of light. Diffraction grating. Spectroscope. Continuous spectrum of light. Radiation spectrum of an absolutely black body. Planck formula. Quantum properties of light. Light quanta. Planck's steel. Photo effect. Experiments of O.G. Stoletov. Laws of photoeffect. Einstein's theory, photoeffect equation. Photon. Photoresistors and photocells. Application of photoelectric effect, solar cells. X-ray radiation, its application in medicine and engineering. Works of I. Puluj. Photochemical action of light. Corpuscular-wave dualism of light. The scale of electromagnetic waves. Properties of electromagnetic waves in different ranges. Electromagnetic waves in nature and technology. **Suggested demonstrations**. 1 Reflection and refraction of light. 2 Total reflection of light. 3 Light guides. 4 Imaging with a lens. 5 Interference of light. 6 Diffraction of light on obstacles of different shapes and sizes. 7 Dispersion of light, obtaining a continuous spectrum. 8 Photoelectric effect.
Chapter 4. Atomic and Nuclear Physics	
The knowledgeable component Operates with concepts and definitions: planetary model of the atom, Bohr's quantum postulates, energy levels of atoms, lasers, corpuscular-wave dualism, line spectra, spectral analysis, atomic binding energy, mass defect, radioactivity, radioactive decay law, half-life, nuclear separation chain reaction, nuclear reactor, elementary particles	The development of ideas about atoms. Rutherford's experiment. Planetary model of the atom, its qualitative justification on the basis of Bohr's postulates. Energy levels of the atom. De Broglie hypothesis. Corpuscular-wave duality as a general property of matter. Emission and absorption of light by atoms. Linear spectra. Principle of laser action. Interaction between nucleons in nucleus, stability of atomic nuclei. Binding energy of atomic nucleus. The defect of masses. Natural and artificial radioactivity, types of radioactive radiation. Law of radioactive decay. Production and use of radionuclides. Methods of registering ionizing radiation and protection from it. Dosimeter. Nuclear reactions, methods of releasing nuclear energy. Nuclear fission chain reaction and thermonuclear reactions. Nuclear reactor, prospects of building a fusion reactor.

The activity component Solves problems applying Bohr's quantum postulates, de Broglie formulae, on the binding energy of atomic nuclei and mass defect. Able to use a dosimeter.	Elementary particles, their classification. The concept of fundamental interactions. **Suggested demonstrations**. 1 Photographs of tracks of charged particles. 2 A Wilson chamber. 3 Dosimeter.
Summary and review of educational material based on achievements in physics and technology.	
The knowledgeable component Uses concepts from different areas of physics to explain the physical basis for the operation of one of the named advances in modern technology. ***The activity component*** Demonstrates the ability to take advantage of modern technology.	An indicative list of advances in modern technology: 1. Recording and reading information via magnetic, solid state and other media. 2. Principle of digital camera operation. 3. mobile communication and GPS navigation. 4. Elementary particle accelerators. 5. Types of electric energy batteries. 6. Liquid crystal displays.
Topics of experimental (laboratory workshop, frontal laboratory, practical) works in physics **(the list of works is approximate)** 1 Checking the laws of series and parallel connection of conductors. 2 Extension of the measurement limits of an ammeter and a voltmeter. 3 Determining the EMF and resistance of a current source. 4 Determination of the temperature coefficient of resistance of a metal (semiconductor). 5 Investigation of an electrical "black box" containing a circle of resistors. 6 Measurement of coil inductance. 7 Investigation of refraction of light. 8 Determination of optical power of a lens and lens system. 9 Investigation of optical systems consisting of mirrors and lenses. 10 Observation of interference and diffraction of light. 11 Determination of the wavelength of light. 12 Modelling radioactive decay. 1 13 Investigation of tracks of charged particles from photographs.	
RESERVE	