Postgraduate Track Program: Physical Sciences and Technology

1. Olympiad Winner's Skill Set

To win the Olympiad, you should have a firm grasp of concepts and techniques related to physical sciences and technology, specifically:

- fundamental knowledge in physics (mechanics, thermodynamics, optics, electrical engineering and electronics, atomic, molecular and chemical physics, condensed matter physics, quantum technologies), essential for studying specialized physical and technical disciplines;
- basic knowledge of fundamental mathematics and mathematical models of physical and technical problems, along with the ability to interpret findings while considering the limitations of the models;
- skills in applying basic physical models in theoretical analysis, describing typical physical processes and phenomena through basic theoretical models, and interpreting the results of model analysis, considering the limitations of the applied methods.
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2. List of Eligible Study Programs

2.1. List of Master's Programs

03.04.02 Physics
12.04.03 Photonics and Optical Informatics
28.04.04 Nanosystems and Nanomaterials
11.04.04 Electronics and Nanoelectronics
04.04.02 Chemistry, Physics, and Mechanics of Materials
11.04.01 Radio Engineering
11.04.03 Design and Technology of Electronic Systems
12.04.01 Instrumentation Engineering
12.04.05 Laser Equipment and Laser Technology
28.04.01 Nanotechnology and Microsystem Engineering

2.2. List of Doctoral Programs

1 1 6 Computational Mathematics
1 1 8 Mechanics of Deformable Solids
1 3 2 Instruments and Methods of Experimental Physics
1 3 3 Theoretical Physics
1 3 4 Radiophysics
1 3 5 Physical Electronics
1 3 6 Optics
1 3 8 Condensed Matter Physics
1 3 11 Physics of Semiconductors
1 3 13 Electrophysics, Electrophysical Installations
1 3 14 Thermophysics and Theoretical Thermal Engineering
1 3 16 Nuclear and Molecular Physics

1 3 17 Chemical Physics, Combustion and Explosion, Physics of Extreme States of Matter
1 3 19 Laser Physics
1 3 20 Crystallography, Physics of Crystals
1 4 4 Physical Chemistry
2 4 1 Theoretical and Applied Electrical Engineering
2 4 2 Complexes and Systems in Electrical Engineering

3. Content

Mechanics

1. Mechanical motion, trajectory, displacement, velocity and speed, acceleration
2. Tangential and normal acceleration
3. Translational motion of a rigid body
4. Rotation around a fixed axis, angular velocity, angular acceleration
5. Relationship between angular and linear velocities and accelerations
6. Newton's first law, inertial frames of reference
7. Newton's second law
8. Newton's third law
9. The law of universal gravitation
10. Elastic forces
11. Frictional forces
12. Force of gravity and weight
13. Non-inertial reference frames, forces of inertia
14. The centrifugal force of inertia
15. The Coriolis force
16. Kinetic energy
17. Work and power
18. Potential energy in an external force field
19. Potential energy of interaction
20. Total mechanical energy, the law of conservation of energy
21. The momentum of a system of particles, law of momentum conservation
22. Angular momentum, torque, law of angular momentum conservation
23. Angular momentum of a rigid body rotating around a fixed axis, moment of inertia
24. Kinetic energy of a rigid body rotating around a fixed axis
25. Mechanics of an incompressible fluid, flow continuity
26. Bernoulli's equation
27. Movement of bodies in a liquid, added mass
28. Einstein's principle of relativity, constancy of the speed of light
29. Relativistic expressions for the energy and momentum of a particle; momentum and energy conversion
30. Rest energy, mass-energy equivalence
31. Harmonic vibrations

32. Mathematical and physical pendulums
33. Damped oscillations, attenuation coefficient, quality factor
34. Forced vibrations, resonance, resonance curves

Thermodynamics

1. Atomic-molecular structure of matter; molecular masses and sizes
2. Thermodynamic equilibrium
3. Thermodynamic quantities as average values of macroscopic parameters in thermodynamic equilibrium
4. Thermodynamic state of a system, thermodynamic process
5. Internal energy of a system, work, and quantity of heat
6. First law of thermodynamics
7. Work done by a body upon a change in volume
8. Temperature
9. Equation of state of an ideal gas
10. Internal energy and heat capacity of an ideal gas
11. Polytropic processes
12. Van der Waals gas; its internal energy and equations of state
13. Entropy and its main properties
14. Second law of thermodynamics
15. Statistical interpretation of the second law of thermodynamics
16. Coefficient of performance (COP) of a heat engine
17. Carnot cycle, efficiency of a Carnot cycle, Carnot theorem
18. Equilibrium condition. Chemical potential
19. Possibility of processes. Criteria for different conditions
20. Surface tension
21. Pressure under a curved liquid surface
22. Phenomena at liquid-solid interfaces
23. Capillary phenomena
24. Evaporation and condensation
25. Melting and crystallization
26. Clapeyron-Clausius equation
27. Triple point, phase diagrams

Electrical and Electronic Engineering

1. Electric charge, the law of electric charge conservation
2. Coulomb's law
3. Electric field, electric field strength
4. Field due to point charge
5. Principle of electric field superposition
6. Electric field potential
7. Interaction energy of a system of charges
8. Relation between electric field strength and potential

9. Gauss's theorem for electric field strength
10. Electric field of one and two charged planes
11. Electric field of charged cylindrical and spherical surfaces
12. Electric field of a charged ball
13. Multipole expansion for electric field; dipole and quadrupole approximations
14. Force and torque on a dipole in an external electric field; dipole energy in an external electric field
15. Polarization of dielectrics
16. Electric field inside a dielectric
17. Free, bound, and total charge
18. Electric displacement vector, permittivity
19. Equilibrium of charges on a conductor
20. Conductor in an external electric field
21. Electric capacity
22. Capacitors
23. Capacity of a flat capacitor
24. Energy of a charged capacitor
25. Electric current
26. Continuity equation for an electric charge
27. Electromotive force
28. Ohm's law, resistance of conductors
29. Multi-loop circuits, Kirchhoff's rules
30. Power of a current, Joule-Lenz law
31. Interaction of currents
32. Magnetic field, induction of magnetic field
33. Principle of magnetic field superposition
34. Biot-Savart law
35. Magnetic field of a line current and a circular current loop
36. Lorentz force
37. Ampere's law
38. Force exerted on a current circuit in a non-uniform magnetic field
39. Divergence and curl of a magnetic field
40. Magnetic field of a solenoid and a toroid
41. Magnetic dipole, force on a dipole in an external magnetic field
42. Magnetic field in a substance, bound currents, magnetization, magnetic field strength
43. Diamagnetic and paramagnetic materials
44. Phenomenon of electromagnetic induction
45. Lenz's law
46. Electromotive force of induction
47. Foucault's currents
48. Self-induction inductance
49. EMF of self-induction
50. Solenoid inductance, energy density of a magnetic field

51. Self-inductance and mutual inductance
52. Vortex electric field
53. Displacement current
54. Electromagnetic field

Optics

1. Elastic waves, longitudinal and transverse waves, wave equation
2. Plane monochromatic waves
3. Standing waves
4. Doppler effect for sound waves
5. Electromagnetic waves
6. Wave equation for an electromagnetic field in a homogeneous isotropic medium
7. Speed of electromagnetic waves
8. Monochromatic electromagnetic plane wave
9. Geometrical optics approximation, light rays, optical path length, Fermat's principle
10. Centered optical system
11. Thin lens
12. Electromagnetic wave interference
13. Interference of plane monochromatic waves, distance between fringes
14. Temporal coherence
15. Spatial coherence
16. Methods for observing light interference, Fresnel diffraction mirrors, the Fresnel biprism, Lloyd's mirror
17. Thin-film interference
18. Newton's rings
19. Anti-reflective coating
20. Michelson interferometer
21. Multipath interference
22. Light diffraction, Huygens-Fresnel principle
23. Fresnel zones
24. Fresnel diffraction on a round hole and a round disk
25. Zone plate
26. Fraunhofer single slit diffraction
27. Diffraction grating
28. Light polarization, natural and polarized light, partially polarized light
29. Polarizers, degree of polarization
30. Reflection and refraction polarization
31. Light reflection and refraction at a flat interface between media, Fresnel equations
32. Total internal reflection, tunnel effect
33. Dispersion of light; wave packet; propagation and spreading of a wave packet in a dispersive medium; phase; group velocity
34. Light absorption
35. Light scattering, Rayleigh's law, molecular scattering

36. Raman scattering
37. Thermal radiation, Stefan-Boltzmann law, Wien's law.
38. Planck's formula, Planck's constant.
39. Braking radiation, short-wave boundary of the bremsstrahlung X-ray spectrum.
40. Photoelectric effect, Stoletov's experiments.

Atomic, Molecular, and Chemical Physics

1. Atomic spectra.
2. Thomson’s atomic model.
3. Alpha particle scattering experiments, Rutherford's formula.
4. Postulates of Bohr’s model.
5. Wave properties of matter, De Broglie hypothesis.
6. Quantization of angular momentum, spin, spin of an electron, addition of angular momenta.
7. Distribution of electrons by energy levels in an atom, Pauli exclusion principle, shells and subshells, the electronic configuration of the atom, the periodic table.
8. Magnetic moment of an atom, orbital and spin magnetic moments, Bohr magneton.
9. Alkali metal spectra.
10. Normal and anomalous Zeeman effect.
11. X-ray spectra, line width.
12. Energy of a molecule.
13. Molecular spectra.
14. Composition of an atomic nucleus, atomic number and mass number, isotopes. Nuclear dimensions and masses.
15. Binding energy and mass defect.
16. Nuclear forces.
17. Radioactivity.
18. Types of radioactive processes.
19. Radioactive decay law.
20. Synthesis of nuclei.

Condensed Matter Physics

1. Crystalline state.
2. Types of crystal lattices.
3. Defects in crystals
4. Diffusion in solids.
5. Symmetry in crystals. Laws of symmetry.
6. Methods for studying the structure of solids: X-ray diffraction and electron microscopy.
7. Mechanical properties of solids.
8. Engineering and physical mechanical characteristics of solids.
9. Solid state spectroscopy.
10. Phase transitions in solids.
11. Phase diagrams of solids.

12. Phonon gas, heat capacity of the crystal lattice.
13. Debye approximation for calculating the heat capacity of a crystal lattice.
14. Einstein approximation for calculating the heat capacity of a crystal lattice.
15. Electron motion in the periodic field of a crystal lattice; band theory.
16. Energy zones in crystals. Metals, semiconductors, and dielectrics from the perspective of band theory.
17. Electrical conductivity of metals.
18. Superconductivity.
19. Heat capacity of metals.
20. Semiconductors.
21. Electrons and holes, semiconductor doping.
22. Statistics of charge carriers in intrinsic and impurity semiconductors.
23. Conductivity in semiconductors.
24. Heat capacity of semiconductors.
25. Dielectrics.
26. Contact phenomena.
27. P-n junction
28. Photoelectric effect in semiconductors.
29. Luminescence of solids.
30. Electromagnetic waves in a conductor.
31. Electromagnetic waves in a semiconductor.
32. Magnetic properties of solids.

Quantum Technologies

1. Generalized coordinates and velocities, number of degrees of freedom for a mechanical system.
2. Mechanical action, principle of least action, Lagrangian function, Lagrange's equations.
3. Generalized momentum, Hamiltonian function. Hamilton's equations.
4. Wave-corpuscle duality, wave field of probability.
5. Dynamic variables of quantum systems, measurement in quantum mechanics, physical quantities.
6. Mechanical state of quantum system, wave function.
7. Principle of superposition, complete set of physical quantities, basis set of states, wave function decomposition into a basis.
8. Schrödinger equation, Hamilton operator, probability flux density, standard requirements for the wave function.
9. Operators of physical quantities.
10. Commutator of operators of physical quantities, uncertainty relations.
11. The differentiation of operators with respect to time; constants of motion.
12. Matrices of operators of physical quantities, Heisenberg's representation.
13. Stationary states, energy representation.
14. Energy spectrum of a linear harmonic oscillator; particle in a rectangular quantum well, in a homogeneous field, and in a centrally symmetric field.

15. Stationary perturbation theory.
16. Momentum operator, its spectrum; states with a certain momentum value, momentum representation.
17. Angular momentum operator, non-commutativity of angular momentum projections on different axes; states with a certain value of the square of the angular momentum and its projection.
18. Tunneling.
19. The time-dependent perturbation theory.
20. Transitions between quantum states caused by a small harmonic perturbation, Fermi's rule.
21. Quasiclassical approximation, quasiclassical solutions of the Schrödinger equation, connection rules of quasiclassical solutions.
22. Bohr-Sommerfeld quantization rule.
23. Spin, its operators, wave-function of a particle with spin.
24. Eigen magnetic moment of a particle, its operator, and spectrum.
25. Energy spectrum of a particle in a homogeneous magnetic field, Landau quantization.
26. Principle of indistinguishability of identical particles, wave function of a system of non-interacting identical particles.
27. System of identical non-interacting fermions, Slater determinant, Pauli exclusion principle.
28. Exchange interaction.
29. Statistical averages of macroscopic quantities of quantum mechanical systems; statistical operators.
30. Gibbs distributions.
31. Planck distribution.
32. Bose-Einstein distribution.
33. Bose condensation.
34. Fermi-Dirac distribution.
35. Degenerate Fermi gas, its chemical potential, equation of state and heat capacity.
36. Nondegenerate ideal gas, transition from the Fermi-Dirac and Bose-Einstein distributions to the Boltzmann distribution.
37. Maxwell's equations, electromagnetic field potentials, their gauge, equations for potentials, gauge invariance of Maxwell equations.
38. Radiation of the electromagnetic field by a linear antenna (oscillator) in the linear approximation; retarded scalar potential in the dipole approximation.
39. Electromagnetic field propagation in a medium with field sources, retarded and advanced potentials.
40. Oscillator radiation, Hertz vector, electromagnetic field in the near and far wave zones, radiation intensity of oscillator electric dipole.
41. Radiative friction, natural broadening of spectral lines.
42. Scattering of electromagnetic waves by free charges.

4. Recommended References

4.1. Reading List

Mechanics

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4. Savelyev I.V. Physics. A General course. Vol. 1: Mechanics and molecular physics. Part I: The physical fundamentals of mechanics. pp. 7-270. Mir Publishers. Moscow, 1989. 441 p. URL:https://archive.org/details/savelyev-physics-a-general-course-vol-1-mir/ (free access)	All
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3. Савельев И.В.. Курс общей физики (в 5-и томах). Т.1: Механика. СПб: Лань, 2022. 340 с. URL: https://www.litres.ru/i-v-savelev/kurs-obschey-fiziki-v-5-t-tom-1-mehanika-66009137/ (free access) or https://avidreaders.ru/book/kurs-obschey-fiziki-v-5-t.html (limited access) free access: https://obuchalka.org/20210301129695/kurs-obschei-fiziki-tom-1-mehanika-kolebaniya-i-volni-molekulyarnaya-fizika-savelev-i-v-1970.html and https://techlibrary.ru/	All
4. Савельев И.В. Сборник вопросов и задач по общей физике. Ч.1: Физические основы механики, стр. 14-70. СПб: Лань, 2022. 292 с. URL: https://www.litres.ru/i-v-savelev/sbornik-voprosov-i-zadach-po-obschey-fizike-66005701/ (limited access) or https://avidreaders.ru/book/sbornik-voprosov-i-zadach-po-obschey-2.html (limited access) free access: https://techlibrary.ru/	All
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Thermodynamics

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Optics

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4.2. Recommended Online Courses

Mechanics

Online courses in English	Link	Summary
How Things Work: An Introduction to Physics	https://ru.coursera.org/learn/how-things-work	The course consists of eight modules and introduces physics through everyday phenomena, such as ice skating, falling balls, Newton's third law, rotational and translational motion, friction forces, and the concepts of momentum and angular momentum.
Mechanics, Part 1	https://www.edx.org/course/introduction-to-mechanics-part-1	An introduction to mechanics, this course follows the standard university physics course of the first semester. It covers the fundamental concepts of mechanics and solutions to mathematical problems necessary for all STEM areas.
Mechanics, Part2	https://www.edx.org/course/mechanics-part-2-2	The course serves as an introduction to mechanics following the standard first-semester university physics course, teaching fundamental concepts and mathematical problem-solving skills required for all STEM fields.
Introduction to Mechanics	https://ru.coursera.org/specializations/introduction-to-mechanics	This course covers graphical and mathematical descriptions of movement, the nature of forces and how they affect movement, the use of energy and momentum in solving mechanics problems, and interactions and energies of gravitational interactions.
Physics	https://stepik.org/48615	This course centers on kinematics, thermodynamics, and electrostatics sections.
Online courses in Russian	**Link**	**Summary**
Университетские уроки физики:	https://openedu.ru/course/spbu/UNIPH	The course focuses on methods of scientific knowledge and the physical worldview, explores the mechanics of a material point and Newton's laws, and provides insights

механика (University physics class: Mechanics)	Y_MECH/?session=summer_2024	into mechanical work, changes, and the conservation of mechanical energy.
Физические эксперименты. Механика (physics experiments. Mechanics)	https://stepik.org/course/93413/promo?search=4732361248	The course delves into the basic laws of mechanics and thermodynamics, focusing on scientific methods of physics, their theoretical and experimental justification. It develops skills in applying the laws and methods of physics to solve theoretical, experimental, and applied problems, as well as in performing physical measurements and evaluating the results obtained. The course provides an understanding of the ideological and methodological aspects of the basic concepts of physics and their evolution.
Кинематика (Kinematics)	https://stepik.org/course/123832/promo?search=4732361253	In this course, the primary sections of kinematics are examined, and various kinematic problems are presented with examples that can be variously approached. Particular emphasis is placed on graphical solution methods.

Thermodynamics

Online courses in English	**Link**	**Summary**
Fundamentals of Macroscopic and Microscopic Thermodynamics	https://www.coursera.org/learn/macroscopic-microscopic-thermodynamics	This course explains the concept of temperature, thermodynamic pressure, and chemical potential in terms of postulates. It also summarizes the role of fundamental relationships in establishing relationships between atomic/molecular structure and macroscopic properties.
Ideal Gasses	https://www.coursera.org/learn/ideal-gases	This course analyzes the behavior of monatomic, diatomic and polyatomic ideal gasses under various conditions. It describes the difference between pure ideal gasses and mixtures of ideal gasses and their industrial applications. Additionally, it identifies the key components of the separation functions used to describe translational, rotational, vibrational, and electronic motion.
Introduction to Thermodynamics: Transferring Energy from Here to There	https://www.coursera.org/learn/thermodynamics-intro	This course offers the tools needed to analyze energy systems. In exploring energy systems and needs, it highlights the connections between energy and challenges related to clean water, health, food resources, and poverty.

Physics	https://stepik.org/48615	This course covers kinematics, thermodynamics, and electrostatics.
Thermodynamics	https://www.edx.org/course/thermodynamics	This course focuses on the precise definitions of terms and concepts used in thermodynamics. It also covers the three laws of thermodynamics (zero, first, and second) in detail, along with the properties of materials.
Online courses in Russian	**Link**	**Summary**
Методы молекулярной динамики в многоуровневом моделировании (Molecular dynamics modeling in multiscale modeling)	https://openedu.ru/course/mephi/mephi_mdmitmsm/	This course covers the physical foundations of molecular dynamics methods as applied in computer modeling the evolution of systems of various dimensions, from molecules to crystals. Topics include the description of interatomic interaction potentials, initialization procedures, selection of boundary conditions, algorithms for integrating equations of motion, thermodynamic ensembles, and methods for controlling temperature during molecular dynamics simulations.
Физическая химия. Термодинамика (Physical chemistry, Thermodynamics)	https://openedu.ru/course/misis/CHTHER/?session=fall_2024	This course examines the basic concepts, methods, and laws of thermodynamics, their application to the investigation of chemical reaction equilibria, phase equilibria, and electrochemical phenomena.
Термодинамика и молекулярная физика (Thermodynamics and molecular physics)	https://stepik.org/course/67117/promo?search=4732361241	This course provides an introduction to thermodynamics and molecular physics, covering key topics such as phase transitions, elements of statistical physics, transport phenomena, and the properties of solids and liquids.
Молекулярная физика и термодинамика (Molecular physics and thermodynamics)	https://stepik.org/course/6283/promo?search=4732361240	The course covers the basic concepts of molecular physics and thermodynamics, focusing on entropy, the relationship between microscopic distributions and thermodynamics, equilibrium establishment, and phase transitions.

Electrical and Electronic Engineering

Online courses in English	**Link**	**Summary**
Physics	https://stepik.org/48615	This course offers insights into kinematics, thermodynamics, and electrostatics.
Electrodynamics: An Introduction	https://www.coursera.org/learn/electrodynamics-introduction	The course bridges the gap between fundamental electromagnetism principles and their practical applications in fields such as materials science, physics, and chemistry, focusing on energy storage and collection.
Electrodynamics: Analysis of Electric Fields	https://www.coursera.org/learn/electrodynamics-analysis-of-electric-fields	This course explores various methods for calculating electric fields, including topics such as polarization, dielectrics, and the creation of dipoles by electric fields.
Electrodynamics: Electric and Magnetic Fields	https://www.coursera.org/learn/electrodynamics-electric-magnetic-fields	This course provides an understanding of magnetostatics, placing it in a broader context. In addition, it looks at the basics of electromotive force and how it can be used to create various devices.
Electrodynamics: In-depth Solutions for Maxwell's Equations	https://www.coursera.org/learn/electrodynamics-solutions-maxwells-equations	In this course, Maxwell's equations are examined and used to derive wave equations applicable to analyzing complex systems like oscillating dipoles. Additionally, the course covers AC circuits, including their simplification, solution, and practical application.
Electricity and Magnetism	https://stepik.org/course/176257	This course provides an overview of fundamental concepts in electricity and magnetism. It covers topics such as capacity and energy, the behavior of conductors and dielectrics, and the principles of direct current, including Ohm's Law and Joule-Lenz Law. It also explores currents in liquids and gasses, the properties and effects of magnetic fields, and the Lorentz force. Additionally, the course focuses on electromagnetic induction, alternating current, and the phenomena of electromagnetic oscillations and waves.
Online courses in Russian	**Link**	**Summary**
Электродинамика для естественных и технических факультетов	https://stepik.org/course/196752/promo?search=4732361259	This course delves into the principles of electrodynamics, starting with the electric field and electric potential, and advancing through topics such as conductors, dielectrics, and Gauss's theorem. It covers electrostatics equations, capacitance, and the energy of

(Electrodynamics of Students of Natural Sciences and Technology)		electric fields, as well as quasi-stationary currents. The course explores the magnetic field of quasi-stationary currents, magnetic fields in materials, electromagnetic induction, Maxwell's equations, and alternating current.
Физика, которую должен знать каждый. Часть 2 (Staples in Physics. Part 2)	https://openedu.ru/course/mephi/fkdzkp2/?session=fall_2024	This course provides an understanding of the transition from classical mechanics to thermodynamics, the principles of statistical physics, and the behavior of fields and waves in various physical systems.
Электродинамика (Electrodynamics)	https://openedu.ru/course/urfu/ELECD/	The course introduces the theory of electromagnetic waves, guided waves, and electromagnetic wave radiation, providing models and methods for calculating the field strength of electromagnetic waves across various ranges. It also lays the groundwork for further study in disciplines related to data transmission systems, including radio and wired communication, fiber-optic channels, high-frequency circuitry, antennas, devices, radar, and navigation and communication systems.
Физика в опытах. Часть 3. Электричество и магнетизм (Physics and experiments. Part 3. Electricity and magnetism)	https://openedu.ru/course/mephi/mephi_012_fvo3/	The course aims to familiarize students with the fundamental laws of physics through their experimental demonstration in physics experiments.

Optics

Online courses in English	**Link**	**Summary**
Optics and Modern Physics	https://www.edx.org/course/ap-physics-2-part-3-optics-and-modern-physics	This course covers the principles of geometric optics, light, and modern physics. Students explore the use of mathematical models and probability to describe properties at the quantum scale, and gain an understanding of how waves transfer energy and momentum over distances.
Vibrations and Waves	https://www.classcentral.com/course/youtube-ph2a-vibrations-and-waves-48197	This course aims to teach students the principles and applications of vibrations and waves. It provides an understanding of simple harmonic motion, damped and controlled harmonic oscillators, coupled oscillators, traveling waves, standing waves, wave interference, diffraction, and dispersion.

Oscillations and Waves	https://www.classcentral.com/course/youtube-core-physics-i-oscillations-and-waves-47657	This course covers topics such as simple harmonic oscillators, resonance, electromagnetic waves, the electromagnetic spectrum, interference, coherence, diffraction, standing waves, polarization, wave-particle duality, the Schrödinger wave equation, particles in potential, potential wells, and quantum tunneling.
Online courses in Russian	**Link**	**Summary**
Физика в опытах. Часть 4. Волны и оптика (Physics and Experiments. Part 4. Waves and Optics)	https://openedu.ru/course/mephi/FVO4VIO/	In this course, physics is showcased through experiments and lecture demonstrations that vividly illustrate the application and outcomes of fundamental physical laws.
Введение в физику. Часть 2 (Introduction to Physics. Part 2)	https://openedu.ru/course/spbu/PHYS2/?session=fall_2021	The course provides an understanding of fundamentals of physics through exploring topics such as statics, operation and power, optics, and modern materials and technology.
Оптика (Optics)	https://stepik.org/course/85243/promo?search=4732716291	The course covers three main areas: geometric optics, wave optics, and quantum optics.

Atomic, Molecular, and Chemical Physics

Online courses in English	**Link**	**Summary**
Particle Physics: An Introduction	https://www.coursera.org/learn/particle-physics	This course explores various aspects of particle physics and related fields. Beginning with foundational knowledge, it covers nuclear physics and the operation of accelerators and detectors. The course delves into the matter and forces described by the Standard Model of particle physics, examines methods for discovering new phenomena, and introduces dark matter and dark energy, two enigmatic components of the universe.
Understanding Modern Physics II: Quantum Mechanics and Atoms	https://www.coursera.org/learn/understanding-modern-physics-2-quantum-mechanics-and-atoms	This course explores how the quantum world differs from everyday experience and why quantum mechanics is essential. It covers the fundamental description of atoms, explaining why they do not collapse and what atomic states are. Additionally, it investigates the nature of quantum information and demonstrates how it is

		fundamentally richer and more complex than classical information.
Nuclear physics: Fundamentals and Applications	https://www.classcentral.com/course/youtube-nuclear-physics-fundamentals-and-applications-47823	This course provides an introductory, but still rigorous description of both experimental and theoretical aspects of the modern understanding of nuclei and their interactions.
Online courses in Russian	**Link**	**Summary**
Молекулярная физика (Molecular Physics)	https://stepik.org/course/85579/promo?search=4732833880	The course is devoted to thermal processes, covering Maxwell and Boltzmann distributions, the equipartition theorem, real gasses, phase transitions, and transport phenomena.
Физика в опытах. Часть 5. Атомная физика (Physica and Experiments. Part 5)	https://openedu.ru/course/mephi/ATPHYS/	The purpose of this course is to familiarize students with the basic laws of physics through experimental demonstration in physics experiments.
Ядерная физика (Nuclear Physics)	https://openedu.ru/course/spbu/PHYSNU/?ysclid=lzyd211r5j922526213	In addition to the standard topics covered in a traditional nuclear physics course, this course includes sections that reflect the current state of the field, its challenges, and future prospects. The lectures feature original research findings often overlooked in many textbooks, providing deep insights into the phenomena being studied.

Condensed Matter Physics

Online courses in English	**Link**	**Summary**
Solid State Physics	https://ocw.tudelft.nl/courses/solid-state-physics/	The course starts with crystallography, followed by the basic principles of quantum mechanics, condensed matter physics, band structure, and the relationship with the electrical properties of solid-state materials.
Structure of Matter: Atoms, Molecules, Nanomaterials. Part 1	https://openedu.ru/course/spbu/CHEM_ENG1/?session=spring_2023	This course is a systematic exploration of Mendeleev's periodic law, the properties of substances and materials in different states, and the relationship between the electronic structure of atoms and molecules. It also covers contemporary advancements in creating functional materials with specific properties and

		introduces the fundamentals of the digital economy within the field of chemical sciences.
Structure of Matter: Atoms, Molecules, Nanomaterials. Part 2	https://openedu.ru/course/spbu/CHEM_ENG2/?session=spring_2023	The course focuses on Mendeleev's periodic law, the properties of substances and materials in different states, and the connection between the electronic structure of atoms and molecules. It also covers recent advancements in the development of functional materials with specific properties and introduces the basics of the digital economy in chemical sciences.
Online courses in Russian	**Link**	**Summary**
Основы физики конденсированного состояния вещества (Basics of Condensed Matter Physics)	https://teach-in.ru/course/ofksv?ysclid=lxlnez0foy404109849	The course covers the origins of condensed matter physics and fundamental concepts of the electronic theory of solids, including band structure formation and crystal lattice vibrations. It also examines the key characteristics of various materials, such as semiconductors, magnetic systems, and superconductors. Additionally, the course introduces the physics of disordered systems, including polymer physics, and explores the effects of self-organization in condensed matter.
Физика в опытах. Часть 3. Электричество и магнетизм (Physics and Experiments. Part 3. Electricity and	https://openedu.ru/course/mephi/mephi_012_fvo3/	The course aims to familiarize students with the fundamental laws of physics through their experimental demonstration in physics experiments.
Строение вещества: от атомов и молекул до материалов и наночастиц (Structure of Matter: From Atoms and Molecules to Materials and Nanoparticles)	https://openedu.ru/course/spbu/CHEM2/?session=spring_2021	The course focuses on Mendeleev's periodic law, the properties of substances and materials in different states, and the connection between the electronic structure of atoms and molecules. It also covers recent advancements in the development of functional materials with specific properties and introduces the basics of the digital economy in chemical sciences.

Введение в материаловедение (Introduction to Materials Science)	https://openedu.ru/course/misis/MATSC1/?session=spring_2024	The course provides insights into the scientific foundations of materials science and methods of materials research.

Quantum Technologies

Online courses in English	**Link**	**Summary**
Introduction to Classical Mechanics	https://www.classcentral.com/classroom/youtube-introduction-to-classical-mechanics-47378	This is a detailed course containing 68 lessons on topics such as classical mechanics, Euler's theorem, Hamiltonian mechanics, harmonic oscillators, etc.
StanfordOnline: Quantum Mechanics for Scientists and Engineers 1	https://www.edx.org/learn/quantum-physics-mechanics/stanford-university-quantum-mechanics-for-scientists-and-engineers-1	This course provides a meaningful introduction to quantum mechanics and how to use it.
Statistical Physics of Non-Interacting and Interacting Systems	https://onlinecourses.nptel.ac.in/noc24_ph46/preview	The course explains the basic concepts of statistical physics from a formal perspective, focusing on ensembles and the ergodic hypothesis. Quantum statistical mechanics is presented as an extension of classical ideas, incorporating particle indistinguishability and applying to the “microscopic world” of bosons and fermions. Topics include Bose-Einstein condensation, the magnetism of fermionic systems, Chandrasekhar limit, and the thermodynamics of black holes. Additionally, the course explores interacting systems through the Ising and Heisenberg models and discusses specialized techniques such as the Bethe ansatz.
Electromagnetic Theory	https://www.classcentral.com/classroom/youtube-physics-electromagnetic-	The course consists of 40 lectures, covering topics such as electric field and potential, Poisson and Laplace equations, magnetic vector potential, Faraday's law and inductance, and Maxwell's equations.

	theory-47544/60d2b6e02c781	
Selected Chapters of Quantum Mechanics for Modern Engineering	https://openedu.ru/course/misis/QMEC/	This course introduces the basic principles of quantum mechanics, giving an idea of the current problems of quantum computer science and related applications in condensed matter physics.
Online courses in Russian	**Link**	**Summary**
Квантовая механика (Quantum Mechanics)	https://teach-in.ru/course/quantum-mechanics-petrov	This course provides an understanding of the microcosm phenomena, aiding participants in solving a wide range of fundamental and applied problems in various fields of physical chemistry.
Теоретическая механика (Theoretical Mechanics)	https://teach-in.ru/course/theoretical-mechanics	The course examines the primary methods for analytically describing the motion of elementary mechanical systems, including the Lagrange, Hamilton, and Hamilton-Jacobi methods. It explores the relationship between conservation laws and the symmetries of space and time, and demonstrates how the principle of least action, a fundamental concept in mechanics, contributes to the development of the canonical transformation method. Additionally, the course analyzes the applications of these methods to systems with Coulomb interactions, such as atoms and molecules.
Модели и методы аналитической механики (Analytical Mechanics: Models and Methods)	https://openedu.ru/course/ITMOUniversity/MANMEH/?session=self_2024	The course examines methods for developing mathematical models of dynamic systems and their mathematical processing. It covers various issues related to the kinematic, static, and dynamic characteristics of robotic and instrumentation systems. Additionally, it addresses the laws and equations of analytical mechanics used to create mathematical models for the motion and equilibrium of technical objects.
Лекции по статистической физике (Lectures on Statistical Physics)	https://stepik.org/course/72317/promo	These lectures focus on distribution functions and key concepts in statistical physics, including quantum statistical physics. They also explore the properties and theories related to solid matter and the theory of fluctuations.
Классическая теория поля	https://teach-in.ru/course/classical-field-theory	The course is dedicated to fundamental topics in field theory, providing a contemporary introduction to the physics of fundamental interactions. It covers both the

(Classical Field Theory)		core concepts of classical field theory and basic models in elementary particle physics.