Bachelor's track program: Physics and Technology

1. Open Doors winner's skill set

Winning the Open Doors competition requires a firm grasp of:

- basic terms, concepts, and laws of physics;
- their theoretical and practical implications;
- their application in explaining natural phenomena.

The winner is expected to demonstrate a solid command of the following skills:

- analyzing physical systems and conditions;
- formulating typical problems in general physics using mathematical language;
- applying appropriate mathematical methods to solve these problems;
- presenting solutions in a logical and well-reasoned manner.

2. List of degree programs covered by the subject area

2.1.List of bachelor's degree programs

03.03.02 Physics
03.03.01 Applied Mathematics and Physics
11.03.04 Electronics and Nanoelectronics
12.03.01 Instrument Engineering
12.03.03 Photonics and Optical Computing
13.03.02 Electric Power and Electrical Engineering
16.03.01 Technical Physics

3. Content

Field of science 1: Mechanics

Mathematics

1. Numbers and calculations: Rational numbers; common and decimal fractions; percentages; infinite periodic fractions. Principal root; operations with principal roots. Power with an integer exponent; power with a rational exponent; properties of powers. Sine, cosine, and tangent of a numerical argument; arcsine, arccosine, arctangent of a numerical argument. Logarithm of a number; decimal and natural logarithms. Real numbers; arithmetic operations with real numbers. Approximate calculations; rounding rules; estimation and evaluation of calculation results. Transformation of expressions.
2. Equations and inequalities: Integer and fractional rational equations. Irrational equations. Systems and sets of equations and inequalities. Equations, inequalities, and systems with parameters.
3. Functions and graphs: Function; methods of defining a function; mutually inverse functions; even and odd functions; periodic functions. Domain and range of a function; zeros of a function; intervals of constant sign; intervals of monotonicity of a function; maxima and minima of functions; greatest and least value of a function on an interval.
4. Geometry: Coordinates and vectors.

Physics

1. Kinematics: Mechanical motion; relativity of mechanical motion; reference systems. Material point: radius vector and trajectory. Displacement. Velocity of a material point. Acceleration of a material point. Uniform rectilinear motion. Uniformly accelerated rectilinear motion. Free fall; acceleration due to gravity; motion of a body projected at an angle α to the horizontal. Curvilinear motion; motion of a material point along a circular path. Angular and linear velocity of a point; centripetal acceleration of a point.
2. Dynamics: Inertial reference systems; Newton's first law; Galileo's principle of relativity. Force; principle of superposition of forces. Newton's second law for a material point in an inertial

reference frame. Newton's third law for material points. Law of universal gravitation. Gravity; center of gravity of body; variation of gravity with altitude above planet's surface. Elastic force; Hooke's law. Friction; dry friction. Pressure.

3. Statics: Moment of force relative to axis of rotation. Center of mass of a body; center of mass of a system of material points. Equilibrium conditions for a rigid body in an inertial reference frame. Pascal's law. Pressure in liquid at rest in an inertial reference frame. Archimedes' law.

4. Conservation laws in mechanics: Momentum of a material point. Momentum of a system of bodies. Law of change and conservation of momentum. Work performed by a force during a small displacement. Power of force. Kinetic energy of a material point. Potential energy. Law of change and conservation of mechanical energy.

5. Mechanical oscillations and waves: Harmonic oscillations of a material point; amplitude and phase of oscillations; kinematic and energy descriptions; relationship between the amplitude of displacement oscillations of a material point and the amplitudes of its velocity and acceleration oscillations. Period of small free oscillations of a mathematical pendulum; period of free oscillations of a spring pendulum. Transverse and longitudinal waves; propagation velocity and wavelength; interference and diffraction of waves. Sound; speed of sound.

Field of science 2: Thermodynamics

Physics

1. Ideal gas model in thermodynamics; ideal gas equation of state; internal energy; expression for the internal energy of a monatomic ideal gas.

2. Isoprocesses in a rarefied gas with a constant number of molecules; graphical representation of isoprocesses.

3. Thermal equilibrium and temperature; heat transfer as a way of changing internal energy without doing work; convection, conduction, radiation.

4. Amount of heat; specific heat capacity of a substance; specific heat of vaporization; specific heat of fusion; specific heat of combustion of fuel; heat balance equation.

5. Elementary work in thermodynamics; calculating work from a process graph; first law of thermodynamics; second law of thermodynamics; irreversible processes.

6. Operating principles of heat engines; efficiency; maximum efficiency value; Carnot cycle.

Field of science 3: Electrical engineering and electronics

Mathematics

1. Basics of Mathematical Analysis: Derivative of a function; derivatives of elementary functions. Application of the derivative to the study of functions for monotonicity and extrema. Finding the largest and smallest values of a function on a segment.

Physics

1. Electric field: Electrification of bodies and its manifestations; electric charge; two types of charge; elementary electric charge; law of conservation of electric charge. Interaction of charges; point charges; Coulomb's law in a homogeneous substance with permittivity. Electric field; its effect on electric charges; electric field strength; point charge field; homogeneous electric field line patterns; electrostatic field potentiality. Potential difference and voltage; potential energy of charge in an electrostatic field; electrostatic field potential; relationship between field strength and potential difference for a homogeneous electrostatic field; principle of superposition of electric fields. Conductors in an electrostatic field; dielectrics in an electrostatic field; dielectric constant of a substance. Capacitor; capacitance of a capacitor; capacitance of a flat capacitor; parallel and series connections of capacitors; energy of a charged capacitor.

2. Laws of direct current: Electric current strength; conditions for the existence of electric current. Ohm's law for a section of a circuit. Electrical resistance; dependence of the resistance of a homogeneous conductor on its length and cross-section; specific resistance of a substance. Current sources; electromotive force (EMF) of a current source; internal resistance of a current

source. Ohm's law for a complete (closed) electric circuit. Parallel and series connections of conductors. Work of electric current. Joule-Lenz law. Electric current power. Thermal power released on a resistor. Power of a current source. Free carriers of electric charges in conductors; mechanisms of conductivity in solid metals, solutions and melts of electrolytes, gases; semiconductors; semiconductor diode.

3. Magnetic field: Mechanical interaction of magnets; magnetic field; magnetic induction vector; principle of superposition of magnetic fields. Magnetic field induction lines; magnetic field line patterns of bar and horseshoe permanent magnets. Oersted's experiment; magnetic field of a current-carrying conductor; patterns of magnetic field lines around a long straight conductor, a circular loop, and a current-carrying solenoid. Ampere force: direction and magnitude. Lorentz force: direction and magnitude.
4. Electromagnetic induction: Induced magnetic flux. Electromagnetic induction; induced electromotive force. Faraday's law of electromagnetic induction. Lenz's rule. Inductance; self-induction; self-induced EMF. Magnetic field energy of a current-carrying coil.
5. Electromagnetic oscillations and waves: Oscillatory circuit; free electromagnetic oscillations in an ideal oscillatory circuit. Thomson's formula; relationship between the amplitude of the capacitor charge and the amplitude of the current in free electromagnetic oscillations within an ideal oscillatory circuit.
6. Law of conservation of energy in an ideal oscillatory circuit. Forced electromagnetic oscillations; resonance. Alternating current; production, transmission, and consumption of electrical energy. Properties of electromagnetic waves; mutual orientation of vectors in an electromagnetic wave in a vacuum. Scale of electromagnetic waves.

Field of science 4: Optics
Mathematics

1. Numbers and calculations: Sine, cosine, and tangent of a numerical argument. Arcsine, arccosine, and arctangent of a numerical argument. Equations and inequalities. Trigonometric equations. Trigonometric inequalities.
2. Geometry: Figures on a plane. Straight lines and planes in space. Polyhedra.

Physics

1. Rectilinear propagation of light in a homogeneous medium; point source; light beam.
2. Laws of light reflection.
3. Construction of images in a plane mirror.
4. Laws of light refraction; ray path in a prism.
5. Ratio of frequencies and ratio of wavelengths when monochromatic light passes through the interface between two optical media.
6. Total internal reflection; limiting angle of total internal reflection.
7. Converging and diverging lenses; thin lens; focal length and optical power of a thin lens.
8. Thin lens formula; magnification given by a lens.
9. Path of a ray passing through a lens at an arbitrary angle to the principal optical axis.
10. Construction of images of a point and a straight-line segment in converging and diverging lenses and their systems.
11. Interference of light; coherent sources; conditions for observing maxima and minima in the interference pattern from two in-phase coherent sources.
12. Diffraction of light; diffraction grating; condition for observing the main maxima during normal incidence of monochromatic light with wavelength λ on a grating with period d.
13. Light dispersion.

Field of science 5. Atomic, molecular, and chemical physics

Physics

1. Molecular physics: Models of the structure of gases, liquids, and solids. Thermal motion of atoms and molecules in matter. Interaction of particles of matter. Diffusion. Brownian motion. Relationship between pressure and the average kinetic energy of molecular translational motion in an ideal gas. Relationship between gas temperature and the average kinetic energy of molecular translational motion in a gas.
2. Atomic physics: Planetary model of the atom. Bohr's postulates; emission and absorption of photons during the transition of an atom from one energy level to another. Line spectra. Spectrum of energy levels of the hydrogen atom.
3. Physics of the atomic nucleus: Heisenberg-Ivanenko nucleon model of the nucleus; charge of the nucleus; mass number of the nucleus; isotopes. Radioactivity. Law of radioactive decay. Nuclear reactions. Fission and synthesis of nuclei.

4. Preparation materials

4.1. Recommended reading

Field of science 1: Mechanics

Reading list in English
Urone P.P., Hinrichs R. Physics. Openstax. Rice University. 2020. 836 p.URL: https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Physics-WEB_Sab7RrQ.pdf
Giancoli D.C. Physics. Principles with Aplications. Pearson Education Inc. 2015. 983 p. URL: https://doctor2019.jumedicine.com/wp-content/uploads/sites/10/2019/09/Giancoli-Physics-Principles-With-Applications-7th-c2014-solutions-ISM.pdf
Landsberg G.S. Elementary Texybook on Physics. Volume 1. Mir Publishers. 1988. 557 p. URL: https://archive.org/details/LandsbergElementaryTextbookOnPhysicsVol1Mir1988/mode/2up

Field of science 2: Thermodynamics

Reading list in English
Urone P.P., Hinrichs R. Physics. Openstax. Rice University. 2020. 836 p.URL: https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Physics-WEB_Sab7RrQ.pdf
Giancoli D.C. Physics. Principles with Aplications. Pearson Education Inc. 2015. 983 p. URL: https://doctor2019.jumedicine.com/wp-content/uploads/sites/10/2019/09/Giancoli-Physics-Principles-With-Applications-7th-c2014-solutions-ISM.pdf
Nirenberg I., Kim J. Physics – Intermediate. CK-12 FlexBook. 2014. 578 p. URL: https://www.dropbox.com/scl/fi/48fj8gn00h43t7q866d69/Intermediate-Physics-Textbook-with-Solutions.pdf?rlkey=up34jqarnewipxqdij1z7sbyj&e=5&st=asozxx38&dl=0

Field of science 3: Electrical engineering and electronics

Reading list in English
Urone P.P., Hinrichs R. Physics. Openstax. Rice University. 2020. 836 p. URL: https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Physics-WEB_Sab7RrQ.pdf
Giancoli D.C. Physics. Principles with Aplications. Pearson Education Inc. 2015. 983 p. URL:

https://doctor2019.jumedicine.com/wp-content/uploads/sites/10/2019/09/Giancoli-Physics-Principles-With-Applications-7th-c2014-solutions-ISM.pdf
Landsberg G.S. Elementary Texybook on Physics. Volume 2. Mir Publishers. 1988. 447 p. URL: https://archive.org/details/LandsbergElementaryTextbookOnPhysicsVol2Mir1988

Field of science 4: Optics

Reading list in English
Urone P.P., Hinrichs R. Physics. Openstax. Rice University. 2020. 836 p.URL: https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Physics-WEB_Sab7RrQ.pdf
Giancoli D.C. Physics. Principles with Aplications. Pearson Education Inc. 2015. 983 p. URL: https://doctor2019.jumedicine.com/wp-content/uploads/sites/10/2019/09/Giancoli-Physics-Principles-With-Applications-7th-c2014-solutions-ISM.pdf
Landsberg G.S. Elementary Texybook on Physics. Volume 3. Mir Publishers. 1989. 567 p. URL: https://archive.org/details/LandsbergElementaryTextbookOnPhysicsVol3Mir1989

Field of science 5. Atomic, molecular, and chemical physics

Reading list in English
Landsberg G.S. Elementary Texybook on Physics. Volume 3. Mir Publishers. 1989. 567 p. URL: https://archive.org/details/LandsbergElementaryTextbookOnPhysicsVol3Mir1989
Urone P.P., Hinrichs R. Physics. Openstax. Rice University. 2020. 836 p.URL: https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Physics-WEB_Sab7RrQ.pdf
Giancoli D.C. Physics. Principles with Aplications. Pearson Education Inc. 2015. 983 p. URL: https://doctor2019.jumedicine.com/wp-content/uploads/sites/10/2019/09/Giancoli-Physics-Principles-With-Applications-7th-c2014-solutions-ISM.pdf

4.2. Recommended online courses

Field of science 1: Mechanics

Online courses in English	**Link**	**Course description**
Physics	URL: /stepik.org/course/48615/promo?search=4670275215	This course serves as an introduction to physics for students in science and engineering fields.
Mechanical principles	URL: /stepik.org/course/65434/promo?search=4670275216	This course provides instruction on applying the principles of mechanics to

		practical engineering problems.
Mechanics: Motion, Forces, Energy and Gravity, from Particles to Planets	URL: https://www.coursera.org/learn/mechanics-particles-s	This course is designed for high school students, applicants, and anyone interested in the fundamentals of physics.

Field of science 2: Thermodynamics

Online courses in English	Link	Course description
Physics	URL: https://stepik.org/course/48615/promo?search=4670275215	This course in physics is designed for students pursuing science and engineering, providing a foundation in key physical principles relevant to their fields.
Introduction to Thermodynamics: Transferring Energy from Here to There	URL: https://www.coursera.org/learn/thermodynamics-intro	This course offers an introduction to thermodynamics, focusing on the fundamental principles of energy transfer and conservation in physical and engineering systems.
General Physics: Thermodynamics and Molecular Physics (Dr. Andrey Vyshnevyi, fall 2021, lectures and seminars)	URL: https://lms.mipt.ru/local/playlist/view.php?search&chair=0&course=5329&teacher=0&semester=0&embedded=1&id=1550&searchpage=0	This course, designed for high school students, introduces the fundamentals of thermodynamics and molecular physics.

Field of science 3: Electrical engineering and electronics

Online courses in English	Link	Course description
Physics	URL: https://stepik.org/course/48615/promo?search=4670275215	This course serves as an introduction to physics for students in science and engineering fields.
General Physics: Introduction to Physics (Prof. Alexey Ilyin, fall 2021)	URL: https://lms.mipt.ru/local/playlist/view.php?search&chair=0&course=5330&teacher=0&semester=0&embedded=1&id=1552&searchpage=0	This course offers high school students a foundational introduction to the core concepts and principles of general physics.

Electricity and Magnetism	URL: https://stepik.org/course/176257/promo	This course is designed to introduce the fundamentals of electricity and magnetism, familiarizing students with the essential concepts and laws of electromagnetism.

Field of science 4: Optics

Online courses in English	Link	Course description
General Physics: Introduction to Physics (Prof. Alexey Ilyin, fall 2021)	URL: https://lms.mipt.ru/local/playlist/view.php?search&chair=0&course=5330&teacher=0&semester=0&embedded=1&id=1552&searchpage=0	This course offers high school students a foundational introduction to the core concepts and principles of general physics.
Optics 101 - Translating Theory into Practice	URL: https://www.classcentral.com/course/youtube-optics-101-translating-theory-into-practice-125868	This course offers insight into key concepts in optics, including the index of refraction, dispersion, reflection, interference, and polarization.
Optics and Modern Physics	URL: https://github.com/gabboraron/edX-Physics2_Part3-Optics_and_Modern_Physics?ysclid=mcqmg5sxbp523335843	This course covers optics and modern physics, exploring light and its interactions with various media, the atomic structure and phenomena, and contemporary applications of nuclear physics.

Field of science 5. Atomic, molecular, and chemical physics

Online courses in English	Link	Course description
Modern Physics	URL: https://www.youtube.com/watch?v=3lTQqEehEhI	This course covers current topics in atomic and molecular physics.
Atomic and Optical Physics	URL: https://mitxonline.mit.edu/courses/course-v1:MITxT+8.421x/	This course provides the foundations for contemporary research in selected areas of atomic and optical physics, including the quantum-mechanical behavior of atoms and photons.
Understanding Modern Physics II: Quantum	URL: https://www.classcentral.com/course/understanding-modern-physics-2-	This course provides an introduction to quantum mechanics, atomic physics, and

Mechanics and Atoms	quantum-mechanics--56555	quantum information, exploring how the quantum world differs from everyday experience and the necessity of quantum mechanics; describing atomic structure, the stability of atoms, and atomic states; and examining the nature of quantum information and its greater richness compared to classical information.