Master's, Doctoral and Post-doctoral Track Program: Physical and Technical Science

1. Open Doors winner's skill set

Winning the Open Doors competition:

- the ability to apply fundamental knowledge of physics— including mechanics, thermodynamics, optics, electrical engineering and electronics, as well as atomic, molecular, and chemical physics—for successful mastery of advanced disciplines in the physical and physical-technical sciences;

The winner is expected to demonstrate:

- the ability to use core mathematical knowledge to develop mathematical models for physical and engineering problems, and to interpret the results with consideration of their domains of applicability;
- proficiency in using physical models to predict the properties of systems and to solve both theoretical and applied problems in physics and engineering.

2. List of degree programs covered by the subject area

2.1. List of doctoral degree programs

1.3.1 Physics of space and astronomy
1.3.5 Physical Electronics
1.3.8 Physics of Condensed Matter
1.3.15 Physics of atomic nuclei and elementary particles, high energy physics
1.3.16 Atomic and molecular physics
2.2.2 Electronic component base of micro- and nanoelectronics, quantum devices
2.6.6 Nanotechnology and nanomaterials

2.2. List of master's degree programs

03.04.01 Applied Mathematics and Physics
03.04.02 Physics
04.04.02 Chemistry, Physics and Mechanics of Materials
11.04.02 Electronics and Nanoelectronics
12.04.03 Photonics and Optoinformatics
13.04.02 Electric Power and Electrical Engineering
16.04.01 Technical Physics

3.Content

Field of science 1: Mechanics

1. Kinematics of translational and rotational motion
2. Statics
3. Dynamics
4. Conservation laws
5. Fluid mechanics
6. Oscillatory motion
7. Solid body, elasticity
8. Special theory of relativity
9. Action principle
10. Lagrange formalism, Lagrange operator, Hamilton operator

Field of science 2: Thermodynamics

1. Thermodynamic systems: the concept of equilibrium

2. Thermodynamic functions and parameters of systems
3. Laws of thermodynamics
4. Equations of state of phases; Gibbs phase rule
5. Spontaneous and non-spontaneous processes; criteria of equilibrium; thermodynamic potentials
6. Phase transitions and phase equilibria
7. Surface phenomena
8. Statistical distributions

Field of science 3: Electrical engineering and electronics

1. Electrostatics. The main characteristics of charged systems and electric fields. Coulomb's Law
2. Electric field in continuous media. Dielectrics. Polarization. Electrical induction. The capacitor
3. A conductor in an electric field. The equilibrium of charges in the conductor. Electric current
4. Electrical circuit. Direct current. Ohm's Law. Kirchhoff's laws. The Joule-Lenz law
5. Interaction of currents. The magnetic field. Magnetic induction. The magnetic field in the medium
6. The magnetic properties of materials. Dia-, para-, and ferro-magnets
7. General classification of conductors
8. Alternating current. The impedance
9. Electrodynamics. Maxwell's equations

Field of science 4: Optics

1. Wave. Longitudinal and transverse waves. Monochromatic and non-monochromatic waves. The speed of wave propagation in the medium. Electromagnetic waves
2. Geometric optics. Lenses
3. Interference. Methods of observation
4. Diffraction. The Huygens-Fresnel principle. Diffraction on the hole and on the slit
5. Polarization
6. Reflection and refraction. Light absorption
7. Light scattering
8. Radiation. Photo Effect

Field of science 5: Atomic, molecular and chemical physics

1. Quantum wave dualism. De Broglie waves
2. The motion of the free quantum particle and the particle in a field. Schrodinger equation
3. Stationary and non-stationary states of quantum systems. Energy levels
4. The Rutherford atom model. The model of the Bohr atom. Atomic spectra
5. The distribution of electrons by energy levels. Electronic shells
6. Energy molecules. Molecular spectra
7. Atomic nucleus. Main features. Nuclear transitions and nuclear reactions. Nuclear fission and synthesis
9. Solid body. Crystal structure. Types of crystal lattices
10. Lattice defects and diffusion in a solid
11. Methods of structure characterization for the solid body. Spectroscopic properties of solids
12. Mechanical properties of solids
13. The thermal capacity of solids
14. The use of statistical distributions in solid state physics. Fermions and bosons. Particles and quasi-particles

15. Energy zones in crystals. Metals, semiconductors and dielectrics from the point of view of band theory
16. Theories of the conductivity of metals, electrolytes and semiconductors
17. Semiconductors and their properties. Contact properties, p-n transitions, photoelectric effect, luminescence
18. Scattering of electromagnetic waves by charged particles

4. Preparation materials

4.1. Recommended reading

Field of science 1. Mechanics

Reading list in English
1. Chen Min. Berkley Physics Problems with Solutions. New Delhi: Prentice Hall, 1974. 356 p. URL://https://archive.org/details/in.ernet.dli.2015.460169
2. Irodov I.E. Problems in General Physics. Part One: Physical fundamentals of mechanics. Moscow: Mir Publishers, 1988. 395 p. URL://https://archive.org/details/IrodovProblemsInGeneralPhysics
3. Kittel C., Knight W.D., Ruderman M.A., Helmholz A.C. and Moyer B.J. Berkeley Physics Course. Vol. 1: Mechanics. NY: McGraw-Hill, 1973, 426 p. URL://https://archive.org/details/BerkeleyPhysicsCourse
4. Savelyev I.V. Physics. A General course. Vol. 1: Mechanics and molecular physics. Part I: The physical fundamentals of mechanics. Mir Publishers. Moscow, 1989. 441 p. URL://https://archive.org/details/savelyev-physics-a-general-course-vol-1-mir/
5. Shankar R. Fundamentals of Physics I. Mechanics, Relativity, and Thermodynamics. New Haven and London: Yale University press, 2019. 496 p. URL://https://yalebooks.yale.edu/book/9780300243772/fundamentals-of-physics-i/

Field of science 2. Thermodynamics

Reading list in English
1. Chen Min. Berkley Physics Problems with Solutions. New Delhi: Prentice Hall, 1974. 356 p. URL://https://archive.org/details/in.ernet.dli.2015.460169/
2. lrodov I. E. Problems in General Physics, Part Two: Thermodynamics and molecular physics. Mir Publishers. Moscow, 1988. 395 p. URL://https://archive.org/details/IrodovProblemsInGeneralPhysics
3. Reif. F. Berkeley Physics Course, Vol. 5: Statistical Physics. NY: McGraw-Hill, 1967. 398 p. URL://https://archive.org/details/berkeleyphysicsc05kitt
4. Savelyev I.V. Physics. A General course. Vol. 1: Mechanics and molecular physics. Part II: Molecular physics and thermodynamics. Mir Publishers. Moscow, 1989. 441 p. URL:// https://archive.org/details/savelyev-physics-a-general-course-vol-1-mir/
5. Shankar R. Fundamentals of Physics I. Mechanics, Relativity, and Thermodynamics. New Haven and London: Yale University press, 2014. 496 p. URL://https://yalebooks.yale.edu/book/9780300243772/fundamentals-of-physics-i/

Field of science 3. Electrotechnics and Electronics

Reading list in English
1. Chen Min. Berkley Physics Problems with Solutions. New Delhi: Prentice Hall, 1974. 356 p URL://https://archive.org/details/in.ernet.dli.2015.460169/
2. lrodov I. E. Problems in General Physics. Part Three: Electrodynamics. Mir Publishers. Moscow, 1988. 395 p. URL://https://archive.org/details/IrodovProblemsInGeneralPhysics

3. Purcell E.M. Berkeley Physics Course, Vol. 2. Electricity and Magnetism. NY: McGraw-Hill Book Comp., 1965. 463 p. URL://https://archive.org/details/berkeleyphysicsc02kitt
4. Savelyev I.V. Physics. A General course. Vol. 2: Electricity and magnetism, waves, optics. Part I: Electricity and magnetism. Mir Publishers. Moscow, 1989. 507 p. URL://https://archive.org/details/SavelyevPhysicsGeneralCourseVol2
5. Shankar R. Fundamentals of Physics II. Electromagnetism, Optics, and Quantum Mechanics. Chapters 1-13. Yale University press, New Haven and London, 2020. 654 p. URL: Fundamentals of Physics II

Field of science 4. Optics

Reading list in English
1. Chen Min. Berkley Physics Problems with Solutions. New Delhi: Prentice Hall, 1974. 356 p URL://https://archive.org/details/in.ernet.dli.2015.460169/
2. Crawford F.S. Berkeley Physics Course, Vol. 3: Waves. NY: McGraw-Hill Book Comp., 1968. 625 p. URL:// URL: Waves berkeley physics course - volume 3 - Frank S. Crawford Jr.
3. lrodov I. E. Problems in General Physics. Part Four: Oscillations and waves, and Part Five: Optics. Mir Publishers. Moscow, 1988. 395 p. URL://https://archive.org/details/IrodovProblemsInGeneralPhysics
4. Savelyev I.V. Physics. A General course. Vol. 2: Electricity and magnetism, waves, optics. Part II: Waves and Part III: Optics. Mir Publishers. Moscow, 1989. 507 p. URL://https://archive.org/details/SavelyevPhysicsGeneralCourseVol2
5. Shankar R. Fundamentals of Physics II. Electromagnetism, Optics, and Quantum Mechanics. Yale University press, New Haven and London, 2020. 654 p. 5. URL://https://yalebooks.yale.edu/book/9780300243789/fundamentals-of-physics-ii/

Field of science 5. Atomic, molecular and chemical physics

Reading list in English
1. Charles Kittel. Introduction to Solid State Physics, John Wiley and Sons, Inc., 8th ed., 2005 URL:// http://metal.elte.hu/~groma/Anyagtudomany/kittel.pdf
2. Chen Min. Berkley Physics Problems with Solutions. New Delhi: Prentice Hall, 1974. 356 p URL://https://archive.org/details/in.ernet.dli.2015.460169/
3. lrodov I. E. Problems in General Physics, Part Six: Atomic and nuclear physics. Mir Publishers. Moscow, 1988. 395 p. URL://https://archive.org/details/IrodovProblemsInGeneralPhysics
4. Landau L.D., Lifshitz E.M. Course of theoretical physics. Volume 3. Quantum mechanics: non-relativistic theory. N.Y: Pergamon press Inc., 1965. 616 p URL://https://archive.org/details/ost-physics-landaulifshitz-quantummechanics/mode/2up
5. Savelyev I.V. Physics. A General course. Vol. 3: Quantum Optics, Atomic Physics, Solid State Physics, Physics of the Atomic Nucleus and Elementary Particles. Mir Publishers. Moscow, 1989. 317 p. URL://https://archive.org/details/SavelyevPhysicsGeneralCourseVol3/
6. Shankar R. Fundamentals of Physics II. Electromagnetism, Optics, and Quantum Mechanics. Yale University press, New Haven and London, 2020. 654 p. URL://https://yalebooks.yale.edu/book/9780300243789/fundamentals-of-physics-ii/
7. Wichmann E.H. Berkeley Physics Course, Vol. 4: Quantum physics. NY: McGraw-Hill, 1971. 440 p. URL:// URL: Berkley 4 Quantum Physics : Free Download, Borrow, and Streaming : Internet Archive

4.2 Recommended online courses

Field of science1. Mechanics

Online courses in English	Link	Course description
How Things Work: An Introduction to Physics	Free Course: How Things Work: An Introduction to Physics from University of Virginia | Class Central	This course offers an introduction to general physics through real-world applications involving everyday objects such as ice skaters and falling balls. It covers Newton's laws of motion, translational and rotational dynamics, frictional forces, as well as the concepts of momentum and angular momentum.
Mechanics, Part 1	https://www.edx.org/course/introduction-to-mechanics-part-1	This course is an introduction to mechanics and follows the standard university physics course of the first term. It describes the fundamental concepts of mechanics and mathematical problem solving.
Mechanics, Part2	https://www.edx.org/course/mechanics-part-2-2	This advanced course is a continuation of the standard physics course and provides a more in-depth exploration of motion in mechanics. It covers the fundamental principles and laws governing mechanical systems, offering a comprehensive understanding of advanced kinematics and dynamics.
Introduction to Mechanics	https://coursera.org/specializations/introduction-to-mechanics	The course provides a geometrical and algebraic description of motion, introduces the concept and nature of forces, and explores the application of energy and momentum to solve problems in mechanics, including gravitational interactions and their associated energies.
Physics	https://stepik.org/48615	This course serves as a general introduction to physics for students in the natural sciences and engineering. It covers key areas including kinematics, thermodynamics, and electrostatics.

Field of science2. Thermodynamics

Online courses in English	Link	Course description
Fundamentals of Macroscopic and Microscopic Thermodynamics	https://www.coursera.org/learn/macroscopic-microscopic-thermodynamics	The course explains key thermodynamic concepts—temperature, thermodynamic pressure, and chemical potential—based on fundamental postulates. It also presents the essential relationships between atomic and molecular structures and macroscopic properties.
Ideal Gases	https://www.coursera.org/learn/ideal-gases	The course provides the tools to analyze the behavior of monatomic, diatomic, and polyatomic ideal gases under diverse conditions. It elucidates the distinctions between pure ideal gases and mixtures, emphasizing their practical industrial applications. The course examines the fundamental components of separation functions that describe translational, rotational, vibrational, and electronic motions.

Physics	https://stepik.org/48615	This course offers a comprehensive introduction to general physics and is designed for students in natural sciences and engineering. It covers fundamental topics including kinematics, thermodynamics, and electrostatics.
Thermodynamics	https://www.edx.org/course/thermodynamics	This course is a basic introduction to thermodynamics, presenting the main thermodynamic principles, the relationships between thermodynamic functions and parameters, and the processes occurring in macroscopic systems.

Field of science 3. Electrotechnics and electronics

Online courses in English	**Link**	**Course description**
Physics	https://stepik.org/48615	This course serves as a comprehensive introduction to general physics and is designed for students in natural sciences and engineering. It covers fundamental topics including Kinematics, Thermodynamics, and Electrostatics.
Electrodynamics: An Introduction	https://www.coursera.org/learn/electrodynamics-introduction	This course provides a comprehensive overview of electromagnetism, beginning with its fundamental principles and progressing toward practical applications in Materials science, Physics, and Chemistry.
Electrodynamics: Analysis of Electric Fields	https://www.coursera.org/learn/electrodynamics-analysis-of-electric-fields	The course presents fundamental methods for calculating electric fields and potentials, introduces the concept of polarization and the properties of dielectric materials, and explores how charge distributions can give rise to electric dipole moments.
Electrodynamics: Electric and Magnetic Fields	https://www.coursera.org/learn/electrodynamics-electric-magnetic-fields	This course is a continuation of the electrodynamics sequence. It introduces the fundamentals of magnetostatics and builds upon previously studied concepts. In addition, the course explores the principles of electromotive force (EMF) and its applications in the design and operation of various electrical devices.
Electrodynamics: In-depth Solutions for Maxwell's Equations	https://www.coursera.org/learn/electrodynamics-solutions-maxwells-equations	This online course covers Maxwell's equations and their application in deriving wave equations for analyzing complex systems such as oscillating dipoles. It also introduces the fundamentals of alternating current (AC) circuits, including methods for their simplification, solution, and use in practical contexts.

Field of science 4. Optics

Online courses in English	**Link**	**Course description**
Optics and Modern Physics	AP® Physics 2 - Part 3: Optics and	This online course provides an introduction to the fundamentals of optics and wave phenomena. It

	Modern Physics from edX	offers clear interpretations of key terms and concepts, laying the groundwork for understanding the behavior of light and other wave-based systems.
Vibrations and Waves	https://www.classcentral.com/course/youtube-ph2a-vibrations-and-waves-48197	This course provides a comprehensive overview of fundamental optical phenomena, grounded in the principles of vibrations and wave theory. It covers the formation of various types of waves, as well as fundamental concepts such as interference, diffraction, and dispersion, emphasizing their practical applications in optics..
Oscillations and Waves	https://www.classcentral.com/course/youtube-core-physics-i-oscillations-and-waves-47657	This course covers the principles of simple harmonic oscillators and resonance, followed by an exploration of electromagnetic waves and the electromagnetic spectrum. Key topics include wave interference, coherence, diffraction, standing waves, and polarization. The course also introduces fundamental concepts of quantum mechanics, such as wave-particle duality, the Schrödinger wave equation, particles in potential wells, and quantum tunneling.

Field of science 5. Atomic Physics

Online courses in English	**Link**	**Course description**
Particle Physics: An Introduction	https://www.coursera.org/learn/particle-physics or Nuclear Physics - Fundamentals and Applications > Mod-01 Lec-01 - Brief Overview of the course | Class Central Classroom	This course provides an introduction to general physics and nuclear physics, covering complex instruments used in nuclear research such as accelerators and detectors. It includes an overview of the Standard Model, as well as foundational concepts related to matter, space, and time. The final module addresses contemporary topics in cosmology, including dark matter and dark energy.
Understanding Modern Physics II: Quantum Mechanics and Atoms	Free Course: Understanding Modern Physics II: Quantum Mechanics and Atoms from The Hong Kong University of Science and Technology | Class Central	This course provides an introduction to quantum mechanics, atomic physics, and quantum information. It contrasts the approaches of quantum physics and quantum mechanics with classical physics, explores the role of atoms in fundamental physics and atomic states, and examines the nature of quantum information, highlighting its greater complexity compared to classical information. Access to this course requires a VPN.
Nuclear Physics: Fundamentals and Applications	https://www.classcentral.com/course/youtube-nuclear-physics-	This course provides an introductory yet comprehensive overview of both experimental and theoretical aspects of the modern understanding of atomic nuclei and their interactions.

	fundamentals-and-applications-47823	
StanfordOnline: Quantum Mechanics for Scientists and Engineers - 1	Quantum Mechanics for Scientists and Engineers I Stanford Online	This course offers an introduction to quantum mechanics and its practical applications. It is specifically designed to be accessible not only to physicists but also to students and technical specialists across various scientific and engineering disciplines.