Master's, Doctoral, and Post-doctoral Track Program: Engineering and Technologies

1. Open Doors winner's skill set

Winning the Open Doors competition requires a firm grasp of concepts in the following fields:

- engineering and technology concepts:
- basics of theoretical mechanics;
- engineering graphics;
- fundamentals of design;
- automatic control;
- electrical and electronic engineering;
- nuclear physics.

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

- analyzing mechanical systems, including the use of CAD tools; calculating motion parameters for material points and mechanical components; determining loads; developing design; documentation; creating solid models and assemblies; and preparing technological processes for CNC machining and additive manufacturing systems;
- analyzing processes in DC and AC electrical circuits, and calculating parameters of electrical circuits and electronic devices;
- evaluating the stability and performance of automatic control systems, including controller synthesis;
- solving engineering and physical problems in the fields of nuclear power engineering and thermal physics.

2. List of degree programs covered by the subject area

2.1. List of doctoral degree programs

2.4.2 Electrical Engineering Complexes and Systems
2.4.3 Electric Power
2.4.5 Energy Systems and Complexes
2.4.9 Nuclear Installation, Fuel Cycle, Radiation Safety
2.3.3 Process and Production Automation Systems
2.5.4 Robots, Mechatronics and Robotic Systems
2.5.6 Mechanical Engineering Technology

2.2. List of master's degree programs

11.04.02 Infocommunication Technologies and Communication Systems
11.04.04 Electronics and Nanoelectronics
13.04.02 Electric Power and Electrical Engineering
14.04.01 Nuclear Power and Thermal Physics
15.04.01 Mechanical Engineering
15.04.06 Mechatronics and Robotics
27.04.04 Management in Engineering Systems

3. Content

Field of science 1. General mechanical engineering

1. The conditions of equilibrium of a mechanical system
2. Kinematics of a point. Translational and rotational motion of a rigid body
3. Velocity and acceleration at points of a rigid body and with complex motion
4. Solid modelling of parts and assembly units. Parametric modelling

5. Methods of metalworking. Machining, welding, metal pressure treatment, heat treatment, foundry technologies, powder metallurgy, and additive technologies.
6. Displacements and deformations. Stressed state
7. Theory of elasticity. Hooke's law. Statement of the problem in the theory of elasticity. Flat tasks
8. Elements of resistance of materials. Bending and twisting of rods

Field of science 2. Robotics

1. Differential equations of motion of a material point
2. General theorems of the dynamics of a material point and a mechanical system, applications to the dynamics of a rigid body
3. Basics of digital manufacturing: additive technologies
4. Programming of CNC machines. G-CODE language. Technology commands. Tool positioning commands

Field of science 3. Automation & control systems

1. Differential equations, transfer functions and frequency response functions of linear continuous systems
2. Performance measures of linear system dynamics in time-, frequency- and root domains
3. Equivalent transformations of linear system block diagrams
4. Mathematical models of dynamic systems in the form of state variables
5. Algebraic and frequency stability criteria
6. State feedback system design: Modal control (pole assignment)
7. System state reconstruction using state observers
8. Equilibrium states of linear and nonlinear systems. Lyapunov's first and second methods in motion stability analysis.
9. PID control

Field of science 4. Engineering, electrical & electronic

1. Analysis of DC electric circuits
2. Analysis of AC electric circuits
3. Transient processes in linear circuits
4. Three-phase circuits
5. The main active components of electronics (diodes, transistors, thyristors)
6. Principles of construction of electronic devices (on the example of designing simple devices)

Field of science 5. Telecommunications

1. Linear electrical circuits
2. Basic semiconductor devices
3. Information signal generation devices (gauges, sensors)
4. Signal processing (amplifiers, converters)
5. Components and display devices (indicators, displays)

Field of science 6. Nuclear science & technology

1. Basics of Molecular Physics and Thermodynamics
2. Wave properties of particles, Louis de Broglie's hypothesis
3. Schrödinger equation
4. Quantization of energy and orbital momentum, spin, the rule of momentum, and

momentum addition
5. Dispersion of electrons into energy levels in the atom, Pauli's principle, shells and subshells, electron configuration of the atom, Mendeleev's periodic system of elements
6. X-ray spectra, the width of spectral lines
7. Basics of atomic nucleus physics. Composition of an atomic nucleus. Atomic number and mass number. Isotopes. Dimensions of an atomic nucleus.
8. Mass and binding energy. Defect of mass. Radioactivity. Types of radioactive processes. Law of decay
9. Nuclear reactions. Nuclear fission. Synthesis of nuclei.
10. Elements of elementary particle physics. Types of interaction and classes of elementary particles. Particles and antiparticles

4. Preparation materials

4.1 Recommended reading

Field of science 1. General mechanical engineering

Reading list in English
Burkova S. P., Vinokurova G. F., Dolotova R. G. Engineering Graphics. Textbook. Tomsk: TPU Press, 2014, 174 p. URL: https://portal.tpu.ru/SHARED/d/DOLOTOVA/in_st/archiv_1/1.pdf (free access)
Gross D., Ehlers W., Wriggers P., Schröder J., Müller R. Engineering Mechanics 1. Statics – Formulas and Problems. Springer-Verlag GmbH Germany 2017. – 240 p. http://ndl.ethernet.edu.et/bitstream/123456789/58558/1/658.pdf (free access)
Gross D., Hauger W., Schröder J., Wall W.A., Rajapakse N. Engineering Mechanics 1. Statics 2nd Edition. - Springer Dordrecht Heidelberg New York London, 2009. - 296 p. URL: http://ndl.ethernet.edu.et/bitstream/123456789/37476/1/Engineering%20Mechanics%201%20Statics.pdf (free access)
Gross D., Hauger W., Schröder J., Wall W.A., Rajapakse N. Engineering Mechanics 2. Mechanics of Materials. - Springer Dordrecht Heidelberg New York London, 2011. - 318 p. URL: http://ndl.ethernet.edu.et/bitstream/123456789/46586/1/29.pdf (free access)
Raghavendra N. V., Krishnamurthy L. Engineering Metrology and Measurements, 2013, Oxford University Press. URL: https://nitsri.ac.in/Department/Mechanical%20Engineering/MEC_405_Book_2,_for_Unit_2B.pdf (free access)
Rajput R.K. Manufacturing Technology. LAXMI Publications LTD, New Dehi. 2007. – 900 p. URL: https://books.google.ru/books?id=6wFuw6wufTMC&printsec=frontcover&hl=ru#v=onepage&q&f=false (limited access)
Stan B. Metalworking: tools and techniques. Ramsbury, Marlborough: Crowood, 2003. - 176 p. URL: https://archive.org/details/metalworkingtool0000bray (limited access)

Field of science 2. Robotics

Reading list in English
Evans K. Programming of CNC Machines, Fourth Edition (PDFDrive). Industrial Press Inc. 2016. – 473 p. URL:

https://fliphtml5.com/eraqv/ijon/Programming_of_CNC_Machines%2C_Fourth_Edition_%28_PDFDrive_%29/ (free access)
Gibson I., Rosen D. W., Stucker B. Additive Manufacturing Technologies. Springer ScienceþBusiness Media, LLC 2010. – 472 p. URL: https://padc-web.obspm.fr/rcsed/data1/springer_books/2010_Book_AdditiveManufacturingTechnolog.pdf (free access)
Gross D., Ehlers W., Wriggers P., Schröder J., Müller R. Engineering Mechanics 3. Dynamics – Formulas and Problems. 2nd Edition. - Springer-Verlag Berlin Heidelberg, 2017. - 296 p. URL: http://ndl.ethernet.edu.et/bitstream/123456789/39432/1/81.pdf (free access)
McLean W. G. Engineering Mechanics, Statics and Dynamics, McGraw-Hill (1962). URL: https://archive.org/details/schaumsoutlineof0000mcle (limited access)
Shivanand H.K., Benal M.M., Koti V. Flexible manufacturing system. New Age International (P) Ltd. 2006. – 165 p. URL: http://ndl.ethernet.edu.et/bitstream/123456789/87815/6/Flexible%20Mnfg%20System-HK%20Shivanand.pdf (free access)

Field of science 3. Automation & control systems

Reading list in English
Golnaraghi F., Ku B.C. Automatic Control Systems. Tenth Edition. McGraw-Hill Education. 2017. – 1505 p. URL: https://mrce.in/ebooks/Control-Automatic%20Control%20Systems%2010th%20Ed.pdf (free access)
Hägglund T. Automatic Control. Lecture Notes. Lund, 2019. - 137 p. URL: https://www.control.lth.se/fileadmin/control/Education/EngineeringProgram/FRTF05/engforel.pdf (free access)
Ogata K. Modern Control. Engineering. Fifth Edition. (2010). Boston, Columbus, Indianapolis, New York, San Francisco, Upper Saddle River. 2010 - 895 p. URL: http://docs.znu.ac.ir/members/pirmohamadi_ali/Control/Katsuhiko%20Ogata%20_%20Modern%20Control%20Engineering%205th%20Edition.pdf (free access)

Field of science 4. Engineering, electrical & electronic

Reading list in English
Alexander C. K., Sadiku M. N. O. Fundamentals of Electric Circuits. 5th edition. McGraw-Hill, 2012. - 995 p. URL: https://archive.org/details/fundamentals-of-electric-circuits-5th-ed_202206/mode/2up (free access)
Iyer B. Basic of Electronics. All India Council for Technical Education (AICTE), New Delhi. 2023. – 290 p. URL: https://mpbou.edu.in/uploads/files/Basic_of_Electronics_compressed.pdf (free access)
Nilsson J.W., Riedel S.A. Electric Circuits. 9th Edition. Pearson Education, Inc., publishing as Prentice Hall, One Lake Street, Upper Saddle River, New Jersey. 2011. – 822 p. URL: https://ece.uprm.edu/~jrosado/oldexams/3105/Materiales/Book-Electric-Circuits-9th-ed-J.-Nilsson-S.-Riedel-Prentice-Hall-2011.pdf (free access)

Field of science 5. Telecommunications

Reading list in English

Maini A.K. Digital Electronics. Principles, Devices and Applications. John Wiley & Sons Ltd. 2007. – 741 p. URL: https://www.shahucollegelatur.org.in/Department/Studymaterial/sci/it/BCA/FY/digielec.pdf (free access)
Oskay W., Schlaepfer E. 2022. Open Circuits: The Inner Beauty of Electronic Components. San Francisco. - 304 p. URL: https://archive.org/details/open-circuits/page/n5/mode/2up (free access)
Thomas R.E., Rosa A.J., Toussaint G.J. The Analysis and Design of Linear Circuits. 7th Edition. John Wiley & Sons, Inc. 2012. – 950 p. URL: https://students.aiu.edu/submissions/profiles/resources/onlineBook/Z9e2A9_Analysis_and_Design_of_Linear_Circuits.pdf (free access)
Whitaker J.C., The Electrical Engineering Handbook Series. 2th Edition. Taylor & Francis Group, LLC. 2005. – 2560 p. URL: https://borsesachin.wordpress.com/wp-content/uploads/2018/07/the-electronics-handbook.pdf (free access)

Field of science 6. Nuclear science & technology

Reading list in English
Martin B. R. Nuclear and particle physics. Thomson Press (India) Limited, John Wiley & Sons, 2006 – 415 p. URL: https://fisica.net/nuclear/Martin%20-%20Nuclear%20and%20Particle%20Physics%20-%20An%20Introduction.pdf (free access)
Urone P.P., Hinrichs R.A., Gozuacik F., Pattison D., Tabor C. Physics. OpenStax, 2020. – 850 p. URL: https://d3bxy9euw4e147.cloudfront.net/oscms-prodcms/media/documents/Physics-WEB_Sab7RrQ.pdf (free access)
Wong. S. M. Introductory Nuclear Physics. Wiley-VCH Verlag GmbH & Co. KGaA, 2004 - 475 p. URL: https://faculty.washington.edu/bulgac/560_2014/[Samuel_S._M._Wong]_Introductory_Nuclear_Physics.pdf (free access)

4.2 Recommended online courses

Field of science 1. General mechanical engineering

Online courses in English	**Link**	**Course description**
Introduction to Engineering Mechanics	URL: https://coursera.org/learn/engineering-mechanics-statics (free access)	This course provides an introduction to the fundamental principles required for solving problems in engineering mechanics. It builds upon students' prior knowledge of mathematics and physics. The course focuses on the modelling and analysis of static equilibrium problems, with particular emphasis on real-world engineering applications. .

Particle Dynamics	URL: https://www.coursera.org/learn/particle-dynamics (free access)	This online course provides a comprehensive introduction to dynamics, a core subject in mechanical engineering. Students will develop a solid understanding of fundamental concepts such as force and motion, work and energy, and momentum, with a focus on applying Newton's second law through integration over time and displacement. The course covers two main areas of engineering dynamics: particle dynamics and rigid body dynamics.
Engineering Graphics and Design	URL: https://www.classcentral.com/course/swayam-engineering-graphics-and-design-43589 (limited access)	This course develops essential visualization skills for engineers, focusing on both traditional hand-drawing techniques and digital graphic representations. It equips students with the ability to interpret and create technical drawings, facilitating clear and effective communication of engineering ideas. The course is designed for all engineering students as well as anyone interested in graphic design and visualization. No prior experience or knowledge is required.

Field of science 2. Robotics

Online courses in English	**Link**	**Course description**
Particle Dynamics	URL: https://www.coursera.org/learn/particle-dynamics (free access)	This online course provides a comprehensive introduction to dynamics, a core subject in mechanical engineering. Students will develop a solid understanding of fundamental concepts such as force and motion, work and energy, and momentum, with a focus on applying Newton's second law through integration over time and displacement. The course covers two main areas of engineering dynamics: particle dynamics and rigid body dynamics.
Digital Manufacturing & Design	URL: https://www.coursera.org/learn/digital-manufacturing-design?specialization=digital-manufacturing-design-technology (limited access)	This course explores the ongoing global transformation in product design and manufacturing driven by digital manufacturing and design (DM&D). It focuses on the transition from traditional paper-based workflows to advanced digital processes within the manufacturing sector. By the end of the course, students will have a comprehensive understanding of DM&D and its profound effects on careers, industry

		practices, and operational workflows in organizations.
Introduction to Additive Manufacturing Processes	URL: https://www.coursera.org/learn/introduction-to-additive-manufacturing-processes?specialization=additive-manufacturing#modules (limited access)	This course is part of the additive manufacturing specialization and provides a comprehensive introduction to additive manufacturing technologies. It establishes the foundation for an in-depth study of specific processes within the field. Students will analyze and differentiate between various additive manufacturing techniques and explore the typical production workflow, encompassing stages from digital to final part fabrication.
CNC Programming with G Code for Beginners	URL: https://www.coursera.org/learn/introduction-to-additive-manufacturing-processes?specialization=additive-manufacturing#modules (free access)	This course provides comprehensive instruction on generating G-Code to program and control CNC (Computer Numerical Control) machines. Learners will be supplied with instructional materials and tutorial demonstrations that illustrate the practical application of G-Code. Through the use of CNC simulation software, students will be able to visualize and validate the outcomes of their code in a virtual environment. The course equips students with the skills and resources necessary to convert technical drawings into G-Code programs, facilitating the fabrication of physical parts.

Field of science 3. Automation & control systems

Online courses in English	**Link**	**Course description**
Classical Control Theory (Brian Douglas).	URL: https://www.youtube.com/playlist?list=PLUMWjy5jgHK1NC52DXXrriwihVrYZKqjk (free access)	This course consists of a series of lectures covering fundamental topics in the theory of control for technical systems. Key subjects include closed-loop control, analysis in the time and frequency domains, linear time-invariant (LTI) systems, transfer functions, Fourier transforms, Bode plots, system stability and control, stability criteria, and proportional-integral-derivative (PID) control.
Principles of Automatic Control	URL: https://ocw.mit.edu/courses/16-06-principles-of-automatic-control-fall-2012/resources/lecture-notes/	This course introduces the design of feedback control systems as applied to a variety of air and spacecraft systems. Topics include the properties and advantages of feedback systems, time-domain and frequency-domain performance measures, stability and degree of stability, the Root

	(free access)	locus method, the Nyquist criterion, frequency-domain design, and state space methods.
Control Systems.	URL: https://www.classcentral.com/course/youtube-control-systems-48209/classroom (free access)	This course introduces the fundamental concepts of control theory, with a focus on the analysis and design of linear control systems. Key topics include principles of system modeling and block diagram simplification, including the application of Mason's Gain Formula. The course examines the dynamic response of closed-loop systems and key time-domain characteristics, highlighting the effect of system zeros on system behavior. Students will study stability analysis using the Routh–Hurwitz criterion, as well as the influence of external disturbances such as noise and the evaluation of steady-state errors. The course covers the design and tuning of PID controllers and offers a detailed introduction to the root locus method, including construction rules and interpretation. Additionally, students will explore compensation techniques, such as lead and lag compensation, and will be introduced to special cases such as zero-degree root loci, illustrating advanced control strategies.

Field of science 4. Engineering, electrical & electronic

Online courses in English	**Link**	**Course description**
Basic Electrical Circuits	URL: https://www.classcentral.com/course/swayam-basic-electrical-circuits-618 (limited access)	This course explores the fundamental principles of electrical circuits, from the tiny circuits found in mobile phones to the large-scale power grids that power homes. Students will gain an understanding of key electrical quantities, basic circuit elements (resistors, inductors, capacitors, and controlled sources), and various circuit analysis techniques applicable to complex circuits. The course also covers circuit theorems and the basics of negative feedback using operational amplifiers.
Circuits and electronics	URL: https://ocw.mit.edu/courses/6-002-circuits-and-electronics-spring-2007/ (free access)	This course is intended for students in Electrical Engineering (EE) or Electrical Engineering and Computer Science (EECS) programs and provides a foundation in the fundamental principles of control systems.

		The course introduces the fundamentals of the lumped circuit abstraction. Topics covered include resistive elements and networks; independent and dependent sources; switches and MOS transistors; digital abstraction; amplifiers; energy storage elements; dynamics of first- and second-order networks; design in the time and frequency domains; and analogue and digital circuits and applications. Design and lab exercises are significant components of the course.
Linear Circuits 1: DC Analysis	URL: https://www.coursera.org/learn/linear-circuits-dcanalysis (free access)	This course explains how to analyze circuits that have direct current (DC) or voltage sources. A DC source is one that is constant. Circuits with resistors, capacitors, and inductors are considered both analytically and experimentally. Some practical applications of sensors are demonstrated.
Linear Circuits 2: AC Analysis	URL: https://www.coursera.org/learn/linear-circuits-ac-analysis (free access)	This course is an introduction to the analysis of electrical circuits powered by alternating current (AC) voltage and current sources. Circuits with resistors, capacitors, and inductors are examined both analytically and experimentally. Selected practical applications of sensors are demonstrated.

Field of science 5. Telecommunications

Online courses in English	**Link**	**Course description**
Introduction to Electronics	URL: https://www.coursera.org/learn/electronics (free access)	This course introduces students to the basic components of electronics: diodes, transistors, and operational amplifiers. It covers basic principles of operation and some common applications.
Semiconductor Fundamentals	URL: https://www.edx.org/course/semiconductor-fundamentals (limited access)	This course lays the foundation for understanding the operation of semiconductor devices, including transistors, diodes, solar cells, and light-emitting devices. It is designed for electrical engineering students interested in applying these devices to circuits and systems.
Circuits and Electronics 1: Basic Circuit Analysis	URL: https://www.edx.org/course/circuits-and-electronics-1-basic-circuit-analysi-2 (limited access)	This course will provide students with the tools and skills necessary to design and analyze electrical circuits. Students will learn to apply fundamental circuit analysis techniques such as the node method, superposition, and Thevenin's theorem. Students will also gain an understanding of lumped circuit models, abstraction

		techniques, and intuition-based circuit solving. The course includes the construction of simple digital gates using MOSFET transistors, along with instruction on using virtual lab tools such as oscilloscopes, multimeters, and signal generators.

Field of science 6. Nuclear science & technology

Online courses in English	**Link**	**Course description**
Introduction To Applied Nuclear Physics	URL: https://ocw.mit.edu/courses/22-02-introduction-to-applied-nuclear-physics-spring-2012/ (free access)	The course introduces the fundamental principles underlying nuclear science and its engineering applications, alongside the essential mathematical tools required to comprehend these concepts. Practical applications within nuclear science and engineering are employed to illustrate and contextualize these often abstract principles.
Applied Nuclear Physics	URL: https://ocw.mit.edu/courses/22-101-applied-nuclear-physics-fall-2006/ (free access)	This course explores elements of nuclear physics for engineering students. It covers basic properties of the nucleus and nuclear radiations; quantum mechanical calculations of deuteron bound-state wave function and energy; n-p scattering cross section; transition probability per unit time, and barrier transmission probability. It also covers binding energy and nuclear stability; interactions of charged particles, neutrons, and gamma rays with matter; radioactive decay; and energetics and general cross-section behavior in nuclear reactions.
Quantum Physics I	URL: https://ocw.mit.edu/courses/8-04-quantum-physics-i-spring-2016/ (free access)	This course introduces the fundamental principles of quantum mechanics as part of the quantum physics. It covers the experimental foundations of quantum physics, wave mechanics, and the formulation of Schrödinger's equation in both one and three dimensions.