NATIONAL TECHNICAL UNIVERSITY OF UKRAINE
"Igor Sikorsky Kyiv Polytechnic Institute"

Approve

Head of the Admissions Committee
Rector

_____ Anatoly MELNYCHENKO
signature

03/28/2025
date

PROGRAM A
entrance exam in the specialty
for admission to the educational and scientific program for the preparation of a Doctor of Philosophy degree
"Micro- and Nanosystems Engineering"

by specialty

G5 Electronics, electronic communications, instrumentation and radio engineering

The program was approved:

Scientific and methodological commission by specialty

G5 Electronics, electronic communications, instrumentation and radio engineering

Minutes No. 2/2025 of March 25, 2025.

Chairman of the NMCU

_____ Sergey NAIDA

Kyiv – 2025

I. GENERAL INFORMATION

The educational program "Micro- and Nanosystems Engineering" corresponds to the mission and strategy of Igor Sikorsky Kyiv Polytechnic Institute, according to which the strategic priority of the university is the fundamentalization of specialist training. The features of the educational program are taken into account by selecting the appropriate sections of the entrance exam program.

Admission to the third (educational and scientific) level of higher education for the degree of Doctor of Philosophy in the educational program "Micro- and Nanosystems Engineering" in the specialty G5 Electronics, Electronic Communications, Instrumentation and Radio Engineering is carried out in accordance with the Admission Rules of Igor Sikorsky Kyiv Polytechnic Institute.

The entrance exam for studies for the degree of Doctor of Philosophy in the educational program "Micro- and Nanosystems Engineering" in the specialty G5 Electronics, Electronic Communications, Instrumentation and Radio Engineering is held for those applicants who have a master's degree (specialist).

Entrance exams to postgraduate studies are conducted by subject committees.

The programs of entrance exams to postgraduate studies are published on the websites of Igor Sikorsky Kyiv Polytechnic Institute, faculties (institutes), the department of postgraduate studies and doctoral studies (https://aspirantura.kpi.ua/). The exam program for admission to the educational program "Micro- and Nanosystems Engineering" in the specialty G5 Electronics, Electronic Communications, Instrumentation and Radio Engineering contains a list of questions that are put on the entrance exam, a list of recommended literature and a methodology for assessing the entrance exam in the specialty.

The entrance exam for admission to the third (educational and scientific) level of higher education for obtaining the scientific degree of "Doctor of Philosophy" in the educational program "Micro- and Nanosystems Engineering" in the specialty G5 Electronics, Electronic Communications, Instrumentation and Radio Engineering includes questions from basic academic disciplines from the program for the preparation of the "Master" level of higher education in the corresponding specialty.

The entrance exam exam ticket contains a list of questions, the answers to which require the ability to apply knowledge of the program material of the relevant disciplines. The exam ticket contains three theoretical questions.

The duration of the applicant's preparation for the answer is up to 2 academic hours.

II. TOPICS SUBMITTED FOR THE INTRODUCTORY TEST

1. SOLID STATE PHYSICS

The nature of chemical bonding in semiconductors. Crystal structure. Ideal and real crystals. Defects in crystals.

Polycrystalline and amorphous semiconductors. Band theory of solids. Energy spectra of electrons in metals, semiconductors, dielectrics.

Conduction band and valence band. Effective mass of an electron. Impurity levels and impurity bands. Surface states. Statistics of electrons and holes in semiconductors.

Fermi-Dirac distribution function. Conditions of electroneutrality. Concentration of charge carriers in intrinsic and doped semiconductors. Temperature dependences. Maxwell-Boltzmann distribution. Criterion for the degeneracy of an electron gas. Degenerate and non-degenerate semiconductors.
Electrical conductivity of semiconductors. Charge carriers in a weak electric field.
Mobility of electrons and holes. Einstein's relation. Diffusion and drift of charge carriers. Equation for electric current density in semiconductors. Continuity equation, Poisson's equation.
Generation and recombination of charge carriers. Interband recombination and recombination due to impurities and defects. Diffusion length and lifetime of carriers. Surface recombination.
Charge carriers in a strong electric field. Hot carriers. Avalanche propagation in semiconductors. Gunn effect.
Kinetic effects in semiconductors. Thermoelectric phenomena. Hall and Gauss effects. Thermomagnetic effects.
Absorption of radiation in semiconductors. Fundamental, impurity and lattice absorption of radiation. Absorption by excitons and free carriers.
Photoconductivity. Spectral characteristics of photoconductivity.
Radiation effects in semiconductors. Direct and indirect transitions of charge carriers. Types of luminescence: injection, cathodo- and photoluminescence.
Basic materials of optoelectronics: A3B5 and A2B6 compounds.

Electro-, magneto- and acousto-optical phenomena in solids.
Features of the energy spectrum of electrons in systems with reduced dimensionality.
Quantization of electron energy in a potential well. Interference effects under the condition of superbarrier electron passage. Transparency and tunneling reflection coefficients. Multibarrier structures. Superlattices. Two-dimensional structures. Quantum Hall effect. One-dimensional and zero-dimensional structures. Aharonov-Bohm effect. Coulomb blockade and single-electron processes.

2. MICRO- AND NANOELECTRONICS DEVICES

Electron-hole (*pn* -) junction. Injection and extraction of charge carriers.
Current-voltage characteristic of *a pn* junction. Currents of charge carriers in *a pn* junction.
Barrier and diffusion capacitance. Types of *pn* junction breakdown: thermal, avalanche, tunnel. Heterojunctions. Metal-semiconductor contact. Schottky barrier. Ohmic contact. Metal-dielectric-semiconductor (MDS) structure. Field effect in MDS structures. Capacitance of MDS structures.
Semiconductor diodes. Main characteristics of diodes, their dependence on temperature and modes. Schematic models.
Pulse and frequency properties of diodes.
Rectifier and pulse diodes. Charge enrichment diodes. Varicaps. Tunnel diodes. Microwave diodes. Avalanche-breakdown diodes. Hann diodes.
Bipolar transistors . Structure and principle of operation. Transistor operating modes. Early effect. Basic parameters and characteristics of transistors. Schematic models: Ebers-Moll, Linville, charge. Pulse and frequency properties of transistors. Transistor operation at high injection levels. Transistor breakdown and junction closure.
Transistor noise. Power transistors. Microwave transistors. Heterostructure bipolar transistors.
Hot electron transistors.
Thyristors: their principle of operation and classification. Basic parameters and characteristics.

Field-effect transistors: MDN transistors with an induced and built-in channel, with a control *pn* - junction, with a Schottky barrier. Principle of operation. Main parameters and characteristics. Frequency and pulse properties. Noise of field-effect transistors.
Features of short-channel transistors. Heterostructure field-effect transistors. Charge-coupled devices.
Integrated circuits (ICs). Classification of ICs. IC elements: transistors, diodes, resistors, capacitors, inductive elements.
Optoelectronic devices. Purpose and areas of application. Photodetectors: photodiodes, phototransistors, photoresistors, photothyristors and avalanche phototransistors. Principle of operation, main parameters: photosensitivity, inertia,
spectral characteristics. Photoelectric converters of solar energy.
Semiconductor emitters: LEDs and lasers. Information display system devices. Optocouplers and optocoupler ICs.
Thermoelectric and galvanomagnetic semiconductor devices.
Nanoelectronic devices. Promising transistor structures on quantum wires, carbon nanotubes, graphene. Optoelectronic devices on quantum wells and dots. Single-electron, molecular electronics and spintronics devices. Concept of quantum computers.

3. TECHNOLOGICAL PROCESSES AND MATERIALS OF MICRO- AND NANOELECTRONICS

Planar technology. Methods of isolating IC elements.
Diffusion. Basic equations. Boundary conditions. Methods of diffusion.
Thermal oxidation of silicon in water vapor, wet and dry oxygen. Anodic oxidation. Methods of depositing silicon oxide and silicon nitride.
Vacuum methods for obtaining thin films. Ion implantation. Methods for eliminating defects.
Plasmachemical and ion-plasma methods for processing semiconductor and metal layers.
Epitaxy. Growth of epitaxial films A3B5 and heterojunctions. Chemical vapor deposition (CVD). Molecular beam epitaxy (MBE).
Using traditional microelectronics methods (MBE and CVD) to create nanostructures. Atomic layer deposition (ALD).
Photolithography. Photoresists. Limitations of optical lithography. Photolithography using deep ultraviolet radiation (EUVL), electron and ion beam lithography, X-ray lithography. Nanoprinting. Resolution of modern lithography methods.
Limitations on further miniaturization of ICs using traditional microelectronics methods.
Methods of studying materials and nanostructures. Scanning tunneling and atomic force microscopes. Electric force and magnetic force microscopy. Near-field optical microscopy. Atomic engineering. Electronic and X-ray spectroscopy.
Self-organization and self-assembly of nanostructures. Self-organization in epitaxy. Deposition of Langmuir-Blodgett films. Sol-gel technology.
Nanoporous silicon and aluminum oxide. Carbon nanostructures: nanotubes, fullerenes and graphene. Methods for forming quantum dots.

4. MICRO- AND NANOELECTROMECHANICAL SYSTEMS

Materials of micro- and nanosystems engineering: structural, functionally active and adaptive. Classification of objects of micro- and nanosystems engineering: sensors, controlled electro-, radio- and optoelectromechanical components, microdevices for information storage, micromachines, analytical and technical microsystems, micro- and nanoinstruments, miniature vehicles, micro- and nanorobots. Nano- and micromechanical sensors: classification, purpose, conversion characteristics, operating conditions. Sensor characteristics: measurement range, sensitivity, accuracy, linearity, selectivity. Measurement errors: temperature and time drift of parameters, noise. Sensors for monitoring the main physical and chemical parameters of environments, orientation, navigation and control sensors (MEMS- accelerometers and gyroscopes). Biomedical sensors and biochips.
Micro-nanosystem actuators. Nano- and micromechanical motion drives: piezoelectric, capacitive, thermomechanical, electromagnetic, pneumatic actuators. Micromachines and micromechanisms.
Micro- and nanosystems for energy generation, conversion and storage.
High-frequency microelectromechanical (HF MEMS) and optoelectromechanical (MOEMS) components. Controlled micro-electronic components: resistors,
capacitors, inductors, resonators and filters, microwaves, microantennas, microelectromechanical relays, switches and commutators.
Special technological processes of surface and bulk micromechanics.
Micromachining of silicon (LIGA technology). Integration of nano- and microelectronics components and nano- and microsystems technology. Prospects for the development and use of nano- and microsystems.

III. EDUCATIONAL AND METHODOLOGICAL MATERIALS

1. Molchanov V.I. Quantum mechanics / V.I. Molchanov // K.: NTUU "KPI", 2013. – 151p. (Registration of the Ministry of Education and Science of Ukraine, letter No. 1/11-7611 dated 25.04.2013)
2. Ilchenko V.I., Poplavko Y.M. Physics of semiconductors. Textbook. - Kyiv: Avers NTUU, 2010. - 318p.
3. Shalymova K.V. Physics of semiconductors. Moscow: Energy, 1976. - 416 p.
4. Zayachuk D.M. Fundamentals of nanoelectronics: In 2 books, Book 1. Quantum mechanical principles, structures, physical properties: Textbook / Zayachuk D.M., Yakymenko Y.I., Orlov A.T., Spivak V.M., Bohdan O.V. – K.: Department, 2014. – 470 p. (Griff of the Ministry of Education and Science of Ukraine, letter No. 1/11-11809 dated 07/22/2013.
5. Zayachuk D.M. Nanoelectronics: Textbook / Zayachuk D.M., Yakymenko Y.I., Orlov A.T., Spivak V.M., Bohdan O.V. – K.: Department, 2013. – 454 p. (Registration of the Ministry of Science, Technology and Innovation of Ukraine, letter No. 1/11-16500 dated 10/23/2012)
6. Nanophysics, nanomaterials, nanoelectronics: Textbook (letter number MES 1/11-2442 dated 03/25/2011) / Yu.M. Poplavko, O.V. Borisov, Yu.I. Yakymenko. -
K.: NTUU "KPI", 2012. – 300 p. (Registration of the Ministry of Education and Science of Ukraine, letter No. 1/11-2442 dated 25.03.2011)
7. Zayachuk D. M. Nanotechnologies and nanostructures: Textbook. Lviv: Lviv Polytechnic Publishing House, 2009. – 580 p.
8. Yu.M. Poplavko. Physics of dielectrics. Textbook. Publishing house "Polytechnics". – 2015. – 568 p. Bulletin of the Ministry of Education and Science of Ukraine (letter No. 1/11-16779 dated

04.11.2013).
9. Solid-state electronics: textbook / O. V. Borisov, Yu. I. Yakymenko; ed. Yu. I. Yakymenko. – K.: NTUU “KPI”, 2015. – 484 p. (Approved by the Academic Council of NTUU “KPI”, protocol No. 2 dated 02.03.2015)
10. Pogosov V.V., Kornich G.V., Vasyutin E.V., Pugina K.V., Kiprich V.I. Fundamentals of nanophysics and nanotechnology. Electronic manual. Zaporizhzhia, 2008. – 630 p.
11. Moskalyuk V.O., Timofeev V.I., Fedyai A.V. “High-speed electronic devices”, textbook with the seal of the Ministry of Education and Science of Ukraine, Kyiv: Publishing House “Polytechnics”. – 2014. – 528 p.
12. Physical foundations of micro- and nanoelectronics: a textbook for students of higher educational institutions / M. G. Nakhodkin, D. I. Sheka, K.: VPC "Kyiv University". – 2005. – 431p.
13. Shvets E.Ya., Chervony I.F., Golovko Yu.V. Materials and components: a textbook. – Zaporizhzhia: ZDIA. – 2011. – 278 p.
14. Semenets V. V. Introduction to microsystems and nanotechnology: a textbook. For students of higher education institutions who study in the field of preparation. Radioelectronic devices / V. V. Semenets, I. Sh. Nevlyudov, V. A. Palagin. – Kh.: SMIT Company. – 2011. – 415 p.
15. Physics of electronic processes,: [Electronic resource]: textbook for students of specialty 153 "Micro- and nanosystems engineering" / V. O. Moskalyuk, V. I. Timofeev, T. A. Saurova; The seal was provided by the Academic Council of Igor Sikorsky Kyiv Polytechnic Institute (protocol No. 5 dated 06/30/2020). – Electronic text data (1 file: 7.21 MB). – Kyiv: Igor Sikorsky Kyiv Polytechnic Institute, 2020. –324 p.

IV. RATING SYSTEM FOR EVALUATION OF THE ENTRANCE TEST

When preparing answers to questions and taking the entrance exam, it is prohibited to use any auxiliary materials and electronic devices (mobile phones, laptops, tablets, etc.).
Criteria for evaluating the results of the entrance exam. The entrance exam is conducted orally. The entrance exam score consists of the points that the applicant receives for:
1) answers to each basic ticket question;
2) answers to additional questions from members of the subject committee.
The final exam score consists of the points for each question on the exam and the points received for answering additional questions.
Ticket questions are scored out of a maximum of 30 points each, additional questions are scored out of a maximum of 10 points for all questions.
Criteria for evaluating responses.
Points are deducted from the maximum number of points under the following conditions:
1) the ticket question is not fully resolved – “minus” 30 points;
2) when answering a ticket question, the essence of physical processes (effects) is not fully disclosed, or the main characteristics or principles of operation of devices (devices), or the essence of technologies, methods are not given - “minus” 5 points for each deficiency;
3) the applicant cannot answer an additional question – “minus” 2 points for each question;
4) the answer to the additional question is incomplete or does not take into account some important aspects – “minus” 1 point for each deficiency.
The maximum number of points is 100.
Entrance exam final results evaluation scale

Number of points	Rating
95-100	perfectly
85-94	very good
75-84	good
65-74	satisfactorily
60-64	enough
0-59	unsatisfactorily

*If an applicant receives an “unsatisfactory” grade, he/she is excluded from the competitive selection process.

The conversion of the score on a 100-point scale to a 200-point scale is carried out according to the table:

The applicant's initial exam rating is calculated based on a 100-point scale. When determining the applicant's overall rating, the initial exam rating is converted to a 200-point scale according to the following table:

Таблиця відповідності оцінок РСО (60…100 балів)
оцінкам 200-бальної шкали (100…200 балів)

шкала РСО	шкала 100…200		шкала РСО	шкала 100…200		шкала РСО	шкала 100…200		шкала РСО	шкала 100…200
60	100		70	140		80	160		90	180
61	105		71	142		81	162		91	182
62	110		72	144		82	164		92	184
63	115		73	146		83	166		93	186
64	120		74	148		84	168		94	188
65	125		75	150		85	170		95	190
66	128		76	152		86	172		96	192
67	131		77	154		87	174		97	194
68	134		78	156		88	176		98	196
69	137		79	158		89	178		99	198
									100	200

V. EXAMPLE OF EXAM TICKET

Form No. H-5.05

National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute"

(full name of higher education institution)

Educational degree *Doctor of Philosophy*

Specialty *G5 Electronics, electronic communications, instrumentation and radio engineering*

(name)

Academic discipline *Entrance exam*

EXAMINATION TICKET NO. _

1. *Question #1*
2. *Question #2*
3. *Question #3*

Approved

Guarantor of the educational program _____Volodymyr TYMOFIEV

DEVELOPERS:

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