MINISTRY OF EDUCATION AND SCIENCE
NATIONAL RESEARCH
TOMSK STATE UNIVERSITY

FACULTY OF PHYSICS

APPROVED BY
Vice-Rector for Academic Affairs
V. V. Dyomin

ENTRANCE EXAMINATION PROGRAMME

subject area

03.04.02 Physics

Profile

Physics Methods and Information Technologies in Biomedicine

Master's Degree

Full-time mode of study

Tomsk – 2016

Перевод верен
переводчик УМС ТГУ
Рябикина А.С.

Authors:

Vladimir P. Demkin, Doctor of Physics and Mathematics, Professor;

Tatyana V. Rudenko, PhD in Pedagogy.

Reviewed and recommended by Teaching and Learning Committee of the Faculty of Physics. Minute No 6-16 dated 30.06.16.

Agreed with

Head of Admission Office E.V. Pavlov

Перевод верен
переводчик УМС ТГУ
Рябикина А.С.

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Abbreviations

BEP – Basic Educational Programme
NR TSU – National Research Tomsk State University

1. GENERAL PROVISIONS

1.1 The Programme of Entrance Examination in subject area 03.04.02 Physics for Master's Programme *Physics Methods and Information Technologies in Biomedicine* includes written exam in Physics and interview on the profile of the Programme which allow assessment of applicants' skills and knowledge to study on the Master's Programme.

1.2 Applicants with a Bachelor's or Specialist's Diploma are enrolled to the Programme according to the results of entrance examination.

One of the main requirements is proficiency in English (B1-B2 according to the Common European Framework of Reference for Languages (CEFR)).

1.3 The Programme of Entrance Examination provides the description of procedure, programmes of entrance exams, and assessment criteria.

1.4 Entrance examination for overseas applicants is held in English. Video conferencing is available. Written exam in Physics for Russian citizens is held in Russian, interview on the profile of the Programme is held in English.

1.5 Entrance exams are organized and held in accordance with the Admission Rules approved by Decree of the Rector of NR TSU and valid for the current year.

1.6 Applicants have the right to appeal the results according to the procedure specified by the Admission Rules valid for the current year.

1.7 The Programme of Entrance Examination in subject area 03.04.02 Physics for Master's Programme *Physics Methods and Information Technologies in Biomedicine* is annually reviewed and updated taking into account changes in legal acts of the Russian Federation in higher education and local documents regulating the admission procedure at NR TSU. Amendments to the Programme of Entrance Examination are considered and approved at the meeting of the Academic Office of the BEP. The Programme of Entrance Examination is approved by the Vice-Rector for Academic Affairs.

1.8. The Programme of Entrance Examination is published on the web-site of NR TSU, section Master's Programmes, before the date specified by the Admission Rules valid for the current year.

1.9. The Programme of Entrance Examination in subject area 03.04.02 Physics for Master's Programme *Physics Methods and Information Technologies in Biomedicine* is kept at the Academic Office of the BEP.

2. GOALS AND TASKS OF ENTRANCE EXAMINATION

2.1. Entrance exams aim to define the preparedness of applicants for studying on the BEP of the Master's Programme and determine their competencies required for BEP *Physics Methods and Information Technologies in Biomedicine* in subject area 03.04.02:

– to have a solid background in physical phenomena and their mechanisms, laws and practical application to biology and medicine;

– to have basic knowledge in molecular-kinetic theory, thermodynamics, organization and properties of liquid and solid, electromagnetic interaction, quantum nature of the microworld;

– to interpret special materials clearly and concisely using general physics notions and terms;

– to have theoretical knowledge and practical problem solving skills in physics;

– to apply basic physical principles and laws to study and practice;

– to apply physical laws to assessment of states, analysis of properties and behavior of different biological systems;

– to use basic technological means: work with computer, computer networks, to use universal programming packages including those for experimental data processing;

– to know the principles of structural and functional organization of biological objects and mechanisms of homeostatic regulation;

– to know the principles of cellular organization of biological objects, biophysics and biochemistry, membrane processes, and molecular mechanisms of life;

– to have understanding of fundamentals of biotechnology and genetic engineering, nanobiotechnology, and molecular modelling;

– to have understanding of ecology;

– to organize research using written operating instructions and technical documentation;

– to work with modern research equipment;

– to apply methods and techniques of data acquisition and processing;

– to perform analysis of information resources: academic, research, bibliographic, reference, and other data;

– to make reports on research results and represent data in diagrams and charts;

– to make academic arguments;

– to know legal issues of research and observe the copyright.

2.2. Exam in the subject area and interview on the profile of the Programme aim to:

– check basic knowledge in physics;

– define applicants' understanding of properties and interactions between subject areas underlying the content of the educational programme (physics, biology, medicine, and computer science), their abilities to apply physics methods of research to biomedicine.

3. ENTRANCE EXAM: STRUCTURE, PROCEDURE, PROGRAMME, AND ASSESSMENT CRITERIA

3.1 Structure of Entrance Exam

3.1.1 Entrance exam encompasses theoretical questions in physics (mechanics; molecular physics, statistical physics, and thermodynamics; electricity and magnetism; optics; quantum mechanics; atomic and nuclear physics).

3.1.2 Exam is held in person and using videoconferencing (for overseas students). It has exam papers consisting of two theoretical questions of equal difficulty and workload.

3.2 Procedure of Entrance Exam

3.2.1 Entrance exam in Physics is held in written form.

3.2.2 Applicants write down their answers in the answer sheet. Candidates are given **90 minutes** to complete the exam. The principles of academic ethics must be observed when taking the exam. It is prohibited to use literature and other aids.

3.2.3 An applicant answers 2 questions of equal difficulty.

Maximum for every question is **50** points.

Maximum for examination is **100** points.

Minimum threshold is **70** points.

Applicants not meeting the minimum passing score will not be admissible for the Programme.

3.2.4 Assessment criteria:

– 50 points – Answer is complete. Issue is exactly and fully stated, terms are correct, a student has a full command of the material, and there are no mistakes.

– From 40 to 50 points –answer is complete, though somewhat short, terms are correct, there are no significant mistakes.

– From 30 to 40 points – some significant elements are omitted and/or there are some significant mistakes.

– From 20 to 30 points – answer is irrelevant or not given at all.

3.2.5 Verification procedure

Results of written examination are announced no later than three working days after the examination date.

Results of entrance examination are recorded in the minute of entrance examination. According to the minute, a ranking list of applicants is compiled. Ranking list provides a total sum of scores awarded for each part of the examination.

Ranking lists are organized in the following way:

– in descending order of total scores;

– in descending order of scores in each part of examination in accordance with the priority set by the University if applicants have equal scores in total.

Applicants are enrolled according to the ranking starting from the top of the list until places are filled.

3.2.6 Appeal procedure

Applicants may challenge the results of exam if think they are wrong. When considering an appeal, an applicant is not given another examination paper and not allowed to answer again. The Appeal Committee consider the answers written in the answer sheet and provides the applicant with reasons for decision. In case of reasonable disagreement of members of the Appeal Committee on the grade, the Appeal Committee can improve the overall score by majority vote.

Appeals are considered separately for each examination part.

3.3 Entrance examination programme

3.3.1 The Programme of entrance exam encompasses the following sections:

MECHANICHS

1. **Frames of reference.** Point particle. Methods of description of point particle motion. Speed. Acceleration. Kinematics of rotational motion. Kinematics of rigid bodies.
2. **Point particle dynamics.** Newton's First law. Inertial frames of reference. Mass of a body. Newton's Second law. Force. Role of initial conditions. Motion of bodies with variable mass. Newton's Third law. Field interaction. Law of momentum conservation. The Galilean relativity principle. Galilean transformations.
3. **Work and energy.** Work and kinetic energy. The König's theorem. Potential and non-potential forces. Potential energy of the particle in the field. Total mechanical energy of a particle. Potential energy of particle system. Principle of conservation of energy for particle point system. Forces and potential energy. Conditions for the equilibrium of mechanical system.
4. **Mechanics of rigid body.** Moment of force and moment of momentum relative to fixed point. Angular momentum conservation law. Momentum equation for rotation around fixed axis. Moment of inertia. The Huygens–Steiner theorem. Kinetic energy of a rotating rigid body.
5. **Vibrational motion and waves.** Small vibration. Harmonic vibration. Dying vibration. Forced vibration. Resonance. Composition of vibrations. Equation of plane and spherical elastic waves. Wave equation. Energy transported by elastic wave. Wave equation effect.
6. **Mechanics of fluids and elastic bodies.** Kinematic description of fluid motion. Bernoulli's equation.
7. **Elements of continuum mechanics.** Deformations of rigid body. Hooke's law. Elastic stress energy.

References:

1. Matveev A.N.. Mekhanika v teorii otnositel'nosti [Mechanics in relativity theory]. ONIKS 21 vek: Mir iobrazovanie, Moscow. 2003.

2. Sivukhin D.V. Obščij kurs fiziki [General course to physics]. PHIZMATLIT, Moscow. 2005.

3. Landau L.D., Lifshitz E.M. Mechanics. PHIZMATLIT, 2007.
4. Savel'ev I.V. Kurs obščej fiziki [Course on general physics]. Nauka, Moscow. 2009.
5. Grabovksy R.I. Kurs fiziki [Course in physics]. Lan', St-Petersburg. 2007.

MOLECULAR PHYSICS, STATISTICAL PHYSICS, AND THERMODYNAMICS

1. **Methods of studying systems** consisting of a large number of particles. Basic principles of molecular-kinetic theory. Ideal gas model. Thermal motion. Statistical and thermodynamic methods of molecular system description.
2. **Statistical method.** Equilibrium. Macroscopic parameters. Maxwellian distribution. Ideal gas equation. Boltzmann distribution.
3. **First law of thermodynamics.** Internal energy of thermodynamic system. Distribution of energy per degree of freedom. First law of thermodynamics. Work of a system under volume change. Specific heat. Processes in ideal gases. Polytropic process. Cyclic process. Cycle efficiency. The Carnot cycle. The Carnot cycle efficiency.
4. **Entropy.** Micro- and macrostate of thermodynamic system, statistical weight. Thermodynamic definition of entropy. Ideal gas entropy. Statistical interpretation of entropy. Second principle of thermodynamics. The Carnot theorem. The Clausius inequality. Thermodynamic potentials. Common criteria for thermodynamic stability.
5. **Real gas.** Molecular forces and departure from the ideal gases law. The Van der Waals equation. Real gas isotherms. Metastable states. Nernst's principle.
6. **Phase and phase transitions.** Conditions for equilibrium of phases of chemically homogeneous substance. Evaporation, condensation, melting, crystallization. The Clausius-Clapeyron equation. Second order phase transitions.
7. **Structure of liquids.** Surface tension. Conditions for equilibrium on the border of two liquids and liquid and a rigid body. Surface active substances. Pressure under curved surface. Laplace's formula. Capillary phenomena. Thermodynamics of surface tension.
8. **Transport phenomena.** Types of transport processes. Cross-section and average distance of free path. General transport equation. Thermal conductivity. Viscosity. Self-diffusion.

References:

1. Matveev A.N. Molekulyarnaja fizika [Molecular physics]. *Lan'*, St-Petersburg. 2010.
2. Sivukhin D.V. Obščij kurs phiziki [General course to physics]. *PHIZMATLIT*, Moscow. 2004.
3. Landau L.D., Lifshitz E.M. Statisticheskaja fizika [Statistical Physics]. *PHIZMATLIT*, Moscow. 2000.

ELECTRICITY AND MAGNETISM

1. **Electric field in vacuum.** Properties of electric charges. Coulomb's law. Systems of units. Electric field. Field strength. Field superposition principle. Gauss's theorem for electric fields. Electric field potential. Relations between strength and potential. Poisson's equation.
2. **Electric field in dielectrics.** Dielectric polarization, types of dielectrics. Field within the dielectrics. Polarization vector. Surface and volume bound charge density. Electric displacement vector. Gauss's theorem for dielectrics.
3. **Conductors in electric field.** Conditions for equilibrium of charges of conductor. Conductors within external electric field. Conductor capacity. Capacitors.
4. **Electric energy.** Electric energy of system of discrete charges. Energy of charged conductors and capacitors. Electric field energy.

5. **Flow of direct current.** Current density, current intensity. Electric charge conservation law. Electromotive force. Ohm law for homogeneous subcircuits. Ohm's law for inhomogeneous subcircuits. Joule's law. Current within electrolytes. Current within gases.

6. **Magnetic field in vacuum.** Induction of magnetic field. The Lorentz force. The Ampère force. The Biot-Savart law. Current loop within magnetic field. Gauss theorem for magnetic fields. Theorem of circulation of magnetic field in vacuum.

7. **Magnetic field in substance.** Molecular currents, magnetization of magnets, magnetic field strength. Magnetic susceptibility and permeability. Types of magnets.

8. **Electromagnetic induction.** Faraday's law of electromagnetic induction. Universal law of electromagnetic induction. Self-induction. Magnetic field energy.

9. **Alternating current.** Quasi-stationary currents. Chain with capacity, induction and resistance. Voltage resonance. Current resonance.

10. Displacement currents. Maxwell's equation.

References:

1. Matveev A.N. Elektrichestvo i magnetizm [Electricity and magnetism]. Lan', St-Petersburg. 2010.

2. Sivukhin D.V. Obščij kurs fiziki [General course to physics]. PHIZMATLIT, Moscow. 2009.

3. Landau L.D., Lifshitz E.M. Teorija polja [Field theory]. PHIZMATLIT, Moscow. 2006.

4. Tamm I.E. Osnovy teorii elektrichestva [Principles of electricity theory]. Oniks, Moscow. 2012.

OPTICS

1. **Electromagnetic waves.** Electric oscillation equation. Electromagnetic radiation. Wave equation for electromagnetic field. Plane electromagnetic waves. Energy and momentum of electromagnetic field. Electromagnetic waves emission. Electromagnetic waves scale. Reflection and refraction of plane wave on the border of two dielectrics.

2. **Optical interference.** Interference of two monochromatic waves. Coherence problem. Interference devices. Optical interference within films and wedges. Newton's rings. Multiple-beam interference.

3. **Optical diffraction.** The Huygens-Fresnel principle. Fresnel zones. The Fresnel diffraction at circular aperture and disc. The Fraunhofer diffraction at single slit. Diffraction grating. X-ray diffraction. Basic physics for holography.

4. **Optical polarization.** Natural and polarized light. Malus's law. Polarization under reflection and refraction. Polarization under birefringence. Polarization devices. Artificial birefringence.

5. **Dispersion, absorption, scattering of electromagnetic waves.** Optical dispersion. Group velocity. Classical theory of optical dispersion. Absorption and dispersion of light. Beer's law, Bouguer's law, Lambert's absorption law.

6. **Quantum optics.** Equilibrium radiation. Kirchhoff's law. Blackbody model. Equilibrium density of radiation energy. The Stefan-Boltzmann law and Wien displacement law. The Rayleigh-Jeans law and Wien law. Planck's radiation law. Photoeffect. Spontaneous and forced transitions. Active medium and means of its formation. Principles of work of laser.

References:

1. Sivukhin D.V. Obščiy kurs fiziki [General course to physics]. PHIZMATLIT, Moscow. 2006.

2. Landsberg G.S. Optika [Optics]. PHIZMATLIT, Moscow. 2010.

3. Butikov E.I. Optika [Optics]. Lan', St-Petersburg. 2012.

QUANTUM MECHANICS

1. **Laws in atomic spectra**. Bohr's postulates. The Franck-Hertz experiment. Bohr's theory of hydrogenous atom. Quantum and mechanic theory of hydrogenous atom. The De Broglie hypothesis, wave properties of matter. Quantum and mechanic description of microparticle movement. The Schrödinger equation. Physical interpretation of wave function. Particle movement in infinite deep potential well. Tunnel effect.
2. **Multielectronatoms.** Alkali metal spectra. Multiplicity of spectra and electron spins. Angular momentum in quantum mechanics. Resultant moment of multielectron atom. Mendeleev's periodic system of elements.

References:

1. Blokhintsev D.I. Osnovy kvantovoj mekhaniki [Basic principles of quantum mechanics]. Oniks, Moscow. 2012.
2. Landau L.D., Lifshitz E.M. Kvantovaja mekhanika. Nereljativistskaja teorija [Quantum mechanics. Nonrelativistic theory]. PHIZMATLIT, Moscow. 2004.

ATOMIC AND NUCLEAR PHYSICS

1. **Structure and properties of atomic nucleus**. Atomic nucleus models. Isotopes. Isobars. Mass and nuclear binding energy. Nuclear energy and stability. Nuclear forces.
2. **Radioactivity.** Alpha decay. Beta decay. Nuclear fission. Nuclear synthesis.
3. **Elementary particles.** Types of interaction and classes of elementary particles. Methods of elementary particles observation. Cosmic rays.

References:

1. Matveev A.N. Atomnaja fizika [Atomic physics]. Oniks. Mir i obrazovanie. 2007.
2. Astakhov A.V., Shirokov Yu.M. Kvantovaja fizika. 1993.

4. INTERVIEW ON THE PROFILE OF THE MASTER'S PROGRAMME: STRUCTURE, PROCEDURE, PROGRAMME, AND ASSESSMENT CRITERIA

4.1 Structure and Procedure of the Interview

4.1.1 Interview consists in the conversation with an applicant based on the documents (motivation letter, curriculum vitae) submitted in English before the start of entrance examination (Part 1) and conversation based on the questions defining the profile of the Programme (Part 2).

Motivation letter is filled in by the applicant. It provides reasons for his/her self-motivation, choice of the Programme, and expectations. A curriculum vita is a written overview of an applicant's personal information, education, other qualifications.

Interview is held in English for all candidates.

4.1.2 Interview lasts 30 minutes taking into account individual characteristics and speech rate of applicants.

4.1.3 Interview helps to identify applicants' interests in interdisciplinary studies in the subject area of the Master's Programme. It allows revealing their knowledge and skills and motivation for future profession.

Candidates must demonstrate their speaking skills (monologue and dialogue). Assessment parameters include fluency of speech, content and reasoning of statements.

4.1.4 Applicant answers one question in the exam paper:

Maximum for every part of the examinations is **50** points.

Maximum for the examination is **100** points.

Minimum threshold is **60** points.

Applicants not meeting the minimum passing score will not be admissible for the Programme.

4.1.5 Assessment criteria**:**

– 50 points – Answer is complete. Issue is exactly and fully stated, terms are correct, a student has a full command of the material, and there are no mistakes.

– From 40 to 50 points –answer is complete, though somewhat short, terms are correct, there are no significant mistakes.

– From 30 to 40 points – some significant elements are omitted and/or there are some significant mistakes.

– From 20 to 30 points –answer is irrelevant or not given at all.

4.1.6 Assessment criteria based on the documents (motivation letter, curriculum vitae):

– 50 points – answer reveals a clear position regarding the choice of the Programme, justification of individual interests including the research ones and further professional development; high motivation to obtain a double degree;

– From 30 to 50 points – answer does not reveal a clear position regarding the choice of the Programme, further professional development, and research.

– From 20 to 30 points – answer is not convincing in terms of motivation to study on the Programme.

4.1.7 Verification procedure

The Examination Board listen to the answer and write it down to the answer sheet. The Examination Board record the answers and follow-up questions in the minute of the meeting of the Examination Board and publicly announce the decision on the score.

4.1.8 Appeal procedure

Applicants may challenge the results of exam if think they are wrong. When considering an appeal, an applicant is not given another examination paper and not allowed to answer again. The Appeal Committee consider the answers written in the answer sheet and answers recorded in the minute and provide the applicant with reasons for decision. In case of reasonable disagreement of members of the Appeal Committee on the grade, the Appeal Committee can improve the overall score by majority vote.

4.2 Programme of the Interview

4.2.1 Sample interview questions:

1. Differences between living and non-living systems. Definition of a biological object. Characteristics of living systems.
2. Interdisciplinary studies and their role in the development of science.
3. Biological, physical and mathematical models of biological systems.
4. Mathematical modelling of biological systems.
5. Physical characteristics of biological systems and their measurement.
6. Physical principles of diagnostic medical equipment.
7. Systems Biology and Bioinformatics.
8. Application of mathematical modelling to numerical experiments in biomedicine.
9. Bioengineering technologies in medicine.
10. Major achievements of the XXI century in the field of biophysics and biomedicine.
11. Appliances for medical purposes and their significance for humans.
12. Management of biological systems by means of external factors.