Federal State Autonomous Educational Institution of Higher Education "Moscow Institute of Physics and Technology (National Research University)"

APPROVED
Vice Rector for Academic Affairs

A.A. Voronov

Work program of the course (training module)

course:	General Physics: Mechanics/Общая физика: механика
major:	Biotechnology
specialization:	Biomedical Engineering/Биомедицинская инженерия
	Phystech School of Biological and Medical Physics
	Chair of General Physics
term:	1
qualification:	Bachelor

Semester, form of interim assessment: 2 (spring) - Exam

Academic hours: 60 AH in total, including:
lectures: 30 AH.
seminars: 30 AH.
laboratory practical: 0 AH.

Independent work: 45 AH.

Exam preparation: 30 AH.

In total: 135 AH, credits in total: 3

Number of course papers, tasks: 2

Authors of the program:

P.V. Popov, candidate of physics and mathematical sciences
A.V. Ilin, candidate of physics and mathematical sciences, associate professor

The program was discussed at the Chair of General Physics 04.06.2020

Annotation

Mastering basic knowledge by students for further study of other branches of physics.

1. Study objective

Purpose of the course

Students master basic knowledge in the field of mechanics for further study of other branches of physics and in-depth study of the fundamental foundations of mechanics.

Tasks of the course

- formation of students ' basic knowledge in the field of mechanics
- formation of skills and abilities to apply the studied theoretical laws and mathematical tools to solve various physical problems
- the formation of physical culture: the ability to distinguish the essential physical phenomena and to disregard the irrelevant;
- ability to conduct evaluations of physical quantities; ability to build a simple theoretical model is described serving the physical processes.

2. List of the planned results of the course (training module), correlated with the planned results of the mastering the educational program

Mastering the discipline is aimed at the formation of the following competencies:

Code and the name of the competence	Competency indicators
UC-1 Search and identify, critically assess, and synthesize information, apply a systematic approach to problem-solving	UC-1.1 Analyze problems, highlight the stages of their solution, plan the actions required to solve them
	UC-1.2 Find, critically assess, and select information required for the task in hand
	UC-1.3 Consider various options for solving a problem, assess the advantages and disadvantages of each option
	UC-1.4 Make competent judgments and estimates supported by logic and reasoning
	UC-1.5 Identify and evaluate practical consequences of possible solutions to a problem
Gen.Pro.C-4 Collect and process scientific and technical and/or technological data for fundamental and applied problem-solving	Gen.Pro.C-4.1 Apply scientific research and intellectual analysis methods for professional problem-solving
	Gen.Pro.C-4.2 Search for primary sources of scientific and technical and/or technological information in professional settings
	Gen.Pro.C-4.4 Use computer and network skills to obtain, store, and process scientific (technical, technological) information
Pro.C-1 Plan and conduct scientific experiments (in a selected subject area) and/or theoretical (analytical and simulation) research	Pro.C-1.1 Understand the fundamental concepts, laws, and theories of modern physics and biology

3. List of the planned results of the course (training module)

As a result of studying the course the student should:

know:

- fundamental laws and concepts of mechanics, as well as the limits of their applicability:
- fundamentals of kinematics: radius-vector, velocity, tangential and normal acceleration, radius of curvature of the trajectory;
- Newton's laws in inertial and non-inertial frames of reference;
- laws of conservation of momentum, energy, momentum;
- laws of motion of bodies in the gravitational field (Kepler's laws);
- laws rotational motion of a rigid body about a fixed axis and planar movement;
- basis of the approximate theory of gyroscopes;
- basic concepts of the theory of oscillations: the equation of harmonic oscillations and its solution, attenuation, q-factor of the oscillatory system;
- basic concepts of the theory of elasticity and hydrodynamics;
- fundamentals of special relativity: basic postulates, Lorentz transformations and their consequences, expressions for momentum and energy of relativistic particles.

be able to:

- apply the studied General physical laws to solve specific problems of mechanics;
- record and solve the equations of motion of the particle and the particle system, including the reactive motion;
- to apply the conservation laws to solutions of problems of dynamics of particles, systems of particles or rigid bodies;
- apply conservation laws in the study of elastic and inelastic collisions of particles, including relativistic ones;
- calculate the parameters of orbits when moving in the gravitational field for the two-body problem;
- apply the laws of mechanics to different reference systems, including non-inertial ones;
- calculate the moments of inertia of symmetric solids and apply to them the laws of rotational motion;
- to count the oscillation periods of various mechanical systems with one degree-new freedom, including fluctuations in solids;
- analyze physical problems, highlighting the essential and non-essential aspects of the phenomenon, and on the basis of the analysis to build a simplified theoretical model of physical phenomena;
- apply various mathematical tools for solving problems based on the formulated physical laws, and carry out the necessary analytical and numerical calculations/

master:

- the main methods for solving problems in mechanics;
- basic mathematical tools pertaining to the problems in mechanics.

4. Content of the course (training module), structured by topics (sections), indicating the number of allocated academic hours and types of training sessions

4.1. The sections of the course (training module) and the complexity of the types of training sessions

№	Topic (section) of the course	Types of training sessions, including independent work			
		Lectures	Seminars	Laboratory practical	Independent work
1	The subject and role of physics	2	2		3
2	The dynamics of point particle.	2	2		3
3	Work done by force. Power. Conservation of energy.	2	2		3
4	Angular momentum of material point.	2	2		3
5	Newton’s law of universal gravitation.	2	2		3
6	Rotation of solid body about a fixed axis.	2	2		3
7	Kinematics of rigid body.	2	2		3
8	General case of rotation of a rigid body.	2	2		3
9	Non-inertial reference frames.	2	2		3
10	Harmonic oscillations of a material point.	2	2		3
11	Free damped oscillations.	2	2		3

12	Elements of elasticity theory and hydrostatics.	2	2		3
13	Propagation of longitudinal elastic perturbations in a continuous medium.	2	2		3
14	Elements of special theory of relativity.	2	2		3
15	Momentum and energy of relativistic particle.	2	2		3
AH in total		30	30		45
Exam preparation		30 AH.			
Total complexity		135 AH., credits in total 3			

4.2. Content of the course (training module), structured by topics (sections)

Semester: 2 (Spring)

1. The subject and role of physics

Limits of applicability of physical laws. Measurement of physical quantities. Units of measurement. The International System (SI), Gaussian System (CGS), and off-system units.
Basics of kinematics. Frame of reference and coordinate systems (Cartesian, polar, and spherical coordinate systems). Radius vector, linear and angular velocity, acceleration. Normal, tangential, and total acceleration. Description of motion along a flat curve, the radius of curvature of a trajectory.

2. The dynamics of point particle.

A state of particle in classical mechanics. The main task of the dynamics. Inertial and non-inertial reference frames. Newton's first law. Force and impulse of force. Inertial mass and gravitational mass. Newton's second law. The equation of motion of a particle, the role of initial conditions. Newton's third law. The law of conservation of momentum.
The motion of a variable-mass system. Jet propulsion. The Tsiolkovsky rocket equation.

3. Work done by force. Power. Conservation of energy.

Conservative and non-conservative forces. A force field. Potential energy, a field potential. Kinetic energy of a particle. The law of conservation of energy in mechanics. The general physics law of conservation of energy.
Dynamics of a system of particles. The center of mass (center of inertia). The law of motion of the center of mass. The center-of-mass frame of reference. Energy transformation under switching between reference frames. Koenig’s theorem. The two-body problem, the reduced mass. Two-particle analysis of absolutely elastic and inelastic collisions. Construction and application of vector diagrams. The threshold energy for inelastic collision of particles.

4. Angular momentum of material point.

The connection of angular momentum of material point with its sectorial velocity. The angular momentum of a system of material points. Torque. The equation of torque. The law of conservation of angular momentum. The motion of a body in a central field.

5. Newton’s law of universal gravitation.

Potential energy in a gravitational field. Kepler’s laws. Classification of trajectories in the field of central gravitational forces, finite motion and infinite motion. The criterion of finite motion. The orbital velocity and escape velocity. The connection of the planet orbit parameters with the total energy and angular momentum of a planet. Gauss’s theorem and its application for calculating gravitational fields.

6. Rotation of solid body about a fixed axis.

Moment of inertia. Calculation of moment of inertia of a solid body. Huygens–Steiner theorem. The equation of rotation about a fixed axis. The kinetic energy of rotating body.

7. Kinematics of rigid body.

Euler's rotation theorem. Instantaneous axis of rotation. Angular velocity as a vector, addition of rotations. Independence of angular velocity of a rigid body on a position of the rotation axis. The equation of rotation relative to the moving coordinate origin and to the moving rotation axis. Planar motion of a rigid body. Rolling motion. Rolling of a rigid body along an inclined plane.

8. General case of rotation of a rigid body.

The inertia tensor and the inertia ellipsoid. Centrifugal moments of inertia. Principal axes of inertia. Regular precession of a free rotating symmetric top. Gyroscopes. Motion of a free gyroscope. The equation of motion of a gyroscope under the action of forces (approximate theory). Gyroscopic forces. Gyro applications.

9. Non-inertial reference frames.

Forces, relative acceleration, drag acceleration, and the Coriolis acceleration. Centrifugal force. The Coriolis force. Newton's second law in a non-inertial reference frame. Potential energy of centrifugal forces. A body weight and weightlessness. A deviation of a falling body from the plumb line. Geophysical manifestations of the Coriolis forces. Foucault's Pendulum.

10. Harmonic oscillations of a material point.

A spring pendulum and a simple gravity pendulum. Frequency, circular frequency, and oscillation period. The role of initial conditions. Oscillation energy, the relationship between the average kinetic energy and average potential energy of a harmonic oscillator. Mechanical oscillations of a rigid body. Physical pendulum. Huygens' theorem on the physical pendulum.

11. Free damped oscillations.

Attenuation (decay) coefficient, logarithmic decrement, quality factor. Forced oscillations of a material point under the action of sinusoidal force. Resonance. Resonance curves, amplitude-frequency and phase-frequency characteristics of oscillator. Phase plane and phase trajectory of oscillator. Superposition of oscillations: The Lissajous figures, oscillation beats. Parametric buildup of oscillations. The concept of self-oscillations.

12. Elements of elasticity theory and hydrostatics.

Solid body equilibrium conditions. Normal and tangential stress. Elastic and plastic deformations. Stretching and compression of rods. Elasticity coefficient, Young's modulus and Poisson’s ratio. The energy density of elastic deformation. Uniform and uniaxial strain and compression. Shear deformation and rotational deformation. Hydrostatics: Pascal's law, Archimedean force, the equation of fluid equilibrium.

13. Propagation of longitudinal elastic perturbations in a continuous medium.

The wave equation. Wavelength, wave number, and phase velocity. Plane wave and standing wave. Reflection of waves on a free boundary and on a rigidly fixed boundary. The condition for standing waves. The wave energy flow density. The Doppler Effect.

14. Elements of special theory of relativity.

Principle of relativity. The independence of interaction propagation velocity (or speed of light) on the reference frame. Galilean and Lorentz transformations. The interval and its invariance under a change of reference frame. Relativity of simultaneity. Time dilation, the proper lifetime of a particle. Lorentz contraction, proper length. Velocity addition. The Relativistic Doppler effect.

15. Momentum and energy of relativistic particle.

Equation of motion of relativistic particle under the action of external force. The kinetic energy of a relativistic particle, the rest energy, and the total energy. Invariance of the mass of a system of particles. Energy–momentum invariant. Particle accelerators.

5. Description of the material and technical facilities that are necessary for the implementation of the educational process of the course (training module)

Facilities and Resources:
- A lecture audience equipped with a multimedia projector and a screen.
- Equipment for lecture demonstrations.
- Classrooms equipped with a board.
- Libraries of educational and technical literature, including electronic libraries, necessary for individual work of students.

6. List of the main and additional literature, that is necessary for the course (training module) mastering

Main literature

1. Physics: A General Course v. 1: Mechanics, Molecular Physics (by I.V. Savelyev), Central Books Ltd (1981), Mir Publishers (1989)
2. General Physics: Mechanics and Molecular Physics (by L. Landau, A. Akhiezer, E. Lifshitz), Pergamon Press (1967)
3. Problems in General Physics (by I.E. Irodov), Mir Publishers (Revised edition 1988)

Additional literature

1. Fundamental Laws of Mechanics (by I.E. Irodov), Mir Publishers (Moscow), CBS Publishers & Distributors (India), 6th edition (2016)
2. Berkeley Physics Course: Vol. 1 - Mechanics (by C. Kittel, W.D. Knight, and M.A. Ruderman), McGraw-Hill, New York, second edition (1973)
3. The Feynman Lectures on Physics, The Definitive Edition Volume 1: (2nd Edition) by Richard P. Feynman and Robert B. Leighton, Addison Wesley; 2nd edition (2005)

7. List of web resources that are necessary for the course (training module) mastering

1. http://mipt.ru/education/chair/physics/S_IV/Metod_4/— методический раздел сайта кафедры Общей физики
2. http://lib.mipt.ru/catalogue/1412/?t=750 – электронная библиотека МФТИ, раздел «Общая физика»

8. List of information technologies used for implementation of the educational process, including a list of software and information reference systems (if necessary)

The List of Informational Resources:
1. Methodical section of the Department of General Physics website: http://mipt.ru/education/chair/physics/S_I/method/.
2. MIPT electronic library, the General Physics section: http://lib.mipt.ru/catalogue/1412/?t=750.
Lecture halls are equipped with multimedia and presentation facilities.
The recommended literature is available in electronic form (see paragraphs [1, 2] of the list of Internet resources necessary for mastering the discipline modules) so that the students may read textbooks using their tablets.

9. Guidelines for students to master the course

Guidelines for Students on Mastering the Discipline:

A student studying the general physics course must learn the general physics laws and concepts, and how to apply them in practice.

Successful mastering of the course requires intensive individual work of each student. The course program informs of the minimum time required for the student to work on the course topics. The individual work includes:

- reading and making summary of recommended literature,
- studying educational materials (lecture notes, educational and scientific literature), preparing answers to questions intended for self-study;
- solving the problems offered to students in lectures and seminars,
- passing assignments and preparing for seminars, tests, and exams.

Guidance and control of individual work is offered to students in the form of individual consultations.

The ability to solve problems is an indicator of the student's mastery of physics. To develop such ability, a student needs to solve as many problems as possible. When solving a problem, a student must be able to explain each action on the basis of the studied theoretical topics and carry out all the necessary calculations to bring the solution to a final answer. A problem is considered solved if it contains substantiated actions including references to the applicable physical laws and correct calculations, as well as the correct numerical answer (if the problem contains numerical data).

When preparing for a seminar, students must learn the basic concepts and laws to which the seminar will be devoted, and solve the problems envisaged for preparation to the seminar topic.

Physics makes use of many concepts and methods of calculus. If a student encounters a mathematical concept that has not yet been studied in the framework of mathematical courses then he/she must learn the relevant section of math individually. The necessary minimum of mathematical information is presented both at lectures and in the recommended literature.

The mid-semester control of knowledge is conducted in the form of a written test, in which the student is offered to solve five problems on the studied topics. The written test is given in the format similar to a written exam. In order to test the student's level of knowledge and understanding of the material, the teacher may ask the student, during the presentation of the assignment, additional theoretical questions on the syllabus or give additional problems to solve. Each student is required to complete, in a special notebook, the homework assignments and submit them for inspection.

At the written exam, the student is asked to solve five problems. The subjects of the problems are fully consistent with the physics course syllabus. However, all the problems in the written exam are completely non-typical. At the exam, students are allowed to use a sheet of paper with formulas written on it in advance. Such form of exam eliminates mindless memorization of formulas and is aimed at checking the depth of understanding of the material and the ability to apply physical laws in an unusual situation.

Students are recommended to study individually various topics related to general physics, possibly beyond the scope of the program, thus expanding their physical horizon. At the exam, the student is offered to present any theoretical or experimental topic prepared in advance and related to the course of physics. This can be either an in-depth presentation of one of the syllabus topics or a topic not covered in the syllabus, which can, however, be considered as part of the physics course studied, thus demonstrating the ability to understand various issues and problems of physics based on the use of general physical laws.

SUPPLEMENT

Assessment funds for course (training module)

major:	Biotechnology
specialization:	Biomedical Engineering/Биомедицинская инженерия
	Phystech School of Biological and Medical Physics
	Chair of General Physics
term:	1
qualification:	Bachelor

Semester, form of interim assessment: 2 (spring) - Exam

Authors:

P.V. Popov, candidate of physics and mathematical sciences
A.V. Ilin, candidate of physics and mathematical sciences, associate professor

1. Competencies formed during the process of studying the course

Code and the name of the competence	Competency indicators
UC-1 Search and identify, critically assess, and synthesize information, apply a systematic approach to problem-solving	UC-1.1 Analyze problems, highlight the stages of their solution, plan the actions required to solve them
	UC-1.2 Find, critically assess, and select information required for the task in hand
	UC-1.3 Consider various options for solving a problem, assess the advantages and disadvantages of each option
	UC-1.4 Make competent judgments and estimates supported by logic and reasoning
	UC-1.5 Identify and evaluate practical consequences of possible solutions to a problem
Gen.Pro.C-4 Collect and process scientific and technical and/or technological data for fundamental and applied problem-solving	Gen.Pro.C-4.1 Apply scientific research and intellectual analysis methods for professional problem-solving
	Gen.Pro.C-4.2 Search for primary sources of scientific and technical and/or technological information in professional settings
	Gen.Pro.C-4.4 Use computer and network skills to obtain, store, and process scientific (technical, technological) information
Pro.C-1 Plan and conduct scientific experiments (in a selected subject area) and/or theoretical (analytical and simulation) research	Pro.C-1.1 Understand the fundamental concepts, laws, and theories of modern physics and biology

2. Competency assessment indicators

As a result of studying the course the student should:

know:

- fundamental laws and concepts of mechanics, as well as the limits of their applicability:
- fundamentals of kinematics: radius-vector, velocity, tangential and normal acceleration, radius of curvature of the trajectory;
- Newton's laws in inertial and non-inertial frames of reference;
- laws of conservation of momentum, energy, momentum;
- laws of motion of bodies in the gravitational field (Kepler's laws);
- laws rotational motion of a rigid body about a fixed axis and planar movement;
- basis of the approximate theory of gyroscopes;
- basic concepts of the theory of oscillations: the equation of harmonic oscillations and its solution, attenuation, q-factor of the oscillatory system;
- basic concepts of the theory of elasticity and hydrodynamics;
- fundamentals of special relativity: basic postulates, Lorentz transformations and their consequences, expressions for momentum and energy of relativistic particles.

be able to:

- apply the studied General physical laws to solve specific problems of mechanics;
- record and solve the equations of motion of the particle and the particle system, including the reactive motion;
- to apply the conservation laws to solutions of problems of dynamics of particles, systems of particles or rigid bodies;
- apply conservation laws in the study of elastic and inelastic collisions of particles, including relativistic ones;
- calculate the parameters of orbits when moving in the gravitational field for the two-body problem;
- apply the laws of mechanics to different reference systems, including non-inertial ones;
- calculate the moments of inertia of symmetric solids and apply to them the laws of rotational motion;
- to count the oscillation periods of various mechanical systems with one degree-new freedom, including fluctuations in solids;
- analyze physical problems, highlighting the essential and non-essential aspects of the phenomenon, and on the basis of the analysis to build a simplified theoretical model of physical phenomena;
- apply various mathematical tools for solving problems based on the formulated physical laws, and carry out the necessary analytical and numerical calculations/

master:

- the main methods for solving problems in mechanics;
- basic mathematical tools pertaining to the problems in mechanics.

3. List of typical control tasks used to evaluate knowledge and skills

1. Normal and tangential acceleration. Calculation of speed and acceleration of particle along a flat curve.
2. Newton’s first law. Inertial and non-inertial reference frames.
3. The law of momentum conservation. Newton's third law.
4. Forces of inertia. The Coriolis acceleration. Centrifugal force. The Coriolis force.
5. Mechanical work. Kinetic and potential energy. Law of mechanical energy conservation. General physical law of energy conservation.
6. Angular momentum of a system of particles. Law of angular momentum conservation.
7. Harmonic oscillations of a material point. A spring pendulum. Frequency, circular frequency, and oscillation period.
8. Mechanical oscillations of a rigid body. Physical pendulum. Huygens' theorem on the physical pendulum.
9. Elements of special theory of relativity. Principle of relativity. Lorentz transformations. The interval and its invariance under a change of reference frame.

4. Evaluation criteria

Intermediate certification of students in General Physics is carried out in the form of examina-tion. The exam consists of two parts: a written test, and an oral exam.

At the written test a student is offered to solve five problems. Each problem is an original au-thor's product especially prepared for the exam.

At the oral exam each student has to choose an exam card from a pile of exam cards. Each card contains a theoretical question from the below list of exam questions. In addition, the student is asked to present a “question of choice” prepared in advance, which may be either one of the items in the below list of questions, or any question that is addressed in the course being studied or directly related to it. Also, the results of a laboratory work done by the student may be pre-sented as a question of choice.

Examples of Questions from the Exam Cards:

1. Normal and tangential acceleration. Calculation of speed and acceleration of particle along a flat curve.
2. Newton’s first law. Inertial and non-inertial reference frames.
3. The law of momentum conservation. Newton's third law.

4. Forces of inertia. The Coriolis acceleration. Centrifugal force. The Coriolis force.
5. Mechanical work. Kinetic and potential energy. Law of mechanical energy conservation. General physical law of energy conservation.
6. Angular momentum of a system of particles. Law of angular momentum conservation.
7. Harmonic oscillations of a material point. A spring pendulum. Frequency, circular fre-quency, and oscillation period.
8. Mechanical oscillations of a rigid body. Physical pendulum. Huygens' theorem on the physical pendulum.
9. Elements of special theory of relativity. Principle of relativity. Lorentz transformations. The interval and its invariance under a change of reference frame.

Examples of Oral Exam Additional Questions:

Below are examples of simple problems that a student may be asked to solve at the oral exam in mechanics to get a satisfactory mark (in order to get a mark higher than satisfactory, the student should be ready to solve more complicated problems):

• Find the speed of an arbitrary point of the rim of the wheel that is rolling on a plane without slipping.
• Find the normal and tangential acceleration at some point of the trajectory of the body thrown at an angle to the horizon.
• Formulate the law of change of momentum of a system of particles. Under what conditions is the momentum conserved?
• Find the dependence of speed versus time for a body falling vertically from a low altitude without any initial velocity if the force of air resistance is considered proportional to the speed of the body.
• Formulate the law of change of mechanical energy in a system of particles. Under what conditions is the me-chanical energy of the system conserved?
• What work is produced by force F on elementary displacement dr? Obtain the formula for the power of the force.
• Derive an expression for the potential energy of a spring that obeys the Hooke's law.
• Define a conservative force. Are the following forces conservative: gravity, elasticity, dry friction, air re-sistance?
• The potential energy of the particle is U(x). Find the force acting on the particle along the x-axis.
• Derive the formula for a rocket speed versus its mass in empty space (the Tsiolkovsky's formula).
• The rocket moves upwards in the field of gravity g. The velocity of the exhaust gases of the rocket is equal to u; fuel consumption is μ. Find the acceleration of the rocket at the moment when its mass is equal to m.
• What is the center of mass of a system of particles? Formulate a theorem on the motion of the center of mass.
• Obtain the relationship between the kinetic energy in the center-of-mass reference frame and in the laboratory reference frame (the König's theorem).
• Find the minimum kinetic energy that a (non-relativistic) particle of mass m must have in order to react with a particle at rest of the same mass if the energy absorbed in this reaction is E.
• Find the direction and magnitude of the angular momentum of a particle having mass m, velocity v, and a ra-dius vector r (relative to the origin).
• Find vector M of the torque produced by force F applied to a point with a radius vector r (relative to the origin).
• Formulate the law of change of the angular momentum of a system of particles. Under what condition does the angular momentum remain constant?
• Obtain an expression for the potential energy of gravitational interaction of two point masses m at a distance r.
• Obtain the expression for the first cosmic velocity (orbital velocity).
• Obtain the expression for the second cosmic velocity (escape velocity).
• What will be the trajectory of a particle moving in the gravitational field if its total energy at some point is (1) positive, (2) negative, (3) equal to zero?
• Draw the trajectory of a planet moving around the Sun. Formulate the squares law of Kepler (third Kepler's law). Derive this law for circular orbits.
• The moment of inertia of a rigid body rotating about fixed z-axis is Iz. Find the angular acceleration of the body if torque Mz is acting on it.

• The rigid body having a moment of inertia Iz rotates about a fixed z-axis with angular velocity ω. Find the an-gular momentum relative to the z-axis and the kinetic energy of the body.
• Derive an expression for the moment of inertia of a uniform rod/flat disk relative to the axis perpendicular to the rod/disk.
• Formulate the Steiner's theorem.
• Find the kinetic energy of an axisymmetric body with a known moment of inertia (ball, cylinder, etc.) rolling without slipping along a plane with velocity V.
• Find the acceleration of an axisymmetric body with a known moment of inertia (ball, sphere, cylinder, etc.), rolling without slipping on an inclined plane.
• Find the angular velocity of precession of symmetric rigid top whose rotation axis is inclined at a certain angle to the vertical, and the fulcrum lies on the axis and is fixed on the table.
• Derive a formula for the period of small oscillations of a physical pendulum suspended in a field of gravity.
• The mathematical pendulum of length L has a small velocity V in the equilibrium position. Write the law of change of the pendulum angle against time.
• Write a differential equation for the movement of a load suspended in a gravity field on a spring. Take into account air resistance.
• The quality factor of the oscillatory system is equal to Q. Find the relative change in the energy of the system in one period of oscillation if Q >> 1.
• Find the period of small oscillations of the mathematical pendulum of length L suspended in a car that moves horizontally with acceleration a.
• The carousel rotates at an angular velocity ω. What inertial forces are acting on the moving body in the refer-ence frame of the carousel?
• Write down the expression for the potential energy of a particle in the field of centrifugal forces.
• Provide definitions of Young's modulus and Poisson's ratio.
• Find the stiffness coefficient k of the rod that is in longitudinal tension if the rod length is L, its cross-section area is S, and Young's modulus is E.
• Find the bulk energy density of the stretched/compressed rod.
• Write an expression for the speed of sound in a thin rod.
• Define the ideal fluid. Write the Bernoulli equation.
• Derive the formula for the rate of flow of fluid from the hole in the gravity field (the Torricelli formula).
• Give the definition of viscosity.
• The momentum of the relativistic particle of mass m is equal to p. Find the full energy and kinetic energy of the particle.
• The photon energy is E. Find the photon momentum.
• The own lifetime of a relativistic particle moving with velocity V is τ0. Find the distance that the particle will pass in the laboratory system before decay.

The mark given for the written exam depends on the problem solutions presented by a student. Each problem solution is evaluated according to a three-point grading scale, i.e. each solution is assigned from 0 to 3 points according to the following criteria:

3 points: The problem is solved completely and correctly, i.e. the correct well-founded solution is given and all questions of the problem are answered. Minor flaws may be present (a slip of the pen, or insignificant arithmetic errors).

2 points: The problem is solved, the logic of solution as a whole is correct but there are significant shortcomings (errors in calculations, an absurd answer, etc.).

1 point: The problem is not solved, but all the basic physical laws necessary for the solution are formulated correctly.

0 points: The problem is not solved or solved incorrectly (the basic laws are written with errors, or not completely, the approach to solving the problem is fundamentally wrong, or the solution to the problem does not match the statement).

The points for the five problems of written exam are summed up, the mark and the final score for the written exam are set according to the following scheme:

The sum of all points	Score	Mark
15	10	Excellent
13-14	9	
12	8	
11	7	Good
9-10	6	
8	5	
6-7	4	Satisfactory
5	3	
2-4	2	Unsatisfactory
0-1	1	

The written exam score determines the maximum final score that a student may get at the oral exam. In exceptional cases, when the student demonstrates, during the oral exam, excellent theo-retical knowledge and superb level of understanding of the subject, the final score for the oral exam may be increased but no more than by two points (on a 10-point scale).

At the oral exam, the teacher will assess the student's answer as a whole and assign a mark ac-cording to the criteria set forth below and the above comments regarding the written exam score:

The mark "Excellent" (10 points) is given to a student who has shown comprehensive and sys-tematic knowledge of the syllabus and beyond, as well as the ability to confidently apply the knowledge in solving complicated non-standard problems.

The mark "Excellent" (9 points) is given to a student who has shown comprehensive and sys-tematic knowledge of the syllabus and the ability to confidently apply the knowledge in solving non-standard problems.

The mark "excellent" (8 points) is given to a student who has shown comprehensive and system-atic knowledge of the syllabus and the ability to confidently apply the knowledge in solving non-standard problems but who has allowed for some inaccuracies.

The mark "good" (7 points) is given to a student who has demonstrated firm knowledge and confident understanding of the syllabus and the ability to apply physical laws in solving typical problems.

The mark "good" (6 points) is given to a student who has demonstrated solid knowledge of the syllabus and the ability to apply physical laws in solving typical problems.

The mark "good" (5 points) is given to a student who has demonstrated firm knowledge and un-derstanding of the syllabus and the ability to apply physical laws in solving typical problems, however, made a number of gross inaccuracies when answering.

The mark "satisfactorily" (4 points) is given to a student who has shown a fragmentary knowledge and made mistakes in formulation of basic laws and concepts, but at the same time demonstrated the ability to solve simple problems and understanding of the main sections of syl-labus necessary for further education.

The mark "satisfactorily" (3 points) is given to a student who has shown a highly fragmented knowledge, made gross mistakes in the formulation of basic laws and concepts, but at the same time demonstrated the ability to solve simple problems and understand the main sections of syl-labus required for further education.

The mark “unsatisfactory” (2 points) or “unsatisfactory” (1 point) is given to a student who knows little of the main content of syllabus, systematically makes gross mistakes in formulating basic physical laws, or is unable to correctly apply physical laws even to solve simple problems.

5. Methodological materials defining the procedures for the assessment of knowledge, skills, abilities and/or experience

The Procedure for Written Exam

The duration of the written exam is four astronomical hours. The exam offers to solve five original problems, which correspond to the topics studied at seminars during the semester. A problem is considered solved if it contains a well-founded solution that includes references to the applied physical laws and correct calculations, as well as the correct numerical answer (if the problem contains numerical data). A student can use at the exam a sheet of paper with formulas prepared in advance. It is strictly forbidden to use any notebooks, or compendiums of lectures, or textbooks, or devices that can serve as means of communication, like laptops, tablets, phones, etc. Violators are removed from the exam with the "unsatisfactory" mark. It is allowed to use calcula-tors with no communication facilities. It is forbidden to use calculators in mobile phones, laptops, etc.

The Procedure for Oral Exam

The oral exam is held in traditional form of teacher's conversation with a student on the topic contained in the examination card. The exam card contains two items: a "question of choice" and a question from the course syllabus.

The question of choice may be selected and prepared by the student well before the exam. The student may ask the physics teacher for advice on the topic for the question of choice. A question of choice may be (1) an in-depth presentation of one of the syllabus topics, (2) a ques-tion or problem directly related to one of the topics of the physics course but not covered in it, or (3) a presentation of the results of a laboratory work made by the student in physics laboratory as an additional assignment. Preparation for the question of choice at the oral exam should take no more than five minutes. The student is given 10 minutes to present his/her question of choice at the oral exam.

While presenting the question of choice, the student is allowed to use a plan of presentation and pre-prepared illustrations or graphs presented either on paper or electronic media like a tablet or laptop. Such graphics or illustrations may not contain any text of the report.

The student is given from 30 to 45 minutes to prepare the answer on the topic given in the exam card. During the exam, the student is not allowed to use any literature, computers, pre-prepared own records, or other materials related to the subject, except for the examination pro-gram of the course.

In discussing the exam card topic, the examiner may ask clarifying questions. Also, the ex-aminer has the right to ask the student any additional questions on the syllabus.

In the aggregate, the duration of oral exam for one student should not exceed two astro-nomical hours.

3. The list of typical assignments used to assess the level of knowledge and skills of the students.

Intermediate certification of students in *General Physics* is carried out in the form of examination. The exam consists of two parts: a written test, and an oral exam.

At the written test a student is offered to solve five problems. Each problem is an original author's product especially prepared for the exam.

At the oral exam each student has to choose an exam card from a pile of exam cards. Each card contains a theoretical question from the below list of exam questions. In addition, the student is asked to present a “question of choice” prepared in advance, which may be either one of the items in the below list of questions, or any question that is addressed in the course being studied or directly related to it. Also, the results of a laboratory work done by the student may be presented as a question of choice.

Examples of Questions from the Exam Cards:

1. Normal and tangential acceleration. Calculation of speed and acceleration of particle along a flat curve.
2. Newton’s first law. Inertial and non-inertial reference frames.
3. The law of momentum conservation. Newton's third law.
4. Forces of inertia. The Coriolis acceleration. Centrifugal force. The Coriolis force.
5. Mechanical work. Kinetic and potential energy. Law of mechanical energy conservation. General physical law of energy conservation.
6. Angular momentum of a system of particles. Law of angular momentum conservation.
7. Harmonic oscillations of a material point. A spring pendulum. Frequency, circular frequency, and oscillation period.
8. Mechanical oscillations of a rigid body. Physical pendulum. Huygens' theorem on the physical pendulum.
9. Elements of special theory of relativity. Principle of relativity. Lorentz transformations. The interval and its invariance under a change of reference frame.

Examples of Oral Exam Additional Questions:

Below are examples of simple problems that a student may be asked to solve at the oral exam in mechanics to get a satisfactory mark (in order to get a mark higher than satisfactory, the student should be ready to solve more complicated problems):

- Find the speed of an arbitrary point of the rim of the wheel that is rolling on a plane without slipping.
- Find the normal and tangential acceleration at some point of the trajectory of the body thrown at an angle to the horizon.
- Formulate the law of change of momentum of a system of particles. Under what conditions is the momentum conserved?
- Find the dependence of speed versus time for a body falling vertically from a low altitude without any initial velocity if the force of air resistance is considered proportional to the speed of the body.
- Formulate the law of change of mechanical energy in a system of particles. Under what conditions is the mechanical energy of the system conserved?
- What work is produced by force $\boldsymbol{F}$ on elementary displacement $d\boldsymbol{r}$? Obtain the formula for the power of the force.
- Derive an expression for the potential energy of a spring that obeys the Hooke's law.

• Define a conservative force. Are the following forces conservative: gravity, elasticity, dry friction, air resistance?

• The potential energy of the particle is $U(x)$. Find the force acting on the particle along the x-axis.

• Derive the formula for a rocket speed versus its mass in empty space (the Tsiolkovsky's formula).

• The rocket moves upwards in the field of gravity g. The velocity of the exhaust gases of the rocket is equal to u; fuel consumption is μ. Find the acceleration of the rocket at the moment when its mass is equal to m.

• What is the center of mass of a system of particles? Formulate a theorem on the motion of the center of mass.

• Obtain the relationship between the kinetic energy in the center-of-mass reference frame and in the laboratory reference frame (the König's theorem).

• Find the minimum kinetic energy that a (non-relativistic) particle of mass m must have in order to react with a particle at rest of the same mass if the energy absorbed in this reaction is E.

• Find the direction and magnitude of the angular momentum of a particle having mass m, velocity $\boldsymbol{v}$, and a radius vector $\boldsymbol{r}$ (relative to the origin).

• Find vector $\boldsymbol{M}$ of the torque produced by force $\boldsymbol{F}$ applied to a point with a radius vector $\boldsymbol{r}$ (relative to the origin).

• Formulate the law of change of the angular momentum of a system of particles. Under what condition does the angular momentum remain constant?

• Obtain an expression for the potential energy of gravitational interaction of two point masses m at a distance r.

• Obtain the expression for the first cosmic velocity (orbital velocity).

• Obtain the expression for the second cosmic velocity (escape velocity).

• What will be the trajectory of a particle moving in the gravitational field if its total energy at some point is (1) positive, (2) negative, (3) equal to zero?

• Draw the trajectory of a planet moving around the Sun. Formulate the squares law of Kepler (third Kepler's law). Derive this law for circular orbits.

• The moment of inertia of a rigid body rotating about fixed z-axis is I_z. Find the angular acceleration of the body if torque M_z is acting on it.

• The rigid body having a moment of inertia I_z rotates about a fixed z-axis with angular velocity ω. Find the angular momentum relative to the z-axis and the kinetic energy of the body.

• Derive an expression for the moment of inertia of a uniform rod/flat disk relative to the axis perpendicular to the rod/disk.

• Formulate the Steiner's theorem.

• Find the kinetic energy of an axisymmetric body with a known moment of inertia (ball, cylinder, etc.) rolling without slipping along a plane with velocity V.

• Find the acceleration of an axisymmetric body with a known moment of inertia (ball, sphere, cylinder, etc.), rolling without slipping on an inclined plane.

• Find the angular velocity of precession of symmetric rigid top whose rotation axis is inclined at a certain angle to the vertical, and the fulcrum lies on the axis and is fixed on the table.

• Derive a formula for the period of small oscillations of a physical pendulum suspended in a field of gravity.

• The mathematical pendulum of length L has a small velocity V in the equilibrium position. Write the law of change of the pendulum angle against time.

• Write a differential equation for the movement of a load suspended in a gravity field on a spring. Take into account air resistance.

• The quality factor of the oscillatory system is equal to Q. Find the relative change in the energy of the system in one period of oscillation if $Q >> 1$.

• Find the period of small oscillations of the mathematical pendulum of length L suspended in a car that moves horizontally with acceleration a.

• The carousel rotates at an angular velocity ω. What inertial forces are acting on the moving body in the reference frame of the carousel?

• Write down the expression for the potential energy of a particle in the field of centrifugal forces.

• Provide definitions of Young's modulus and Poisson's ratio.

• Find the stiffness coefficient k of the rod that is in longitudinal tension if the rod length is L, its cross-section area is S, and Young's modulus is E.

• Find the bulk energy density of the stretched/compressed rod.

• Write an expression for the speed of sound in a thin rod.

• Define the ideal fluid. Write the Bernoulli equation.

• Derive the formula for the rate of flow of fluid from the hole in the gravity field (the Torricelli formula).

• Give the definition of viscosity.

• The momentum of the relativistic particle of mass m is equal to p. Find the full energy and kinetic energy of the particle.

• The photon energy is E. Find the photon momentum.

• The own lifetime of a relativistic particle moving with velocity V is τ_0. Find the distance that the particle will pass in the laboratory system before decay.

4. Evaluation Criteria

The mark given for the written exam depends on the problem solutions presented by a student. Each problem solution is evaluated according to a three-point grading scale, i.e. each solution is assigned from 0 to 3 points according to the following criteria:

3 points: The problem is solved completely and correctly, i.e. the correct well-founded solution is given and all questions of the problem are answered. Minor flaws may be present (a slip of the pen, or insignificant arithmetic errors).

2 points: The problem is solved, the logic of solution as a whole is correct but there are significant shortcomings (errors in calculations, an absurd answer, etc.).

1 point: The problem is not solved, but all the basic physical laws necessary for the solution are formulated correctly.

0 points: The problem is not solved or solved incorrectly (the basic laws are written with errors, or not completely, the approach to solving the problem is fundamentally wrong, or the solution to the problem does not match the statement).

The points for the five problems of written exam are summed up, the mark and the final score for the written exam are set according to the following scheme:

The sum of all points	**Score**	**Mark**
15	10	Excellent
13-14	9	
12	8	
11	7	Good
9-10	6	
8	5	
6-7	4	Satisfactory
5	3	
2-4	2	Unsatisfactory
0-1	1	

The written exam score determines the maximum final score that a student may get at the oral exam. In exceptional cases, when the student demonstrates, during the oral exam, excellent theoretical knowledge and superb level of understanding of the subject, the final score for the oral exam may be increased but no more than by two points (on a 10-point scale).

At the oral exam, the teacher will assess the student's answer as a whole and assign a mark according to the criteria set forth below and the above comments regarding the written exam score:

The mark **"Excellent"** (10 points) is given to a student who has shown comprehensive and systematic knowledge of the syllabus and beyond, as well as the ability to confidently apply the knowledge in solving complicated non-standard problems.

The mark **"Excellent"** (9 points) is given to a student who has shown comprehensive and systematic knowledge of the syllabus and the ability to confidently apply the knowledge in solving non-standard problems.

The mark **"excellent"** (8 points) is given to a student who has shown comprehensive and systematic knowledge of the syllabus and the ability to confidently apply the knowledge in solving non-standard problems but who has allowed for some inaccuracies.

The mark **"good"** (7 points) is given to a student who has demonstrated firm knowledge and confident understanding of the syllabus and the ability to apply physical laws in solving typical problems.

The mark **"good"** (6 points) is given to a student who has demonstrated solid knowledge of the syllabus and the ability to apply physical laws in solving typical problems.

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5. Teaching Aids Defining the Procedures for Assessing Knowledge, Skills, Abilities and/or Experience

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In discussing the exam card topic, the examiner may ask clarifying questions. Also, the examiner has the right to ask the student any additional questions on the syllabus.

In the aggregate, the duration of oral exam for one student should not exceed two astronomical hours.