



**RUSSIAN DEPARTMENT OF SCIENCE AND HIGHER EDUCATION
FEDERAL STATE BUDGET
HIGHER EDUCATION INSTITUTION
«DON STATE TECHNICAL UNIVERSITY»
(DSTU)**

**ACADEMIC COMPETITION «MASTERSIUM»
FOR ENTRANT TO MASTER`S PROGRAM IN 2026**

**THE DIRECTION OF PREPARATION «MECHATRONICS AND ROBOTICS»
THE PROGRAM «DESIGNING AND INTELLECTUAL ROBOT CONTROL AND
MECHATRONIC SYSTEMS»**

**METHODOLOGICAL RECOMMENDATIONS FOR PREPARATION TO THE
CONCLUDING STAGE OF ACADEMIC COMPETITION**

The Department «Robotics and Mechatronics »

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CONCLUDING STAGE

The nature and level of complexity of the Academic Competition tasks are aimed at achieving the objectives of the Academic Competition: identification of individuals with abilities to research activities for the formation of a qualitative contingent of students oriented towards continuing their academic career; Attracting talented young people, including from foreign countries, to study in the master's degree.

The tasks contain theoretical questions and practical tasks and also require knowledge and skills acquired in a bachelor's degree. The tasks are aimed at identifying the abilities of participants to logically explain theoretical questions and apply their knowledge to solve practical problems.

The main stage of the Academic Competition is held only in written form. Each participant of the Academic Competition receives a form with a task containing four questions of theoretical nature and practical problem. When answering questions of a theoretical nature, it is necessary to clearly and competently present the material, based on facts and knowledge, to reveal the essence of the concept, use generally accepted terminology and demonstrate an understanding of the relationship between theory and practice. The answer should be logical: explain the subject area, show the connection of the issue under consideration with the problems of mechatronics and robotics. In the answer you need to look at the problem from different angles, to show the depth of your knowledge.

During solving practical problems it is necessary to perform analysis of the problem, determine which methods, using what known laws the problem can be solved. In the process of making a decision, make sure to write down your comments in order to understand your actions during the check. .

In the preparation for an Academic Competition you should repeat below topics:

- Physics, Mathematics;
- Machine parts and their designing;
- Sensors and measurements in mechatronics systems;
- Management and modelling of mechatronics and robotics systems;
- Robot and mechatronic devices;
- Artificial intelligence.

**LIST OF CONTENT ELEMENTS INCLUDED IN THE FINAL ACADEMIC
COMPETITION PHASE 2025/2026 ACADEMIC YEAR**

The topic 1. Machine parts and their designing

Description of the section. This section includes general principles of designing, calculation and creation of basic machine elements, mechatronic devices and robots. The design and operation of assemblies, connections, transmissions, shafts, bearings and other elements are considered, which is important for the design and maintenance of machines in general.

An example of question. «Types and classification of mechanical transmissions. General fields of application of mechanical transmissions».

Analysis of the task.

Mechatronic and robotics studies, designs and uses various devices and robots. Each of these devices use mechanical transmissions. Transmitting motion, moment, force from the engine to the actuator or instrument. Mechanical transmissions are usually classified according to the principle of transmission of movement on friction and drive gears (toothed, chain, worm, screw). The main types include toothed (cylindrical, conical), belt, chain, worm and frictional (with discs, variators) as well as screw and planetary. They have a gear ratio (constant or adjustable) and are used to change the speed and torque. A description of these types should be given, indicating the principle of action, characteristics, areas of application of transmissions.

The topic 2. Topic name «Sensors and measurements in mechatronics systems».

Description of the section. Sensors and measurements in mechatronic systems provide the necessary for management and interaction with other information systems. Sensors (sensors) convert physical quantities (temperature, pressure, displacement, speed) into electrical signals for processing in processor control systems.

An example of question. «Basic parameters of the sensors. Physical quantities to be measured in mechatronic systems».

Analysis of the task (if detailed analysis of the task is required).

In mechatronic systems, depending on their purpose, the mechanical, electrical and thermal values are measured, including speed and acceleration, displacement, force, torque, pressure, as well as other parameters that need to be known for the operation of the object.

The main parameters of the sensors are:

sensitivity (change of output to input unit);

error/accuracy (deviation of measurement result from true value);

measurement range;

response time (reaction rate);

linearity (straightness of the characteristics);

permission (minimal change of the input that is being recorded)..

The sensors also differ in the characteristics of the output signal. The output signal can be analog (e.g., changing voltage or current) or digital.

The main metrological characteristics of sensors are:

- Error - deviation of the measurement result from the true value.
- Accuracy is the maximum expected measurement error; inverse error characteristic.
- Linearity - the degree of compliance of the sensor's real characteristics with a perfect direct relationship between input and output..
- Zero deviation - the value of the output signal at zero input.
- Result uncertainty is the variation of possible measurement results for the same output signal.

Modern microprocessor sensors can have additional functions, such as:

- Filtering and processing data in the sensor itself;
- Correction of measurement errors;
- Storage and transformation of signals;
- Protection against interference;
- Linearization of sensor input characteristics.

With the help of sensors, mechatronic and robotic systems are able to perceive the «outside world» and make decisions about interaction with it.

The topic 3. Topic name ««Management and modelling of mechatronic and robotic systems»»

Section description. Mechatronic and robotic systems management and modelling is an interdisciplinary field that combines mechanics, electronics, informatics and control theory to create, analyze and design mechatronic and robotic systems including intelligent ones. Modeling is the main tool for studying the behavior of systems in different conditions, taking into account the interaction with humans, with other robots.

Example of question. «Model, its purpose. Physical, analog and mathematical models».

Analysis of the task.

A mathematical model is a simplified description of a real object, system or phenomenon using mathematical concepts, formulas, equations and graphs. Its main purpose is to study the behavior of a real object in different conditions, conducting virtual experiments, optimizing parameters, making informed decisions when designing and developing new systems.

Physical models are real, material reduced or enlarged copies of objects, analog - based on similar processes of different nature, but which are described by single equations (for example, processes in the electrical circuit and in the hydraulic system. Mathematical models are equations describing the relationships between parameters (variables) of a real object, linking them to the physical model.

An example of a physical model is a mock-up of an aircraft for aerodynamic tests.

An example of an analog model is the study of mechanical oscillations in the drive of a robot by means of a developed electrical circuit, in which the oscillations of currents and voltages correspond to the mechanical oscillations in the real drive.

An example of a mathematical model - equations describing the movements of the robot depending on the speed of rotation of each wheel. For a mobile robot with two independently controlled driving wheels, its coordinates on the plane (x, y) and angular orientation in the stationary coordinate system depend on the speeds of its left (w_L) and right wheel (w_R).

Robot speed V

$$V = \frac{R}{2} * (w_L + w_R)$$

Angular speed of the robot chassis

$$w = \frac{R}{2*L} * (w_R - w_L)$$

where

R – wheel radius, m;

L – the distance between the wheels, m.

To construct a complete mathematical model of the dynamics of the robot, these equations must be supplemented by equations of balance, forces, moments taking into account inertial forces and forces of friction. To model the control, it is also necessary to add equations describing the processes in the wheel motors.

The topic 4. Topic name «Physics, Mathematics»

Section description. Physics, mathematics, dynamics of movement of solid bodies. The design, management and research of mechatronic and robotic systems is impossible without the application of knowledge. Methods, algorithms for solving problems from such areas of knowledge as mathematics, physics and description and solution of tasks of the dynamics of movement of robot links.

An example of question. «The solid body falls at zero initial speed and travels to the ground distance h. After what time t1 starts moving, the body will travel half the distance from the ground? What speed would v1 have at that moment?».

Analysis of the task.

It is necessary to be able to apply the laws of motion physics to solve this problem. Initial velocity of the body $v_0 = 0$, traveled when falling distance h.

Find:

time t1 and speed v1, when the body will fly half a distance

Solution:

For equal acceleration without initial speed:

Equation of motion: $h = g*t^2 / 2$

Speed: $v = g*t$

Half distance: $h/2$

Find time t1. Put in the equation of motion:

$h/2 = g*t_1^2/2$;

$$h = g \cdot t^2 ;$$

$$t = \sqrt{h/g}$$

Find speed v .

Use speed formula: $v = g \cdot t$;

$$v = \sqrt{h \cdot g}$$

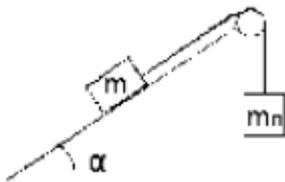
Found values v and t are the answer to this task.

The topic 5. Topic name «Robot and mechatronic devices»

Section description. This section discusses theoretical issues and practical tasks related to mechatronic and robotic systems drives.

Example of practical task.

The calculation diagram of the drive of one link of the mechatronic system is given below. The figure shows the load m and the counterweight m_n connected through the pulley of the engine by a cable.



Determine the amount of effort required:

a) to accelerate the load m with an acceleration of 1 m/s^2 when lifted; mass of the load $m = 150 \text{ kg}$; angle of inclination of the surface $\alpha = 60^\circ$; weight of the counterweight $m_n = 50 \text{ kg}$;

Analysis of the task.

The equation of motion of the system is determined by the balance of forces (in vector form):

$$F = F_c + F_d$$

where F – is an equal force, F_c - the sum of static forces, F_d - the sum of dynamic forces.

In this case the static forces are determined by the difference between the load m and the counterweight m_p ., and the friction force must also be taken into account..

Sliding force

$$F_1 = F_m \cdot \sin(\alpha);$$

Where $F_m = m \cdot g$; $g = 9.8$;

$$F_1 = 1272 \text{ N};$$

Friction force

$$F_2 = \mu \cdot F_m \cdot \cos(\alpha); F_2 = 147 \text{ N};$$

Static force created by counterweight

$$F_{cp} = m_p \cdot g; F_{cp} = 490 \text{ N};$$

Total sum of static forces

$$F_c = F_1 + F_2 - F_{cp}; F_c = 1272 + 147 - 490 = 929 \text{ N};$$

Dynamic force occurs in accelerated movement of cargo and counterweight

$$F_d = m \cdot a + m_p \cdot a;$$

For the given acceleration $a = 1 \text{ m/s}^2$

$$F_d = 1 \cdot (50 + 150) = 200 \text{ N};$$

Thus, the required force should be:

$$F_{\text{drive}} = 929 + 200 = 1129 \text{ N};$$

The task is solved.

The topic 6. Topic name «Artificial intelligence»

Section description. Mechatronics and robotics management and modelling.

An example of question. «Main tasks solved on the basis of methods of artificial intelligence in mechatronics and robotics».

Analysis of the task.

Robotics and mechatronics apply different approaches and directions of artificial intelligence: machine learning, artificial neural networks (NC), fuzzy logic, evolutionary calculations and genetic algorithms.

Algorithms are used for management or decision-making based on knowledge extracted from experimentally obtained patterns by analyzing large data sets. It can be used INE, which after their training will allow to effectively manage non-linear systems in noise conditions and provide adaptability. There are some drawbacks to the use of INE, such as the considerable time required to set up and train an INE, which is clearly unpredictable in terms of the outcome of INE management.

Fuzzy logic methods are widely used to create expert systems, decision-making systems or robot controls. The apparatus of the fuzzy developed by L. Zadeh, is based on the concept of the odd set as an object with a function of belonging, taking the value in the interval $[0, 1]$.

Various bio-inspired artificial intelligence techniques have recently become more common. These include evolutionary algorithms, particle cluster algorithms, ant algorithm and others. Their application is effective in solving optimization tasks, finding trajectories and solutions.

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