Appendix to the working program

Federal State Budgetary Educational Institution of Higher Education
"Privolzhsky Research Medical University"
Ministry of Health of the Russian Federation

BANK OF ASSESSMENT TOOLS FOR DISCIPLINE

« BIOPHYSICS »

Training program (specialty): **31.05.01 GENERAL MEDICINE**

Department: **MEDICAL BIOPHYSICS**

Mode of study: **FULL-TIME**

Nizhniy Novgorod
2021

1. Bank of assessment tools for the current monitoring of academic performance, mid-term assessment of students in the discipline / practice

This Bank of Assessment Tools (BAT) for the discipline " Biophysics" is an integral appendix to the working program of the discipline " Biophysics ". All the details of the approval submitted in the WPD for this discipline apply to this BAT.

(Banks of assessment tools allow us to evaluate the achievement of the planned results stated in the educational program.

Assessment tools are a bank of control tasks, as well as a description of forms and procedures designed to determine the quality of mastering study material by students.)

2. List of assessment tools

The following assessment tools are used to determine the quality of mastering the academic material by students in the discipline “Biophysics”:

No.	Assessment tool	Brief description of the assessment tool	Presentation of the assessment tool in the BAT
1.	Test №1	A system of standardized tasks that allows you to automate the procedure of measuring the level of knowledge and skills of a student.	Bank of test tasks
	Test №2		
2.	Situational tasks	A method of control that allows you to assess the criticality of thinking and the degree of the material comprehension, the ability to apply theoretical knowledge in practice.	List of tasks
3.	Individual survey	A control tool that allows you to assess the degree of comprehension of the material	List of questions
4.	Control work	A tool of checking the ability to apply acquired knowledge for solving problems of a certain type by topic or section	Set of control tasks in variants
5.	Colloquium	A tool of controlling the mastering of study materials of a topic, section or sections of a discipline, organized as a class in the form of an interview between a teacher and students.	Questions on topics/sections of the discipline

3. A list of competencies indicating the stages of their formation in the process of mastering the educational program and the types of evaluation tools

Code and formulation of competence*	Stage of competence formation	Controlled sections of the discipline	Assessment tools
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 1.** *Biomechanics.*	Situational tasks Individual survey Control work

UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 2.** *Molecular physics, thermodynamics.*	Situational tasks Individual survey Control work Colloquium
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 3.** *Physical processes in biological membranes.*	Situational tasks Individual survey Colloquium
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 4.** *Biophysics of transport processes and formation of biopotentials.*	Situational tasks Individual survey Control work Colloquium
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 5.** *Electrical properties of organs and tissues of the human body. Physical processes in tissues when exposed to current and electromagnetic fields.*	Situational tasks Individual survey Control work
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 6.** *Optics, microscopy methods.*	
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 7.** *Quantum biophysics.*	
UC-1 Able to carry out a critical analysis of problem situations based on a systematic approach, develop an action strategy.	Current	**Section 8.** *Interaction of ionizing radiation with matter. Dosimetry.*	
Credit		***All Sections***	***Credit Test***

4. The content of the assessment tools of entry, current control

Entry /current control is carried out by the discipline teacher when conducting classes in the form of: Test, Situational tasks, Individual survey, Control work, Colloquium.

4.1. Tasks for the assessment of competence “UC-1” *(the competence code):*

Situational tasks

Biomechanics.

1. What additional pressure should be applied to push the air bubble formed in the blood vessel, if one meniscus of the bubble has a radius of curvature equal to 1.5 mm, and the second to 2.5 mm?

2. Determine at what velocity the flow of blood in a vessel with a radius of 1 cm will become turbulent. The critical value of the Reynolds number is 1500.

3. In the aorta of a dog with a diameter of 1.5 cm, determine the average blood flow rate, considering the kinematic viscosity coefficient equal to $5{\cdot}10^{-6}$ m^2/s, and the Reynolds number equal to 4500. (The blood flow changes from laminar to turbulent.)

4. What is the mechanical work of the right ventricle of the heart, performed during active muscle activity, if the work of a single contraction of the heart is equal to 2.4 J?

5. What is the mechanical work of a single heart contraction, if the average static pressure in the aorta is 14,000 Pa, the shock volume of blood is $6{\cdot}10^{-5}$ m^3, and the blood velocity in the aorta is 0.8 m/s?

6. Determine the wavelength for the fundamental tone having a frequency of 440 Hz, if the velocity of sound in the air is 330 m/s.

7. Find the volume of a Newtonian fluid flowing through a system of rigid cylindrical tubes in 5 minutes (see Fig. 1), if the fluid current is laminar and the dynamic viscosity coefficient is 3.14 mPa·s, r_1=2mm, $r_2 = r_3 = r_4$ = 1 mm, l_1= 2 cm, $l_2 = l_3 = l_4$ = 4 mm. (r_1, r_2, r_3, r_4 are the radii of the tubes , l_1, l_2, l_3 , l_4 are their lengths, respectively), the pressure drop in this system was $2{\cdot}10^3$ Pa.

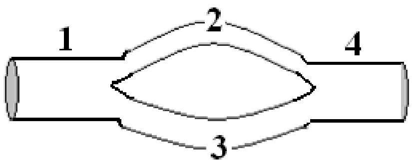

Fig. 1.

8. Find the hydraulic resistance of a rigid cylindrical tube with a diameter of 2 mm and a length of 10 cm, if there is a laminar flow of liquid through it, the viscosity coefficient of which is 0.7 mPa·s.

9. Determine at what velocity the flow of blood in a vessel with a radius of 1 cm will become turbulent. The critical value of the Reynolds number is 1500.

10. In the aorta of a dog with a diameter of 1.5 cm, determine the average blood flow rate, considering the kinematic viscosity coefficient equal to $5{\cdot}10^{-6}$ m^2/s, and the Reynolds number equal to 4500. (The blood flow changes from laminar to turbulent.)

11. The frequency range of the human ear ranges from 16 Hz to 16 kHz. Determine the long-wave range corresponding to the above – frequency, if the velocity of sound in the air is equal to 330 m/s. Find the appropriate ranges for water, whole blood, soft tissue, and bone.

12. The ultrasonic wave, with a frequency of 1 megahertz, is reflected from the surface of the heart valve, moving towards the propagation of the wave at a velocity of $6{\cdot}10^{-2}$ m/s. Determine the change in the frequency of vibrations in the reflected wave caused by the Doppler effect.

13. What is the surface tension of gasoline poured into a U-shaped capillary, if the radius of one knee is 1 mm, the second is 0.5 mm, and the difference in gasoline levels is 20 mm? (The shape of the menisci in the capillaries is considered spherical).

14. A bubble of air formed in the tube. Determine the additional pressure in the bubble if both menisci have the same radius of curvature equal to 1 mm.

15. The ultrasonic wave, with a frequency of 1.2 megahertz, is reflected from the surface of the heart valve, moving towards the propagation of the wave at a velocity of $5.8\cdot10^{-2}$ m/s. Determine the change in the frequency of vibrations in the reflected wave caused by the Doppler effect.

16. The ultrasonic wave, with a frequency of 1.1 megahertz, is reflected from the surface of the heart valve, moving towards the propagation of the wave at a velocity of $6.2\cdot10^{-2}$m/s. Determine the change in the frequency of vibrations in the reflected wave caused by the Doppler effect.

17. What is the mechanical work of the right ventricle of the heart, performed during active muscle activity, if the work of a single contraction of the heart is equal to 2.4 J?

18. What is the mechanical work of a single heart contraction, if the average static pressure in the aorta is 14,000 Pa, the shock volume of blood is $6\cdot10^{-5}$ m^3, and the blood velocity in the aorta is 0.8 m/s?

Physical processes in biological membranes. Biophysics of transport processes and formation of biopotentials.

19. Determine the concentration of cations: a - in the intracellular fluid, b - in the extracellular fluid, calculate the Donnan's ratio if the concentrations of chlorine ions in the intra-and extra-cellular fluid are equal, respectively, 110 mM/*l* and 117 mM/*l*. The charge of protein ions (in units of electron charge) is 14, and the protein concentration is 1 mM/*l*.

20. The relationship of Donnan for a cell with a damaged membrane is 1,06 and a concentration of cations inside the cell is 130 mM/ *l* and a charge of peptide ions is 12. Find the concentration of chlorine ions inside and outside the cell and also a concentration of cations outside the cell.

21. The Donnan's potential of the dying cell was $-3{,}2\cdot10^{-3}$V. Find the concentration of ions in the extracellular fluid, if the concentration of protein in the cell is 1.2 mM/l, the charge of protein ions (in units of electron charge) is 16, if the temperature is 37° C.

22. The Donnan's potential of the damaged cell at a temperature of 27°C is $-1{,}5\cdot10^{-3}$ V. Determine the concentration of proteins in the cell and the dimensionless potential, if the charge of protein ions (in units of electron charge) is 16, and the concentration of ions in the extracellular fluid is 140 mM/*l*.

23. The Donnan's resting potential of the damaged cell at a temperature of 27°C is $-2.0\cdot10^{-3}$ V, the concentration of ions in the extracellular fluid is 160 mM/*l*. Determine the electric charge of protein ions if the protein concentration in the cell is 1.6 mM/*l*.

24. What is the permeability coefficient of the cytoplasmic membrane with a thickness of 9 nm, if the diffusion coefficient is $3\cdot10^{-14}$ m^2/s, and the distribution coefficient of the substance in the membrane is 3.

25. Determine the thickness of the cytoplasmic membrane, if the diffusion coefficient is $6\cdot10^{-12}$ m^2/s, the value of the distribution coefficient of the substance in the membrane is 2, and the permeability coefficient is $3\cdot10^{-3}$ m/s.

26. Find the concentration of sodium ions in the extracellular fluid, if the concentration of these

ions in the cytoplasm is 18 mM/*l*, the permeability coefficient is 10^{-6} m/s, the density of the substance flow is $2\cdot10^{-7}$ Mol/(s·m^2).

27. Determine the change in the value of the electrochemical potential during the transfer of sodium ions in the frog muscle fiber at a temperature of 27°C. (Take the necessary data from Table № 1).

28. What is the change in the value of the electrochemical potential at a temperature of 30°C that occurs as a result of the transfer of chlorine ions in the frog muscle fiber. (Take the necessary data from Table № 1).

29. Determine the change in the value of the electrochemical potential during the transfer of potassium ions in the frog muscle fiber, if the medium temperature is 17°C. (Take the necessary data from Table № 1).

30. Find the equilibrium Nernst potential of the cytoplasmic membrane of the giant cuttlefish axon for potassium ions. The temperature is 17°C. (Take the necessary data from Table № 1).
31. What is the equilibrium Nernst potential of the cytoplasmic membrane of the giant cuttlefish axon for sodium ions? The temperature is 37°C. (Take the necessary data from Table № 1).

32. Determine the equilibrium Nernst potential of the cytoplasmic membrane of the giant cuttlefish axon for chlorine ions. The temperature is 27°C. (Take the necessary data from Table № 1).

33. What is the equilibrium Nernst potential of the cytoplasmic membrane of the giant squid axon for potassium ions? The temperature is 37°C. (Take the necessary data from Table № 1).

34. Calculate the equilibrium Nernst potential for sodium ions diffusing through the cytoplasmic membrane of a giant squid axon at a temperature of 27°C. (Take the necessary data from Table № 1).

35. Determine the equilibrium Nernst potential of the cytoplasmic membrane of the giant cuttlefish axon for chlorine ions. The temperature is 37°C. (Take the necessary data from Table № 1).

36. What is the equilibrium Nernst potential of the frog muscle fiber cytoplasmic membrane for potassium ions? The temperature is 27°C. (Take the necessary data from Table № 1).

37. Find the resting potential of the cytoplasmic membrane of the frog muscle fiber. The ambient temperature is 27°C. The coefficients of membrane permeability and ion concentration should be taken as standard. (Take the necessary data from Table № 1).

38. What is the resting potential of the cytoplasmic membrane of the squid axon at a temperature of 37°C? The coefficients of membrane permeability and ion concentration should be taken as standard. (Take the necessary data from Table № 1).

Optics, microscopy methods.

39. Find the resolution of the microscope when illuminating an object with light with a wavelength of 600 nm, if the angle of opening of the lens is 130°. Cedar oil (n=1.5) is used as an immersion medium.

40. Calculate the magnitude of maximum velocity of photoelectrons ejected from a metallic surface illuminated by a light beam, if the work function of the metal is 2.0 eV and wavelength

of light is 320 nm.

41. Calculate the magnitude of maximum velocity of photoelectrons ejected from a metallic surface illuminated by a light beam, if the work function of the metal is 2.0 eV and wavelength of light is 530 nm.

42. Find the maximum wavelength of light, which is able to cause a photoelectric effect on a dielectric surface, if the work function of the metal is 4.75 eV.

43. Find the maximum wavelength of light, which is able to cause a photoelectric effect on a dielectric surface, if the work function of the metal is 4.50 eV.

44.Determine the transmittance and optical density of a substance that is illuminated by light with an intensity of I_o = 85 W / m^2. The substance, 2 cm thick, has a concentration of 0.1 M, and the molar index χ is 450.

45.What is the intensity of light transmitted through a layer of matter with a molar concentration of 0.4 M and a thickness of 1 cm, if the molar index χ is 500, and the intensity of the incident radiation I0 = 100 W / m^2 ?

46. How many times is the intensity of blue light scattered by an ultra-small particle greater than the intensity of red light scattered by the same particle? (Take the wavelength of blue light as 470 nm, and the wavelength of red light as 650 nm.)
47. Determine the mass concentration of sugar in the solution, if the length of the cell is 20 cm, and the angle of rotation of the plane of polarization was equal to 2°. The specific rotation of sugar is taken to be equal to A = 0.5 [degrees·m^2 · kg^{-1}].

48. Determine the angle of rotation of the polarization plane, if the mass concentration of sugar c = 20 kg / m^3, the length of the tube l =10 cm. The specific rotation of sugar is taken to be equal to 0.4 deg · m^2/kg.

49. Find the intensity of the light coming out of the analyzer, if the intensity of the light incident on the polarizer I_o = 70 W / m^2, and the angle between the main planes of the polarizer and the analyzer φ= 45°.

50.The intensity of the light passed through the analyzer-polarizer system is 27 W/m^2. What is the intensity of the light incident on the polarizer, if the angle between the main planes of the polarizer and the analyzer φ = 30°?

Molecular physics, thermodynamics.

51. What is the absolute humidity of the air at a temperature of 50 ° C and a partial vapor pressure of 20 kPa in it?

52. Determine the absolute humidity of the air at a temperature of 30 ° C and a partial vapor pressure of 15 kPa in it.

53. What is the absolute humidity of the air at a temperature of 70 ° C and a partial vapor pressure of 28 kPa in it.

54. The relative humidity of the air is 85% at a temperature of 17 ° C. What is its absolute humidity?

55. Find the absolute humidity of the air if its relative humidity at a temperature of 27 ° C is 92%.

56. What is the change in entropy when 5 g of water with an initial temperature of 5 ° C evaporates?

57. What is the change in entropy when melting 3 kg of ice having an initial temperature of 0°C?

Electrical properties of organs and tissues of the human body. Physical processes in tissues when exposed to current and electromagnetic fields.

1.What is the DC power consumed for heating the soft tissue area? The soft tissues has the following dimensions: the cross-sectional area of the circuit is 10 cm^2, a depth is 5 mm, the resistivity of the living tissues is 2 Ohms×m. The current density is 10 mA / mm^2.

2.What is the DC power consumed for heating the soft tissue area? The soft tissues has the following dimensions: the cross-sectional area of the circuit is 10 cm^2, a depth is 5 mm, the resistivity of the living tissues is 2 Ohms×m. The current density is 10 mA / mm^2.

3. In a physiological experiment a tetanizing current (triangular-shaped pulses) was used. The pulse length τ_i is 1 ms, and the frequency is 80 Hz. What is the duty cycle of the pulses Q, the period T of their repetition rate and the duration of the pause? Draw a signal waveform.

4. In a physiological experiment an exponential current was used. The pulse duration τ_i and is 20 ms, and the repetition frequency is 50 Hz. What is the duty cycle of the pulses Q and the period of their repetition? Draw a signal waveform.

5. Determine the impedance and phase shift between the sinusoidal current and the voltage in the gum tissues, if the capacitance of the circuit section through which the current flows is 6×10^{-9} Farad, the electrical resistance is 30 kOhms, and the cyclic frequency is 2000 Hz. Consider the resistance and capacitance connected in parallel.

6. Determine the impedance and phase shift between the sinusoidal current and the voltage in the gum tissues, if the capacitance of the circuit section through which the current flows is 3×10^{-9} Farad, the electrical resistance is 60 kOhms, and the circular frequency is 2000 Hz. Consider the resistance and capacitance included in series.

7. What is the impedance and phase shift between the sinusoidal current and the voltage in soft tissues, if the capacitance of the circuit section through which the current flows is 6×10^{-9} Farad, the electrical resistance is 100 kOhms, and the circular frequency is 3000 Hz. Consider the resistance and capacitance connected in parallel.

8. Calculate the impedance and phase shift between the sinusoidal electric current and voltage, if the total capacitance in the circuit is 5×10^{-9} Farad, the electrical resistance is 100 kOhms, and the cyclic frequency is 3000 Hz. Consider the resistance and capacitance included in series.

9. What is the amount of heat released in bone tissues during UHF therapy, if the amplitude of the electric component of the UHF electromagnetic field is equal to 2000 V/m, the capacitance of the therapeutic (Lc) circuit capacitor is 3 μF, the inductance of the inductor is 3×10^{-12} Henry. (The relative dielectric permittivity of bone tissues is taken to be equal to 7.6, and the angle of dielectric losses is 30°).

10. Determine the amount of heat released in the fat layer with a relative permittivity of 8 in UHF therapy, if the angle of dielectric loss is 10°, the amplitude of the electric component of the UHF electromagnetic field is 3000 V/m. (For calculations, use a frequency equal to 40.5 MHz).

11. What is the amount of heat released in bone tissue during UHF therapy, if the relative permittivity of the tissue is 50, the angle of dielectric loss is 15°, the amplitude of the electric component of the electromagnetic field is 2500 V/m? (For calculations, use a frequency equal to 40.5 MHz).

12. Determine the amount of heat released during inductothermy in adipose tissue with a resistivity of 20 Ohms×m and in muscles with a resistivity of 2 Ohms×m. The cyclic frequency of the field oscillations is 13 MHz, the amplitude value of the magnetic induction is 0.01 T. The procedure takes 20 minutes. The results obtained should be compared with each other and analyzed. (The calculation is made according to the formula $q = t \times k \times \omega^2 \times B^2_{max}/\rho$, the coefficient k is taken to be 3×10^{-7} m^2. Check the physical units of the result).

13. Determine the amount of heat released during inductothermy in dry skin with a resistivity of 10 Ohms×m and in blood with a resistivity of 2 Ohms×m. The cyclic frequency of the device used in the hospital is 13 MHz, the amplitude value of the magnetic induction is 0.01 T. The procedure takes 10 minutes. The results obtained should be compared with each other and analyzed. (The calculation is made according to the formula $q = t \times k \times \omega^2 \times B^2_{max}/\rho$, the coefficient k is taken to be 2×10^{-7} m^2. Check the physical units of the result).

14. Considering the heart as a current dipole, determine the dipole moment of the heart. The distance between the source and the drain is 2 cm, and the current strength is 0.1 mA.

15. The value of the dipole moment of the current dipole is 2 mA×cm. What is the moment of the force acting on this dipole, if the angle between the direction of the dipole moment and the intensity of the external homogeneous electric field is 30°, and the intensity of this field is 50 mV/cm?

Table № 1

The content of K^+, Na^+ and Cl^- ions, equilibrium potentials, rest and action potentials for some biological cells

Cells	The ratio of a concentration of ions in the cytoplasm to their concentration in an extra-cellular fluid, [mM/*l*]			The equilibrium Nernst potential due to the permeability of a membrane for a given ion, [mV]			Values of membrane potentials, measured experimentally, [mV]	
	$\frac{C^{in}_{K^+}}{C^{o}_{K^+}}$	$\frac{C^{in}_{Na^+}}{C^{o}_{Na^+}}$	$\frac{C^{in}_{Cl^-}}{C^{o}_{Cl^-}}$	K^+	Na^+	Cl^-	resting	at the maximum spike
Giant cuttlefish axon	340 / 10,4	49 / 463	114 / 592	- 88	+57	-42	-60	+50
Squid axon	360 / 10,0	69 / 425	157 / 496	-90	+46	-29	-60	+35
Frog Muscle Fiber	48 / 1	1 / 7	1 / 64	-98	+49	-105	-88	+34
Cat motor neuron	150 / 5,5	15 / 150	9 / 125	-90	+60	- 70	-70	+30

4.3. Questions for colloquiums *(the competence code UC-1,* GPC -1*):*

« *Biomechanics*».

1. Surface tension. Surfactants and surfactants. The phenomenon of capillarity. Gas embolism.

2. Phenomena of wetting, non-wetting, ideal wetting, edge angle. Hydrophilic and hydrophobic surfaces.

3.The equation of continuity of the jet. The Bernoulli equation. The Torricelli formula. Methods of measuring statistical, dynamic and total pressure.

4. The total pressure in the flow of the ideal liquid. A method for measuring static pressure and fluid flow velocity using pressure gauge tubes.

5. The concepts of stationary flow are laminar and turbulent flows. Lines, current surfaces (layers). Reynolds number. The critical value of the Reynolds number. Kinematic viscosity coefficient. Turbulence in the cardiovascular system.

6. Viscosity. Newton's formula. The viscosity coefficient. Newtonian and non-Newtonian fluids, examples. Blood flow rates in various departments of the Cardiovascular System (give a graph, explain qualitatively from the point of view of the continuity equation of the jet).

7. Laws of viscous fluid flow. Poiseuille formula, hydraulic resistance. The flow of viscous liquid through pipes (sequential and parallel connection of pipes). To draw an analogy with Ohm's law for a section of the chain.

8. Serial connection of the tubes, two conditions. Derive the formula for the hydraulic connection of series-connected tubes.

9. Parallel connection of the tubes, two conditions. Deduce the formula for the hydraulic connection of parallel connected tubes.

10. Methods for the determination of viscous liquid. Capillary method, Hess method, rotational viscometry. Types of viscometers, the principle of their operation. The concept of relative viscosity.

11. The phenomenon of a decrease in equivalent viscosity in small vessels. The Caisson equation. Theory of the cutting cylinder. "Coin column."

12. Stokes' law. Derive the formula for the viscosity of the liquid, the relationship of dynamic and kinematic viscosities.

13. Newton's equation. Newtonian and non-Newtonian fluids corresponding to their viscosities. Examples.

14. Describe the principle of pressure measurement by the "Korotkov Sounds" method.

15. Pulse waves, graphs of pressure fluctuations near the heart and in arterioles. Pulse wave length. Equation for pressure wave, pulse wave velocity

16. The work and power of the heart, the principle of operation of the artificial circulation apparatus.

«Physical processes in biological membranes».

1. Modern conception about the structure of biological membranes, their functions. Membrane models.

2. Mechanical and electrical properties of membranes.

3. Conformational transitions of phospholipids, phase transitions in membranes. Temperatures of phase transitions.

4. Types of passive transport, their features, examples.

5. Simple diffusion of neutral particles. Derivation of the Fick equation.

6. Simple diffusion of charged particles. Derivation of the Theorell equation.

7. The Nernst-Planck equation, the name and the physical meaning of the quantities included in it.

8. Transformation of the Fick equation, applied to a homogeneous biological membrane, derivation of the formula for the permeability coefficient of the membrane.

9. The potential of rest according to Donnan. (Its magnitude, sign, formula, the main position on the basis of which it is derived, its significance for medicine.)

10. The resting potential of the membrane according to Nernst. (Its magnitude, sign, formula, the main position on the basis of which it is derived, its significance for medicine.)

11. The Goldman-Hodgkin-Katz equation. The Nernst equation, as a special case of the Goldman equation. The ratio of permeability coefficients for sodium, potassium, and chlorine ions.

12. Structure of ion channels. Selectivity. Examples.

13. Operation of sodium channels in an excited membrane.

14. Active transport. Potassium-sodium pump. An equivalent scheme of a biological membrane at rest.

15. Electrochemical potential. The physical meaning of the electrochemical potential.

16. Pharmacokinetic model.

17. Problems on this topic.

«Molecular physics, thermodynamics»

1. Thermodynamics, basic concepts. The first law of thermodynamics. The second law of thermodynamics.

2. Reversible and irreversible processes. Carnot cycle. Thermodynamic efficiency.

3. Третий закон термодинамики. Приведенная теплота. Энтропия.

3. The third law of thermodynamics. Reduced heat. Entropy.

4. Open systems. Stationary state. The body as an open system.

5. Characteristics of thermal radiation. A completely black body. Kirchhoff's law. The spectrum of radiation of a completely black body.

6. The laws of blackbody radiation (Stefan-Boltzmann, Wine).

7. The body's thermal balance. The concept of thermography.

8. Problems on this topic.

« *Medical optics. Quantum Biophysics*.»

1. Geometric and wave optics. Coherence of waves. Forced radiation. Features of laser radiation. The structure and principle of operation of the laser.

2. The device of a biological microscope. Image construction in the lens, eyepiece and microscope. Derivation of the formula for linear magnification of lenses and microscopes. Characteristics of images.

3. The basic positions of Abbe's theory. Characteristics of the microscope: useful and useless magnification. Resolution and resolution distance (resolution limit). The formula of the resolution of the microscope.

4. Immersion lens. The course of the rays. The aperture angle. Numerical aperture. Advantages and purposes of using immersion.

5. Ultraviolet microscopy. Features, advantages, disadvantages.

6. Electron microscopy. The structure of an electron microscope, the structure of magnetic lenses.

7. The course of the rays in an electron microscope. The resolution limit of the electron microscope.

8. Ultramicroscopy. The course of the rays. The dark field method. Rayleigh's law.

9. Phase contrast method.

10. Polarizing microscope. Optical scheme and structure of the microscope. Use when working with histological samples.

11. The laws of refraction and reflection of light. The concept of total internal reflection. Limit angle of total reflection, limit angle of refraction.

12. The course of the rays in the optical fiber. Fiber optics and its use in medicine. Light guides. Endoscopes.

13. The optical system of the eye, its features. Accommodation. The distance of the best vision. The angle of view. The smallest angle of view. Visual acuity. Disadvantages of the optical system of the eye and their elimination. The concept of aberrations.

14. Types of luminescence. Stokes' law for photoluminescence.

15. Chemiluminescence, mechanisms of its generation, application in biomedical analysis.
16. Luminescence spectra. Spectrofluorimeter.
17. Problems on this topic.

4.4. Tasks (assessment tools) for the credit *(the competence code UC-1, GPC -1):*

CARD № 1

1. Subjective characteristics of sound, their connection with objective ones.
2. Pharmacokinetic model.
3. To find the equilibrium Nernst potential of the cytoplasmic membrane of the giant cuttlefish axon for potassium ions. The ambient temperature is 17 °C. (Take the necessary data from the table №1).

CARD № 2

1. The Weber-Fechner law (verbal formulation, formula, explanation; values of the audibility limit and the pain limit).
2. Ohm's law for alternating current and voltage. The total resistance (impedance) in electrical circuits containing capacitive and resistive components. The dependence of the impedance on the frequency of the current.
3. What is the equilibrium Nernst potential of the cytoplasmic membrane of the giant cuttlefish axon for sodium ions? The ambient temperature is 37 °C. (Take the necessary data from the table №1).

CARD № 3

1. Audiogram. Audiometry. Graphs, explanations.
2. Medical polarimetry. Optical activity of substances. The structure and principle of operation of the polarimeter-saccharimeter.
3. To determine the equilibrium Nernst potential of the cytoplasmic membrane of the giant axon of the cuttlefish for chlorine ions. The ambient temperature is 27 °C. (Take the necessary data from the table №1).

CARD № 4

1. Physical foundations of the Korotkov sound method. Physical foundations of hemodynamics.
2. Types of luminescence. Stokes' law for photoluminescence.
3. At a temperature of 37° C, the Donnan potential of the dying cell was $-3.2 \cdot 10^{-3}$ V. Determine the concentration of ions in the extracellular fluid if the protein concentration in the cell is 1.2 mM / l, and the charge of protein ions (in units of electron charge) is 16.

CARD № 5

1. Features of blood flow through large vessels, medium and small vessels, capillaries; blood flow during vasoconstriction, sound effects.
2. Ultraviolet radiation. Ranges of ultraviolet radiation. Application in medicine.
3. The Donnan potential of the damaged cell at a temperature of *27° C* is $-1.5 \cdot 10^{-3}$ *V*. Determine the concentration of protein in the cell and the dimensionless potential if the charge of protein ions (in units of electron charge) is 16, and the concentration of ions in the extracellular fluid is *140 mM/ l.*

CARD № 6

1. Natural and polarized light. Methods of obtaining polarized light. Double refraction. Malus' law. Brewster's law. Nicolas's prism.
2. Ion transport through membranes. The electrodiffusion equation. The Nernst-Planck equation.
3. Determine the concentration of cations: a – in the intracellular fluid, b – in the extracellular fluid, calculate the Donnan ratio if the concentrations of chlorine ions inside and outside the cellular fluid are *110 mM/l* and *117 mM/l*, respectively. The charge of protein ions (in units of electron charge) is *14*, and the protein concentration is *1 mM/l.*

CARD № 7
1. Medical polarimetry. Optical activity of substances (examples of optically active tissues in the human body. The structure and principle of operation of the polarimeter-saccharimeter.
2. Biological membranes, their structure and physical properties.
3. What is the equilibrium Nernst potential of the cytoplasmic membrane of the giant squid axon for potassium ions? The ambient temperature is 37 °C. (Take the necessary data from the table №1).

CARD № 8
1. Active transport. Scheme of a potassium–sodium pump (using the example of a cat's motor neuron). An equivalent scheme of a biological membrane. The scheme of the sodium channels in the excitable membrane of the nerve fiber.
2. Infrared radiation. Infrared radiation ranges. Application in medicine.
3. The Donnan resting potential of the damaged cell at a temperature of $27° C$ is $–2.0 \cdot 10^{-3}$ V, the concentration of ions in the extracellular fluid is *160 mM/l*. Determine the electric charge of protein ions if the protein concentration in the cell is *1.6 mM / l.*

CARD № 9
1. Modeling of biophysical processes. Mathematical models of population growth. The Volterra model.
2. Natural and polarized light. Methods of obtaining polarized light. Double refraction. Malus' law. Brewster's law. Nicolas's prism.
3. What is the permeability coefficient of a cytoplasmic membrane with a thickness of 9 nm, if the diffusion coefficient is $3 \cdot 10^{-14}$ m^2 / s, and the distribution coefficient of the substance in the membrane is 3.

CARD № 10
1. Active transport. Scheme of a potassium–sodium pump (using the example of a cat's motor neuron). An equivalent scheme of a biological membrane. The scheme of the sodium channels in the excitable membrane of the nerve fiber.
2. Diffraction of light on living cells. Measurement of the size of erythrocytes by light diffraction.
3. Determine the thickness of the cytoplasmic membrane if the diffusion coefficient is $6 \cdot 10^{-12}$ m^2 / s, the value of the distribution coefficient of the substance in the membrane is 2, and the permeability coefficient is $3 \cdot 10^{-3}$ m / s.

5. The content of the assessment tools of mid-term assessment

Mid-term assessment is carried out in the form of a credit.

5.1 The list of control tasks and other materials necessary for the assessment of knowledge, skills and work experience.

5.1.1. Questions for the discipline exam
FSES are not provided

5.1.2. Questions for the credit in the discipline “Biophysics”
https://sdo.pimunn.net/mod/resource/view.php?id=205163

Question	Competence code (according to the WPD)
1. THE TRANSMEMBRANE REDISTRIBUTION OF K^+ AND Na^+ IONS IS CHARACTERISTIC OF THE INITIAL MOMENT OF THE DEVELOPMENT OF THE ACTION POTENTIAL, NAMELY	UC-1

1) active penetration of K+ ions into the cell 2) active penetration of Na+ ions into the cell 3) active release of K+ ions from the cell 4) active release of Na+ ions from the cell	
2. THE DIFFERENCE OF ELECTRICAL POTENTIALS BETWEEN THE INNER AND OUTER SURFACES OF CELL MEMBRANES AT REST HAS THE SIGN 1) positive 2) negative 3) the potential difference is zero 4) the sign of the potential difference changes at rest	UC-1
3. SELECTIVITY OF ION TRANSMISSION THROUGH THE MEMBRANES OF LIVING CELLS HAVE 1) ionophores 2) potassium flows 3) ion channels 4) ion traps	UC-1
4. THE VISCOSITY COEFFICIENT OF THE PHOSPHOLIPID BILAYER OF MEMBRANES HAS VALUES IN THE RANGE 1) 30 - 100 microPa·s 2) 30 - 100 milliPa·s 3) 30 - 100 Pa·s 4) 30 - 100 kiloPa·s	UC-1
5. THE SURFACE TENSION COEFFICIENT HAS VALUES IN THE RANGE 1) 0.03 - 1 microN/m 2) 0.03 - 1 millioN/m 3) 0.03 - 1 N/m 4) 0.03 - 1 kiloN/m	UC-1
6. SUBSTANCES CAPABLE OF CARRYING IONS THROUGH MEMBRANES ARE CALLED 1) ionizers 2) ionites 3) ionophores 4) monocytes	UC-1
7. THE EFFECT OF THE ELECTRIC FIELD ON THE DIFFUSION OF CHARGED PARTICLES IS REFLECTED IN THE EQUATION 1) Fika 2) Newton 3) Nernst – Planck 4) Goldman– Hodgkin– Katz	UC-1
8. PERMEABILITY DOMINATES IN THE PLASMA MEMBRANES OF NEURONS 1) calcium 2) chlorine 3) potassium 4) sodium	UC-1
9. THE DONNAN MODEL IS BASED ON THE CONDITION 1) membrane electrogenicity 2) ionic equilibrium of cytoplasm and extracellular fluid 3) membrane polarization 4) electroneutrality of cytoplasm and extracellular fluid	UC-1
10. THE DONNAN POTENTIAL IS FORMED ON THE MEMBRANES OF BIOLOGICAL CELLS WHEN	UC-1

1) weakened metabolism of living cells and the appearance of pores 2) K^+ – Na^+ – pump operation 3) increasing the permeability of the membrane to sodium ions 4) decrease in the activity of ATP–aza	
11. AT REST, IN THE GIANT SQUID AXON, THE RATIO OF THE PERMEABILITY COEFFICIENTS OF BIOLOGICAL MEMBRANES FOR K^+, Na^+ and Cl^- IONS IS EQUAL TO 1) $P_K : P_{Na} : P_{Cl}$ = 1 : 0,0005 : 0,45 2) $P_K : P_{Na} : P_{Cl}$ = 1 : 0,005 : 0,04 3) $P_K : P_{Na} : P_{Cl}$ = 1 : 0,04 : 0,045 4) $P_K : P_{Na} : P_{Cl}$ = 1 : 0,4 : 0,45	UC-1
12. THE SELECTIVE CENTER OF THE ION CHANNEL OF THE CELL MEMBRANE PROVIDES PREFERENTIAL ION TRANSMISSION 1) small diameter 2) of a certain diameter 3) large diameter 4) any diameter	UC-1
13. THE PERMEABILITY COEFFICIENT OF THE MEMBRANE OF A LIVING CELL INCREASES WITH GROWTH 1) ion mobility and medium temperature 2) medium temperature and potassium concentration 3) ion mobility and sodium concentration 4) medium temperature and viscosity coefficient	UC-1
14. Na^+ - K^+ IS A PUMP, Ca^{+2} IS A PUMP, and H^+ IS A PUMP, FROM THE POINT OF VIEW OF THE THEORY OF ELECTRICAL CIRCUITS, IT MAKES SENSE: 1) electromotive force 2) electrical resistance 3) electrical capacity 4) inductive element	UC-1
15. THE MODEL IS BASED ON THE CONDITION OF STATIONARY ION FLOWS THROUGH THE MEMBRANE OF A BIOLOGICAL CELL 1) Nernsta 2) Donnan 3) Goldman- Hodgkin–Katz 4) Huxley	UC-1
16. MODELS ARE BASED ON THE CONDITION OF EQUILIBRIUM OF ION FLOWS THROUGH THE MEMBRANE OF A BIOLOGICAL CELL 1) Huxley and Dana 2) Nernst and Don on 3) Goldman-Hodgkin– Katz and Donnan 4) Goldman- Hodgkin– Katz and Nernst	UC-1
17. THE STATIONARITY CONDITION FOR ION FLOWS THROUGH A BIOLOGICAL MEMBRANE REQUIRES 1) the equality of the algebraic sum of ion fluxes to zero, taking into account signs of their charges 2) the equality of the arithmetic mean values of ion fluxes to zero, taking into account their signs 3) equal to zero the fluxes of each of the types of ions passing through the membrane 4) equality of flows of cations and anions passing through membranes	UC-1
18. THE DENSITY OF THE MASS FLOW OF PARTICLES PASSING THROUGH THE MEMBRANE IS 1) the mass of particles that have passed through the unit area of the membrane	UC-1

2) the mass of particles that have passed through a unit area of the membrane, per unit time 3) the mass of particles that have passed through the pores of the membrane 4) the mass of particles that have passed through the membrane per unit of time	
19. AT DONNAN EQUILIBRIUM, AN ELECTRICAL POTENTIAL DIFFERENCE (DONNAN POTENTIAL) IS APPROXIMATELY EQUAL ON THE MEMBRANE 1) - 60 mV 2) + 60 mV 3) + 1.4 mV 4) - 1.4 mV	UC-1
20. THE RATE OF STEADY MOTION OF AN ION IN A VISCOUS MEDIUM IS DETERMINED BY ITS 1) by weight 2) electric charge 3) mobility 4) radius	UC-1
21. CELL MEMBRANES HAVE 1) high dielectric constant 2) high specific electric power 3) high specific electrical inductance 4) high specific electrical capacity	UC-1
22. THE AUDIBLE SOUND FREQUENCY RANGE IS 1) 1.6 Hz - 16 Hz 2) 16 Hz - 16 MHz 3) 16 Hz - 16 kHz 4) 16 kHz - 16 MHz	UC-1
23. UNITS "W/M^2" MEASURE THE FOLLOWING ENERGY CHARACTERISTIC OF THE SOUND 1) strength 2) a flow 3) amplitude 4) intensity	UC-1
24. THE ULTRASOUND IS 1) electrical oscillation with a frequency higher than a sound 2) mechanical oscillation and waves with a frequency of less than 16 Hz 3) mechanical oscillation and waves with a frequency of more than 16 kHz 4) mechanical oscillation of molecules of a medium	UC-1
25. WHEN A TEMPERATURE REDUCES, THE VISCOSITY OF A LIQUID 1) decreases 2) increases 3) remains unchanged 4) grows quadratically	UC-1
26. UHF OSCILLATION FREQUENCY IS 1) 3 ÷ 30 MHz 2) 30 ÷ 300 MHz 3) 300 MHz ÷ 30 GHz 4) 30 GHz ÷ 3000 GHz	UC-1
27. THE CALIBRATION VOLTAGE USED IN THE ELECTROCARDIOGRAPH IS 1) 1 mV (milliVolt) 2) 1 V (Volt) 3) 1 kV (kiloVolt) 4) 1 MV (MegaVolt)	UC-1

28. THE ELECTRIC DIPOLE IS 1) a system of two bipolar electrical terminals in a conductive environment 2) a system of two bipolar electrical terminals in a dielectric medium 3) a system of two oppositely polar electric charges located in a conductive environment 4) a system of two oppositely polar electric charges located in a dielectric medium	UC-1
29. WITH AN INCREASE IN TEMPERATURE, A RATE OF THE THERMAL MOTION OF MOLECULES 1) decreases 2) increases 3) does not change 4) varies with viscosity	UC-1
30. IT IS KNOWN THAT BLOOD IS A NON-NEWTONIAN LIQUID. THIS IS EXPLAINED BY THE FACT THAT 1) blood cells vary in shape and size 2) blood cells move chaotically 3) blood plasma has high viscosity 4) blood corpuscles form aggregations	UC-1
31. THE SPECIFIC FEATURES OF LASER RADIATION ARE 1) monochromaticity, spectrum saturation, beam narrowness 2) monochromaticity, unidirectionality, high spectral density 3) monochromaticity, divergence, polarization 4) monochromaticity, brightness, rigidity	UC-1
32. LIGHT IS 1) an ultrasonic wave 2) a mechanical wave 3) heat radiation 4) electromagnetic radiation	UC-1
33. PHYSICAL BASIS FOR A LIVING TISSUE RHEOGRAPHY METHOD IS 1) a spectral analysis and registration of heart murmurs 2) registration of a magnetic field of the body's biocurrents 3) registration of changes in tissue impedance in the process of cardiac activities 4) measurement of tissue resistance to the direct current	UC-1
34. THE ESSENCE OF THE METHOD OF MICROWAVE THERAPY CONSISTS OF 1) heating tissues using a high-frequency magnetic field 2) heating tissues using ultra-high frequency electric field 3) heating tissues using a microwave electromagnetic range 4) heating tissues using electromagnetic waves of a EHF- range	UC-1
35. THE RATIO OF ENERGY TRANSFERRED TO THE ELEMENT OF AN IRRADIATED SUBSTANCE TO A MASS OF THIS ELEMENT IS CALLED 1) an absorbed dose 2) an exposure dose 3) an equivalent dose 4) a dose rate	UC-1
36. THE UNIT OF MEASUREMENT OF AN EQUIVALENT DOSE IN THE SI SYSTEM IS 1) gray 2) rad 3) X-ray 4) sievert 5) Cl / kg	UC-1

37. UHF OSCILLATION FREQUENCY IS 1) 3 ÷ 30 MHz 2) 30 ÷ 300 MHz 3) 300 MHz ÷ 30 GHz 4) 30 GHz ÷ 3000 GHz	UC-1

Theoretical Questions for the test	
Question	Competence code (according to the WPD)
1. Surface tension. Surfactants and surfactants. The phenomenon of capillarity. Gas embolism.	UC-1
2. Phenomena of wetting, non-wetting, ideal wetting, edge angle. Hydrophilic and hydrophobic surfaces.	UC-1
3.The equation of continuity of the jet. The Bernoulli equation. The Torricelli formula. Methods of measuring statistical, dynamic and total pressure.	UC-1
4. The total pressure in the flow of the ideal liquid. A method for measuring static pressure and fluid flow velocity using pressure gauge tubes.	UC-1
5. The concepts of stationary flow are laminar and turbulent flows. Lines, current surfaces (layers). Reynolds number. The critical value of the Reynolds number. Kinematic viscosity coefficient. Turbulence in the cardiovascular system.	UC-1
6. Viscosity. Newton's formula. The viscosity coefficient. Newtonian and non-Newtonian fluids, examples. Blood flow rates in various departments of the Cardiovascular System (give a graph, explain qualitatively from the point of view of the continuity equation of the jet).	UC-1
7. Laws of viscous fluid flow. Poiseuille formula, hydraulic resistance. The flow of viscous liquid through pipes (sequential and parallel connection of pipes). To draw an analogy with Ohm's law for a section of the chain.	UC-1
8. Serial and Parallel connections of the tubes, two conditions. Derive the formula for the hydraulic connection of series-connected tubes and parallel connected tubes.	UC-1
9. The phenomenon of a decrease in equivalent viscosity in small vessels. The Caisson equation. Theory of the cutting cylinder. "Coin column."	UC-1
10. Stokes' law. Derive the formula for the viscosity of the liquid, the relationship of dynamic and kinematic viscosities.	UC-1
11. Newton's equation. Newtonian and non-Newtonian fluids corresponding to their viscosities. Examples.	UC-1
12. Describe the principle of pressure measurement by the "Korotkov Sounds" method.	UC-1
13. The work and power of the heart, the principle of operation of the artificial circulation apparatus.	UC-1
14. Modern conception about the structure of biological membranes, their functions. Membrane models.	UC-1
15. Mechanical and electrical properties of membranes.	UC-1
16. Conformational transitions of phospholipids, phase transitions in membranes. Temperatures of phase transitions.	UC-1
17. Types of passive transport, their features, examples.	UC-1
18. Simple diffusion of neutral particles. Derivation of the Fick equation. Derivation of the Theorell equation.	UC-1

19. The Nernst-Planck equation, the name and the physical meaning of the quantities included in it.	UC-1
20. Transformation of the Fick equation, applied to a homogeneous biological membrane, derivation of the formula for the permeability coefficient of the membrane.	UC-1
21. The potential of rest according to Donnan.	UC-1
22. The Goldman-Hodgkin-Katz equation. The Nernst equation, as a special case of the Goldman equation. The ratio of permeability coefficients for sodium, potassium, and chlorine ions.	UC-1
23. Structure of ion channels. Selectivity. Examples.	UC-1
24. Active transport. Potassium-sodium pump. An equivalent scheme of a biological membrane at rest.	UC-1
25. Electrochemical potential. The physical meaning of the electrochemical potential.	UC-1
26. Pharmacokinetic model.	UC-1
27. Thermodynamics, basic concepts. The first law of thermodynamics. The second law of thermodynamics.	UC-1
28. The third law of thermodynamics. Reduced heat. Entropy.	UC-1
29. Open systems. Stationary state. The body as an open system.	UC-1
30. Characteristics of thermal radiation. A completely black body. Kirchhoff's law. The spectrum of radiation of a completely black body.	UC-1
31. The laws of blackbody radiation (Stefan-Boltzmann, Wine). The body's thermal balance.	UC-1
32. Geometric and wave optics. Coherence of waves. Forced radiation. Features of laser radiation. The structure and principle of operation of the laser.	UC-1
33. The device of a biological microscope. Image construction in the lens, eyepiece and microscope. Derivation of the formula for linear magnification of lenses and microscopes. Characteristics of images.	UC-1
34. The basic positions of Abbe's theory. Characteristics of the microscope: useful and useless magnification. Resolution and resolution distance (resolution limit). The formula of the resolution of the microscope.	UC-1
35. Immersion lens. The course of the rays. The aperture angle. Numerical aperture. Advantages and purposes of using immersion.	UC-1
36. Ultraviolet microscopy. Features, advantages, disadvantages.	UC-1
37. Electron microscopy. The structure of an electron microscope, the structure of magnetic lenses. The course of the rays in an electron microscope. The resolution limit of the electron microscope.	UC-1
38. Ultramicroscopy. The course of the rays. The dark field method. Rayleigh's law.	UC-1
39. Phase contrast method.	UC-1
40. Polarizing microscope. Optical scheme and structure of the microscope. Use when working with histological samples.	UC-1
41. The laws of refraction and reflection of light. The concept of total internal reflection. Limit angle of total reflection, limit angle of refraction.	UC-1
42. The course of the rays in the optical fiber. Fiber optics and its use in medicine. Light guides. Endoscopes.	UC-1
43. The optical system of the eye, its features. Accommodation. The distance of the best vision. The angle of view. The smallest angle of view. Visual acuity. Disadvantages of the optical system of the eye and their elimination. The concept of aberrations.	UC-1
44. Types of luminescence. Stokes' law for photoluminescence.	UC-1
45. Chemiluminescence, mechanisms of its generation, application in biomedical analysis.	UC-1

46. Passive electrical properties of living tissues. Impedance measurement. The impedance of living tissues.	UC-1
47. External low-frequency EMF of tissues, organs, biophysical fundamentals of electrocardiography.	UC-1
48. Interaction of the electrical component of the electromagnetic field with the body: biological effect of high-frequency EMF (diathermy, darsonvalization, inductothermy, laser therapy, UHF therapy, microwave therapy).	UC-1
49. Physical fundamentals of radiology. The use of X-ray radiation in medicine.	UC-1
50. Physical fundamentals of medical tomography. The structure of the massive anode of X-ray tubes. Computed tomography.	UC-1

5.1.3. The subject of term papers *(if provided by the curriculum)*
FSES are not provided

6. Criteria for evaluating learning outcomes
For the credit

Learning outcomes	Evaluation criteria	
	Not passed	**Passed**
Completeness of knowledge	The level of knowledge is below the minimum requirements. There were bad mistakes.	The level of knowledge in the volume corresponding to the training program. Minor mistakes may be made
Availability of skills	Basic skills are not demonstrated when solving standard tasks. There were bad mistakes.	Basic skills are demonstrated. Typical tasks have been solved, all tasks have been completed. Minor mistakes may be made.
Availability of skills (possession of experience)	Basic skills are not demonstrated when solving standard tasks. There were bad mistakes.	Basic skills in solving standard tasks are demonstrated. Minor mistakes may be made.
Motivation (personal attitude)	Educational activity and motivation are poorly expressed, there is no willingness to solve the tasks qualitatively	Educational activity and motivation are manifested, readiness to perform assigned tasks is demonstrated.
Characteristics of competence formation*	The competence is not fully formed. The available knowledge and skills are not enough to solve practical (professional) tasks. Repeated training is required	The competence developed meets the requirements. The available knowledge, skills and motivation are generally sufficient to solve practical (professional) tasks.
The level of competence formation*	Low	Medium/High

For testing:

Mark "5" (Excellent) - points (100-90%)
Mark"4" (Good) - points (89-80%)
Mark "3" (Satisfactory) - points (79-70%)

Less than 70% – Unsatisfactory – Mark "2"

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