QUESTIONS FOR THE CREDIT (I SEMESTER) ON DISCIPLINE “MEDICAL AND BIOLOGICAL PHYSICS” FOR THE SPECIALTY: 7-07-911-01 GENERAL MEDICINE»

I.Theoretical questions

1. Mechanical deformations. Hooke's law, modulus of elasticity.
2. Harmonic oscillations. Energy of harmonic oscillations.
3. Superposition of harmonic oscillations. Harmonic spectrum of complex oscillations. Fourier theorem for processing diagnostic data.
4. Mechanical waves. Energy characteristics of the wave: energy flux, intensity.
5. Sound classification. Physical characteristics of sound: frequency, intensity, harmonic spectrum. Characteristics of the acoustic sensation and their relationship to the physical characteristics of sound. Reflection and absorption of sound waves.
6. Audition diagram. Sound intensity level and sound loudness level, relation between them, their units.
7. Weber-Fechner's Law.
8. Reflection and absorption of sound waves. Acoustic impedance.
9. Principles of ultrasound imaging of organs and tissues of the human body. Ultrasound diagnostics.
10. Therapeutic and surgical applications of ultrasound.
11. Application of the Doppler effect for non-invasive measurement of blood flow velocity.
12. Continuity equation.
13. Bernoulli’s equation. Application of the Bernoulli equation for the study of blood flow in large arteries and aorta (blockage of the artery, arterial murmur, aneurysm behavior).
14. Viscous fluid flow. Newton’s formula.
15. Poiseuille’s law. Hydraulic resistance.
16. Laminar and turbulent flow. Reynolds number.
17. Factors affecting blood viscosity in the human body.
18. The role of vascular elasticity, pulse wave. Moens-Korteweg formula.
19. Distribution of blood flow velocity and blood pressure in the systemic circulation.
20. Measuring methods of pressure and blood flow velocity.
21. Heart work and heard power.
22. Physical fundamentals of the surface tension phenomenon. Coefficient of surface tension.
23. Wetting. Capillary phenomena.
24. Pressure excess across a curved liquid interface, Laplace's formula.
25. Structure and physical properties of the biological membranes.
26. Passive transport of substances across the biological membranes, its types.
27. Mathematical description of passive transport of substances: Theorell equation.
28. Mathematical description of passive transport of substances: Fick equations.
29. Mathematical description of passive transport of substances: Nernst-Planck equation.
30. Active transport of ions.
31. Resting membrane potentials. Nernst equation.
32. The Goldman-Hodgkin- Katz equation for the resting potential of a cell.
33. Action potential generation mechanism, its main phases. Refractory period.
34. Propagation of the action potential along unmyelinated axons.
35. Propagation of the action potential along myelinated axons.
36. Electrocardiography, Einthoven's theory. Standard limb leads, augmented unipolar limb leads and chest leads.
37. Formation of electrocardiogram waves, their connection with physiological processes in the myocardium.
38. Electrical conductivity of biological tissues. Galvanization and therapeutic electrophoresis.
39. Equivalent electrical circuit of living tissue. The impedance of living tissue, its dependence on the alternating current frequency. Assessment of tissue viability.
40. Electroexcitability of tissues. Strength-duration curve, rheobase and chronaxy. Weiss–Lapicque law.

41. Du Bois–Reymond law.
42. Electrical stimulation of the heart.
43. Diathermy.
44. Inductothermy.
45. Ultra-high-frequency therapy.
46. Microwave therapy.
47. Extremely high-frequency therapy.
48. Local d'arsonvalization.
49. General characteristics and classification of biomedical information sensors. Temperature sensors.
50. General principles of electrical signal amplification. Requirements for bioelectric signal amplifiers.
51. Determination of the frequency (bandwidth) and amplitude (dynamic range) characteristics of the amplifier.

II. Problems

1. Muscle with a length of 10 cm and a diameter of 1 cm is extended by 7 mm under the load of 49 N. Determine the Young's modulus of the muscle tissue.
2. Muscle with a length of 5 cm and a diameter of 4 mm was contracted by 1 mm. Young's modulus of muscle tissue is equal to 10^7 Pa. Determine the work done by the muscle.
3. The damping factor is equal to 4 c^{-1}, and the logarithmic decrement is equal to 2. What is the frequency of the damped oscillations?
4. Sound intensity level is equal to 40 dB. Calculate the intensity of this sound.
5. Loudness level of the sound at frequency 1000Hz is decreased as the result of passing through the wall from the value of 100 phones to 20 phones. How many times the intensity level will be changed?
6. The absorption coefficient for ultrasound at frequency 3MHz is equal to 0,7 cm^{-1}, at frequency 10MHz the absorption coefficient is equal to 7 cm^{-1}. What frequency is more preferable for thyroid ultrasound investigation?
7. Determine the loudness of the threshold of hearing and threshold of pain for sound frequency 1000 Hz.
8. Sound intensity level of the sound source is equal 50 dB. Determine total intensity level if hundred identical sound sources act together.
9. The aorta radius is equal to 1 cm, the linear flow rate of blood in the aorta is equal to 0.3 m/s. Find the linear flow rate of blood in the capillaries if their total cross-section area is about $2000cm^2$.
10. The linear flow rate of water is equal to 60 cm/s (ρ=1000 kg/m^3) in wide part of the horizontal tube. What is the water rate in the narrow part of the tube, if the static pressure difference between the wide and narrow tube parts is equal to 1.82 kPa?
11. Calculate Reynolds number for the aorta. Aorta diameter is equal to 2 cm; blood velocity is equal to 0.5 m/s; viscosity of blood is equal to 5 mPa· s; density of blood is equal to 1050 kg/m^3.
12. Determine the linear flow rate of blood in aorta with the radius of 1.5 cm, if the duration of systole is 0.25 s, stroke volume is 60 ml. What is the character of the blood flow if the critical Reynolds number is equal to 1160, blood density is 1050 kg/$m^3$and viscosity is 5 mPa·s?
13. Estimate pulse wave velocity in the hip arteries. Young's modulus of the hip arteries is about 10^6 Pa, the attitude of vessel wall thickness (h) to vessel diameter (d) is 0.05 (h/d~0.05); the blood density is equal to 1000 kg/m^3.
14. A capillary of 2.8 mm diameter is immersed in water perpendicular to the surface. The water level in the capillary raises to a height of 1 cm. Determine the surface tension of water.
15. The air bubble in blood vessel has the curvature radii of 0.2 mm and 0.6 mm. Determine the excess pressure in the bubble, preventing blood flow (σ_{blood} = 67 m N / m).
16. The concentration difference on the cell membrane is equal to 0 ,5 × 10^{-4} mol/l and flux density $\Phi = 8 \times 10^{-4}$ mol/cm^2×s. Find the permeability coefficient.
17. Sodium-potassium pump has carried out 8 cycles in the erythrocyte membrane. Calculate the total number of sodium and potassium ions actively transported through the membrane.

18. Determine the equilibrium membrane potential generated by potassium ions across the membrane at the temperature 37°C. Potassium concentration on the inner side of the membrane is 10^{-2} mol/l, on the outer side it is equal to 10^{-4} mol/l.
19. If the potential outside the cell is taken to be zero, then the interior resting potential is (−80) mV. What is the electric field within the membrane, if the potential drop is equal to 80 mV and the membrane thickness is equal to 8 nm?
20. The amplitude of the ECG wave in the first lead is equal to 0,6 mV and the amplitude of the same ECG wave in the second lead is equal to 0,8 mV. What is the amplitude of this wave in the third lead?
21. The speed of the ECG record is equal to 25mm/s, the length of the RR interval is 20mm. Determine the heart rate (the number of beats per minute).
22. Determine the charge passing through the biological tissue during galvanization, if the current density is equal to 0.1mA/cm^2, the procedure duration is 1 min and the electrode area is 25 cm^2.
23. Apparatus for the electrical stimulation provides the rectangular pulses with a period of 0,4 s and a duty cycle of 200. Determine the pulse duration.
24. To cause muscle contraction the rectangular pulses with the pulse duration of 1ms and 4ms were used. For these rectangular pulses the threshold values of current are 10mA and 4mA respectively. Find the rheobase and the chronaxie for these rectangular pulses.
25. Calculate the specific amount of heat released during electrotomy (dissection) of muscle tissue, which occurs when a current with density of 40 kA/m^2 passes through the tissue in 1 second, if the muscle tissue resistivity is equal to 2 Ω·m.
26. The thermocouple sensitivity α is equal to 30 μV/^{0}C and generated electromotive force ε is 0.45 mV. Determine a temperature of the measurement junction of thermocouple if the reference junction has temperature of ice melting.
27. Temperature difference ΔT between the measurement junction and the reference one is equal to 40°C. Generated electromotive force ε is 0.8 mV. Determine the thermocouple sensitivity.
28. Sensor with the initial resistance of 500 Ω is heated. Temperature coefficient of resistance of the sensor is equal to 0,01 $(C^0)^{-1}$. The sensor heating leads to the resistance difference of 20 Ω. Find corresponding temperature difference ΔT.
29. R-wave amplitude of ECG applied to the amplifier input is 2 mV. Determine the gain of the amplifier if the output amplitude is equal to 4V.
30. The dynamic range of the amplifier falls into the range from 0.1 mV to 10 mV. Calculate its dynamic range in decibels.

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The list of questions was approved at the medical and biological physics department meeting (protocol # 4 of 26.11.2025)