The course “Physics, Mathematic”
Questions for the examination

1. Function: definition of function, the domain of the function, the range of the function. Periodic function. Increasing and decreasing functions. Even and odd functions. Elementary functions and their properties and graphs. Composite function.

2. Function derivative. Concept of derivative. Basic differentiation rules. Geometric and physical interpretation of a derivative. Derivatives of basic elementary functions. Higher-order derivatives. Differentiation of a composite function.

3. Differential of function: definition, differential formulas, geometric meaning. Finding differentials. Approximate calculus using a differential.

4. Definition of antiderivative. Indefinite integral. Geometrical meaning of an indefinite integral. Table of basic indefinite integrals. Properties of indefinite integrals. The methods of integration: direct integration, integration by substitution, method of bringing to differential sign, integration by parts.

5. Definite integral. Riemann sum. Geometric and physical meaning of a definite integral. Properties of a definite integral. Newton—Leibniz formula. The methods of integration: direct integration, integration by substitution, method of bringing to differential sign, integration by parts.

6. Differential equation. The order of a differential equation. General and particular solutions. First-order differential equations with variables separated. Homogeneous first-order differential equations.

7. The probability theory. Random events. Types of events. Classic definition of probabilities addition rules. Multiplication rules. Total probability rule. Bayes’ theorem.

8. Random variables. Probability distribution law of a discrete random variable. Distribution function and probability density of a continuous random variable. Properties of the distribution function.

9. Characteristics of a random variable: mean, variance, skewness, kurtosis, mode, and median. Formulas for discrete and continuous random variables. Units of measurement.

10. Basic laws of distribution for random variables: binomial distribution, Poisson distribution, normal distribution (Gaussian distribution). The three sigma rule.

11. Mathematical statistics. Basic concepts of mathematical statistics: population, sample, representative sample, sample size, observations, no ordered types of samples, variational series, discrete series, continuous series, frequency polygon, histogram.

12. Describing data of a sample: the mean, the variance, the standard deviation (practical meaning, formulas, units of measurement).

13. Estimating population parameters: point and interval estimates. The confidence probability. The confidence interval for the mean. The half-length of the confidence interval.

14. Hypothesis testing. Parametric and non-parametric tests. Unpaired (two-sample) *t*-test. *F*-test to compare two variances. Mann–Whitney *U*-test.

15. Correlation analysis. Pearson correlation coefficient. Linear regression analysis. Regression coefficients.

16. Biological membranes. Functions of membranes. Structure and models of membranes. Physical properties and parameters of membranes.

17. Transport of substances across cell membranes. Mathematical description of the passive transport. The Theorell equation. The transport of neutral molecules across membranes. The Fick equation. Transport of ions across membranes. The Nernst–Planck equation.

18. Active transport. Sodium-potassium pump. Calcium pumps.

19. Membrane potential. Resting membrane potential. Mathematical models of the resting potential. Equilibrium model: Bernstein model, Gibbs—Donnan model. Stationary model: Goldman—Hodgkin—Katz model, Thomas model.

20. Action potential. Properties of the action potential. The main stages of the action potential. Propagation of the action potential along a nerve fiber. Telegraph equation for the membrane. The constant of the length of the nerve fiber.

21. Electrical fields of organs and tissues. Electrography. Tasks of the electrography. Dipole electric generator (current dipole). Physical principles of electrocardiography. Electromyography.

22. Physical processes in tissues under action of current and electromagnetic fields. Methods of physiotherapy: galvanization treatment, iontophoresis, diadynamic therapy, electrical sleep, microwave therapy, inductothermy. Effects of alternating electric fields on tissues. Effects of alternating magnetic fields on tissues.

23. Hemodynamics: viscosity of a fluid, Newtonian and non-Newtonian fluids, physical parameters of blood as a non-Newtonian fluid, laminar and turbulent flows, Reynolds number, Poiseuille’s equation. Pulse wave.

24. Biorheology: deformation, elasticity, plasticity, viscosity, types of deformation, modeling of elastic deformation, modeling of viscous deformation, the Maxwell model, the Kelvin—Voigt model. Mechanical properties of biological tissues: bone tissues, skin, muscles, vascular tissue.

25. Thin lenses. Characteristics of thin lenses: the axis of a lens, the focal point, the power of a lens, the magnification of a lens. The thin lens equation.

26. Geometrical optics. Reflection and refraction. Snell’s law. Total internal reflection. Fiber optics as medical instruments.

27. Optical system of the human eye. Defects of the eye optical system and their elimination.

28. Optical microscopy. Components of an optical microscope. The overall angular magnification of an optical microscope. Resolution of microscopes. Angular aperture. Immersion liquid. Limited resolution. Useful magnification. Certain techniques of optical microscopy.

29. Reflection and refraction. The angle of incidence. The angle of refraction. Laws of reflection and refraction. The index of refraction. Total internal reflection and its using in medicine. Refractometry. Construction of a refractometer.

30. Polarization of light. Natural and polarized light. Malus' law. Optical active materials. Polarimetry. Description of a polarimeter.

31. Specifics of energy emission and absorption by atoms and molecules. Emission and absorption spectra. Atomic and molecular spectra as sources of different information. Spectrometer. Spectrometry in medicine.

32. Light absorption. Bouguer's law. Lambert–Beer–Bouguer law. Optical properties of substance (transmittance and optical density). Photoelectric colorimetry: determining the concentration of a colored solution.

33. Energy levels and stimulated emissions. Population inversion. Lasers. Types of lasers (crystals, glasses, semiconductors, gases, liquids). Laser elements. Laser beam characteristics. Laser applications in medicine.

34. Mechanical oscillations. Classification of oscillations: free undamped and damped oscillations, forced oscillations, self-oscillations. Characteristics of oscillations: the period, the position, the amplitude, the frequency, the angular velocity, the oscillation phase, the velocity, the acceleration, the damping factor, the logarithmic decrement, damping frequency, mechanical resonance. Differential equations for oscillations and their solutions.

35. Mechanical waves. Equation of mechanical waves. Energy flow rate of waves. Umov—Poynting vector. Doppler effect. Applications of Doppler Effect in medicine.

36. Sound. Infrasound and ultrasound. Physical characteristics of sound. Physiological characteristics of sound. The Weber—Fechner law. Audiometry.

37. Ultrasound. Ultrasound transducers. Ultrasound receivers. Medical uses of ultrasound: ultrasonic in diagnostic, ultrasound in therapy, ultrasound in surgery.

38. Ionizing radiation. Types of ionizing radiation. X-ray radiation: bremsstrahlung X-rays and characteristic X-rays. Protection against ionizing radiation. Interaction between X-ray and matter. X-ray application in medicine.

39. Radioactivity. Types of radioactive decay: alpha-decay, negative beta-decay, positive beta-decay, electron capture. Radioactive decay law: decay constant, half-life *T*. Activity of radioactive substances.

40. Dosimetry. Radiation doses and dose rates (definitions, formulas, units of measurement): exposure dose X, exposure dose rate N_X, absorbed dose D, absorbed dose rate N_D, equivalent dose H, equivalent dose rate N_H, effective equivalent dose H_{eff}. A connection between the activity of a radioactive material and the rate of exposure dose.