Medical biophysics semifinal questions EM 2019

1. Radiations: basic concepts, fundamentals of geometric optics

Types of radiations. Radiometric quantities (radiance, irradiance, radiation intensity), dependence on direction, steradian. Dependence of intensity on distance in case of radiation sources of various geometry (graphical representation). Attenuation of radiation passing through medium (differential and integral form of the law, interpretation). Geometric optics as model. Fermat's principle. Absolute and relative index of refraction, law of refraction andr eflection. Calculation of critical angle. Phenomenon of total internal reflection and its application.

2. Image formation of simple optical systems

Image formation on a single curved surface, power, law of image formation. Image formation by lenses, principal light rays, lens equation. Magnification and angular magnification. Equivalent power of lens systems. Construction of microscope, light rays, magnification.

3. Fundamentals of wave optics

Oscillations and waves, types of waves. Huygens-Fresnel principle, interference, diffraction on slit and optical grating. Calculation of diffraction angle. Concept of polarized light. Application of light polarization: polarimetry, phase contrast and polarization microscope (the principle briefly). Wave optical limit of resolution. Wave optical meaning of colors.

4. Dual nature of light

Phenomenon referring to wave nature and interpretation of them. The electromagnetic spectrum. Photoelectric effect, its interpretation by Einstein and applications of it. Photon energy, the eV scale. Interpretation of momentum of light, application: laser tweezer. Concept of matter wave. Parts and resolution of electron microscope.

5. Models of atom, electron as particle and wave

Models of atom. The Bohr model. Franck-Hertz experiment. Concept of matter wave and calculation of its wavelength. Wave nature of electron (wavelength, experimental proofs). Wave properties of the free electron, Heisenberg's uncertainty relation. Characterization of bound electron, quantum numbers. Structure of periodic table.

6. Atomic and molecular interactions

Interactions in physics. General description of intra- and interatomic interactions, potential energy, bond distance, bond energy (concepts and graphical representation). Electronegativity. Primary bonds (covalent, metallic, ionic), secondary bonds (dipole-dipole, van der Waals, hydrogen bond, hydrophobic bond). Atomic radius. Types of scanning probe microscopy: STM, AFM (principle, components, application).

7. Multiatomic systems I. ideal and real gases

Macrostate and microstate. Boltzmann's definition of entropy. Ideal gas. Kinetic gas theory. Origin of pressure of ideal gases. Maxwell-Boltzmann velocity distribution. State equation of real gases (van der Waals equation). Boltzmann distribution and condition of its validity. Barometric altitude formula, thermal emission of metals, Nernst equation, equilibrium and speed of chemical reactions,

Arrhenius plot. Strength of bond, interpretation of breaking of various types of bonds by Boltzmann distribution. Temperature dependence of electric conductivity of semiconductors.

8. Multiatomic systems II. Solids, liquids and liquid crystals

Characterization of crystalline state, unit cell, crystal defects. Energy levels in crystals, and structure (insulators, conductors, intrinsic and doped semiconductors). Interpretation of electric and optical properties of crystalline materials. Function of semiconductor diode. Order in liquid state. Properties of mesomorphous state. Thermotropic and lyotropic liquid crystalline structures. Biological examples for liquid crystalline systems. Electro- and thermooptical phenomenon and application of them.

9. Interaction of light with atoms and molecules

Light scattering. Rayleigh- and Mie-scattering with examples. Turbidimetry, nephelometry. Dynamic light scattering and the information obtained from it. Law of radiation attenuation and derivation of Beer-Lambert law from it. Measurement of absorption spectrum (parts and function of the equipment) characteristic parameters and information obtained from it. Energy levels and spectra of atoms and molecules.

10. Thermal radiation

Energetics of thermal radiation. Absolute black body. Kirchhoff's law, Stefan-Boltzmann law, Wien's law. Planck's explanation. Emission spectrum of absolute black body. Explanation of some phenomena (shadow of candle flame, ignescent bodies with different colors). Light sources based on thermal radiation. Medical application of thermal radiation.

11. Luminescence and its forms

Types of luminescence (according to the ways of excitation and relaxation with examples). Emission mechanisms of atoms. Electron-energy system of molecules, Jablonski-diagram (singlet and triplet levels, vibrational relaxation, intersystem crossing). Kasha's rule. Luminescence spectra, explanation of Stokes-shift. Quantum yield, luminescence lifetime. Parts and function of fluorescence spectrometer. Medical.biological applications of fluorescence: FRET, FRAP, luminescent microscopic methods.

12. Laser

Fundamentals of production of laser radiation: spontaneous and induced emission, population inversion, optical resonator, conditions for resonance. Properties of laser light. Types of lasers. Medical (surgical, ophthalmological and dermatological) and other applications of the special properties of laser light with examples.

13. Atomic nucleus, isotopes. Ways of radioactive decay,nuclear radiations

Parts of atomic nucleus and the factors influencing its stability. Isotopes. Types of decays, detailed description of them. What does the type of decay occurring in a nucleus depend on? Comparison of electron and positron (interpretation of their production and annihilation on the basis of conservation laws). Production of gamma radiation. Energy spectra of alpha-, beta-, and gamma-radiations. Ways of production of isotopes (natural and artificial).

14. Radioactive decay law. Characteristics of radioactive isotopes. Interactions of nuclear radiations with matter

Definition of activity. Differential and integral form of decay law. Half-life and average lifetime.

Decrease of activity in the function of time. Classification of ionizing radiations according to the interaction with matter. Interaction of α-, β^--, β^+- and γ-radiations with matter. Effect of neutron radiation. Proton radiation, the Bragg-peak and its significance.

15. Measurement of nuclear radiations

Parts and function of the devices used for measurement of nuclear radiations: scintillation counter, detectors based on gas ionization, thermoluminescent dosimeter, photographic (film) methods, semiconductor detectors. Field of application of them.

16. Dosimetry, dose concepts, radiation protection

Biological effects of ionizing radiations: mechanism of radiation effect (physical, chemical, biological phases) stochastic and deterministic effect.
Dose concepts: absorbed dose, exposure, equivalent dose, effective dose, dose rate. Measurement of exposure, relations of doses in air and in tissue, weighting factors and meaning of them.
Radiation protection: ALARA-principle (graphical explanation) dose limits.

17. Fundamentals of isotope diagnostics. Viewpoints for selection of the proper isotope

Information obtained from isotope tests. Cost-benefit principle. Viewpoints for selection of the isotope: chemical element (definition of radiopharmaceutical), activity, half-life, type and energy of emitted radiation, practical significance of them. Parts and function of Tc-generator.

18. Methods of isotope diagnostics, fundamentals of radiotherapy

Classification of isotope diagnostic methods. Parts and function of gamma-camera. Scintigraphy. Dynamic examination, ROI. Interpretation of typical isotope accumulation curve. Determination of biological half-life of an organ. SPECT. Parts and working principle of PET. Multimodal imaging. Selection of radiation based on absorption and caused ionization. Relative depth dose. The applied dose. Radiation sources. Teletherapy, geometric viewpoints. concept and rule of collimators (examples), gamma-knife. Principles of brachytherapy.

19. Types of biolofical signals, signal processing

Classification of signals according to different viewpoints (with examples). Comparison of signals (decibel scale). Fourier-theorem for periodic and aperiodic signals (examples). Typical frequency and amplitude ranges of biological signals. Voltage divider, parts and function of filter circuits for alternating current. Function of amplifier, functions showing the working of amplifier, effect of feedback. Digitalization of analogue signals. Shannon-Nyquist theorem. Processing of pulse signals, examples for medical application.