MEDICAL AND BIOLOGICAL PHYSICS

For international Students

(English medium of instruction)

Contents

Lesson № 1

chapter topic	**Introduction to the subject**
lesson topic	**Introduction to Subject of Medical and Biological Physics**
the purpose of the lesson is	**to recognize the basic information about the course of Medical and Biological Physics, to study safety in the physics laboratory**

Questions

1. Course Overview
2. Organizing of lectures and lessons on Medical and Biological Physics
3. Course requirements and student responsibilities, class rules
4. Safety in the physics laboratory. Theoretical and practical aspects of electrical safety

Lesson № 2

chapter topic	**Mechanical Oscillation and Wave Processes. Mechanical properties of biological tissues**
lesson topic	**Mechanical Oscillations**
the purpose of the lesson is	**to recognize physical characteristics of mechanical oscillations and oscillating systems**

Questions

1. Mechanical oscillations. Simple Harmonic Motion
2. Energy in Simple Harmonic motion
3. Superposition of Oscillations
4. Resonance
5. Self-oscillations
6. Compound oscillations. Fourier theorem. Harmonic content of compound oscillations
7. Harmonic analysis of medical signals

Practical part

1. Discussion of solution of homework tasks
2. Solve the problem:

A spring-mass system oscillates according the equation $y = 3\sin(5\pi t - \pi/4)$. All values are given in units of SI. Its mass is m=10kg.

1.1. Find (write with units):
   a) the amplitude
   b) the angular frequency
   c) the frequency
   d) the period
   e) the initial phase
   f) the phase in time moment t=3s

1.2. Write the oscillation of velocity and find the amplitude of velocity

1.3. Write the oscillation of acceleration and find the amplitude of acceleration

1.4. Find the spring constant of this oscillating system

1.5. Find the maximal elastic force in this oscillating system

1.6. Find the kinetic energy in t = 5s

1.7. Find the maximal potential energy of oscillation

1.8. Find the total energy of oscillation

Lesson № 3

chapter topic	**Mechanical Oscillation and Wave Processes. Mechanical properties of biological tissues**
lesson topic	**Mechanical Waves**
the purpose of the lesson is	**to study physical characteristics of mechanical waves, to understand the Doppler effect**

Questions

1. Waves. Types of mechanical waves
   - ✓ transverse waves
   - ✓ longitudinal waves
2. Velocity of wave propagation
3. Wave function for a sinusoidal plane wave
4. Energy of wave motion:
   - ✓ energy flux
   - ✓ intensity
   - ✓ energy density
   - ✓ Umov–Poynting vector
5. Doppler effect

Practical part

1. Discussion of solution of homework tasks
2. Find the solution of the tasks

Problem

A source of sound emits waves of frequency 500 Hz. This is detected as 540 Hz by a stationary observer as the source of sound approaches. What is the frequency of the sound detected by the stationary observer as the source moves away from the observer?

Lesson № 4

chapter topic	**Biorheology. Physical basics of hemodynamics**
lesson topic	**Physical principles of hydrodynamics of ideal and viscous fluid. Hemodynamics and biorheology**
the purpose of the lesson is	**to study the basic notions and laws of hydrodynamics, to recognize the physical properties of blood flow and cardio-vascular system**

Questions

1. The basic concepts of hydrodynamics
2. Ideal fluid. Steady-state fluid flow
   - ✓ The continuity equation
   - ✓ Bernoulli's law
3. Viscosity. Newton's law of viscosity. Newtonian and non-Newtonian fluids
4. Poiseuille's law. Hydraulic resistance coefficient
5. The elasticity of blood vessels, a pulse wave
6. Measurement of blood pressure and blood flow rate

Practical part

1. Discussion of solution of homework tasks
2. Find the solution of the tasks

Lesson № 5

chapter topic	**Biorheology. Physical basics of hemodynamics**
lesson topic	**Viscosity measurement by capillary viscometer**
the purpose of the lesson is	**to study the physical properties of blood flow and cardio-vascular system, to recognize viscosity measurement techniques**

Questions

1. Viscous blood properties. Determinants of blood viscosity
2. Fahraeus-Lindqvist effect
3. Viscosity measurement
   - ✓ Ostwald viscometer
   - ✓ Stokes' technique
   - ✓ Rotational method
4. Blood flow rate and blood pressure distribution along cardiovascular system
5. Work and power of the heart

Practical part

1. Discussion of solution of homework tasks
2. Find the solution of the tasks
3. Laboratory work «Determination of liquid viscosity by capillary viscosimeter. Investigation of solution viscosity dependence on its concentration»

Problem

Calculate the Reynolds number if a fluid flows through a diameter of 100 mm with velocity 70 m/s having density of 1400 kg/m3 and having viscosity of 0.9 Pa·s. Do the conclusion about a type of the flow.

Lesson № 6

chapter topic	**Mechanical Oscillation and Wave Processes. Mechanical properties of biological tissues**
lesson topic	**Mechanical properties of biological tissues**
the purpose of the lesson is	**to study the theoretical basics of the mechanical properties of solids, to recognize test methods for Young's modulus, to understand kinematics and dynamics of human motion**

Questions

1. Types of mechanical deformation.
2. Stress-Strain Relationship. Hooke's Law. Young's Modulus.
3. Typical engineering stress-strain plot.
4. Biomechanical properties of bones, muscles, blood vessels tissue, cartilage.
5. Test methods for Young's modulus
6. Mechanical models of viscoelastic properties of biological tissues

Practical part

1. Laboratory work «Determination of Young's modulus of a bone».
2. Knowledge control.

Lesson № 7

chapter topic	**Fluids. Physical basics of hemodynamics and biorheology**
lesson topic	**Surface tension of liquids. Capillary action**
the purpose of the lesson is	**to recognize some peculiarities of the molecular structure of liquids, to study surface phenomena and their manifestation in biological systems**

Questions

1. Molecular structure of liquids. Surface tension
2. Surface curvature and pressure. LaPlace's Law
3. Phenomena of wetting and non-wetting
4. Phenomena and physics of capillary action
5. Surface tension measurement
6. Gas embolism in the vascular system
7. Surfactant role in respiration

Practical part

1. Discussion of solution of homework tasks
2. Find the solution of the tasks
3. Laboratory work «Determination of liquid surface tension. Dependence of surface tension on temperature»

Problem

Calculate the pressure inside a drop of blood of

a) 2mm diameter

b) 20 μm diameter

if water surface tension coefficient of water $\sigma = 58 \cdot 10^{-3}$ N/m.

Lesson № 8

chapter topic	**Mechanical Oscillation and Wave Processes**
lesson topic	**Acoustics. Acoustic techniques in medicine**
the purpose of the lesson is	**to study objective sound characteristics and sound perception ones, to understand the biophysics aspects of hearing**

Questions

1. Objective sound wave characteristics (frequency, period, harmonic content) and sound wave species (musical tone: simple tone, compound tone and noise)
2. Intensity of sound wave, level of intensity in decibels, sound pressure. Threshold of hearing, threshold of pain
3. Subjective sound perception: pitch, loudness, and quality. Their dependence on objective sound characteristics
4. Loudness in phons. Equal loudness curves
5. Audiometry and phonocardiography
6. Ear and hearing
7. Reflection and refraction of sound wave. Specific acoustic impedance

Practical part

1. Discussion of solution of homework tasks
2. Find the solution of the tasks
3. Laboratory work “determination of a personal level of threshold of hearing”

Problems

1. What is the frequency region of sound?
2. What is ultrasound?
3. What is the threshold of hearing?
   a) minimal frequency perceived by the human ear
   b) maximal frequency perceived by the human ear
   c) minimal intensity of sound perceived by the human ear
   d) maximal intensity of sound perceived by the human ear
4. Choose the correct answer. Objective sound characteristics are
   a) loudness, intensity, quality
   b) frequency, intensity, harmonic content
   c) acoustic pressure, harmonic content, pitch
5. Choose the correct answer. Subjective sound characteristics are
   a) loudness, pitch, quality
   b) frequency, intensity, harmonic content
   c) acoustic pressure, harmonic content, pitch
6. What is the threshold of pain?
   a) minimal frequency perceived by the human ear

b) maximal frequency perceived by the human ear
c) minimal intensity of sound perceived by the human ear
d) maximal intensity of sound perceived by the human ear

7. The threshold of hearing depends on frequency:
a) it is maximal for frequencies 20 Hz and 20 kHz and minimal for frequencies from 1 to 3 kHz
b) it is minimal for frequencies 20 Hz - 20 kHz and maximal for frequencies from 1 to 3 kHz
c) it is independent of frequency

8. What is the characteristic of mechanical wave independent of medium property?
a) frequency
b) speed of wave propagation
c) wavelength

9. The fundamental frequency of an oscillator depends on:
a) frequency of applied outer force
b) oscillator property
c) both written above
d) medium property

Free oscillations in real systems are
a) damped
b) undamped simple harmonic motion
c) compound

10. What property of mechanical wave doesn't vary when the wave transfers from one medium to another one?
a) frequency
b) speed of wave propagation
c) wavelength
d) intensity

Lesson № 9

chapter topic	**Mechanical Oscillation and Wave Processes**
lesson topic	**Ultrasound and Infrasound. Ultrasonic techniques in medicine**
the purpose of the lesson is	**to study ultrasound generation, to recognize ultrasound imaging techniques and application of ultrasound in medicine, to discuss infrasound influence on living organism**

Questions

1. Ultrasonic transducers
2. Interaction of ultrasound and biological tissues
3. Ultrasound-based diagnostic imaging technique
4. Application of ultrasound in therapy and surgery
5. Infrasound and its influence biological objects

Practical part

1. Laboratory work «Studying of working principles of ultrasonic flow meter».
2. Knowledge control.

Lesson № 10

chapter topic	**Biophysics of cell membranes**
lesson topic	**Structure and Functions of Cell Membranes** **Passive and Active Membrane Transport**
the purpose of the lesson is	**to recognize structural and functional organization of plasma membrane, to study the main kinds of membrane transport in biological cells**

Questions

1. Structural organization of cell membrane
2. Physical properties of cell membranes
3. Passive transport. The main kinds of passive transport
4. Theorell equation. Nernst–Planck equation
5. Active transport. Sodium-Potassium Pump

Practical part

1. Find the solution of the tasks
2. **Laboratory work** «Diffusion of Ions through a Semipermeable Film»

Lesson № 11

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**Membrane Biopotentials**
the purpose of the lesson is	**to study the bioelectrogenesis phenomena in cells**

Questions

1. Membrane potential and their ion origin
2. Resting potential. Nernst potential. Goldman-Hodgkin-Katz equation
3. Action potential. Stages of action potential
4. Action potential propagation in an unmyelinated axon
5. Action potential propagation in an myelinated axon

Practical part

1. Discussion of solution of homework tasks
2. Knowledge control. Test

Lesson № 12

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**External Electric Fields of Biological Organs and Tissues. Physical Basics of Electrography**
the purpose of the lesson is	**to understand the physical origin of biopotentials of organs and tissues**

Questions

1. Electric field and its characteristics
2. Electric dipole. Electric field potential of an electric dipole. Electric dipole in electric field
3. The cardiac dipole and its wanderings
4. The concept of electrography of organs and tissues

Practical part

1. Discussion of solution of homework tasks
2. Test work

Lesson № 13

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**The Basics of Electrocardiography**
the purpose of the lesson is	**to study technical principles of ECG recording, to perform ECG measurement**

Questions

1. Physical basics of electrocardiography. Einthoven's theory.
2. Electrocardiogram standard limb leads (bipolar), augmented limb leads (unipolar) and (chest precordial) leads (unipolar)
3. The waves of ECG and their formation
4. Determination of amplitude and time parameters of the ECG.

Practical part

1. Discussion of solution of homework tasks
2. Test work
3. **Laboratory work** «Electrocardiograph: Technical Principles. ECG recording. Time and Amplitude Analysis of ECG Waveform»

Lesson № 14

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**The Basics of Amplification of Biological Signals**
the purpose of the lesson is	**to recognize working principle of amplifier and to study some main characteristics of amplifier**

Questions

1. Amplifiers of biopotential signals
2. Amplitude characteristic of amplifier. Amplitude distortions
3. Frequency characteristic of amplifier. Frequency distortions
4. Amplitude and frequency ranges of biopotential signals
5. Differential amplifier

Practical part

1. Discussion of solution of homework tasks
2. Test work
3. **Laboratory work** «Amplitude characteristic and frequency response of amplifier».

Lesson № 15

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**Direct and Alternating Electric Current**
the purpose of the lesson is	**to study characteristics and laws of direct and alternating current, to distinguish resistance, reactance and impedance and to explore capacitive and inductive reactancesdependence on frequency**

Questions

1. Direct electric current. Current, current density
2. Ohm's law. Electric resistance, resistivity. Conductance, conductivity
3. Alternating electric current
4. Resistor in an AC circuit
5. Root mean square (rms) voltage and current
6. Capacitor in an AC circuit
7. Inductor in an AC circuit
8. Impedance and the phase difference between voltage and current in an AC circuit
9. Power in AC Circuit

Practical part

1. Discussion of solution of homework tasks
2. **Laboratory work** «Capacitive and inductive reactances dependence on frequency»

Problems

1. A 60 W light bulb operates on a peak voltage of 156 V. Find the V_{rms}, I_{rms}, and resistance of the light bulb.

2. An AC circuit carries an rms current of 7.0 Amps. The current travels through a 12 Ohm resistor.
   a) What is the peak current?
   b) What is the power dissipated in the resistor?
   c) What is the peak voltage drop across the resistor?

3. Consider the *LC* circuit to the right. If one needs to tune this circuit to a frequency of 84 kHz, and the capacitor has a capacitance C = 3.0 μF, what inductance L is needed?

4. What is the impedance of the circuit to the right if: f = 60 Hz, L = 20 mH, R = 4.0 W?
   b.) If the r.m.s. voltage of the source is V_{rms} = 110 V, what is the r.m.s. current?
   c.) What is the peak current?

d.) What is the power dissipated in the resistor?

5. What is the capacitance such that the current through the circuit is a maximum?
DATA: f = 60 Hz, L = 20 mH, R = 4.0 Ω, V_{rms} = 110 V?

b.) What is the r.m.s. current through the circuit for the capacitance found in part a?

c.) Find the capacitance to make the impedance equal to 8 Ohms.

Lesson № 16

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**Electroconductivity of Biological Tissues for Direct Current (DC) and Alternating Current (AC)**
the purpose of the lesson is	**to study particular featuresof biological tissues electroconductivityfor direct and alternating current, to recognize physical principles of rheography andquantification of tissue vitality on the basis of impedance dispersion**

Questions

1. Conductivity of electrolytes
2. DC influence on body tissues
3. Galvanization and medicinal electrophoresis
4. AC influence on body tissues, capacitive properties of body tissues
5. Impedance of biological tissues
6. Three-element model of tissue impedance
7. Assessment of tissue vitality by means of electrical impedance dispersion
8. Rheography (impedance plethysmography)

Practical part

1. Discussion of solution of homework tasks
2. **Laboratory work** «Resistance and impedance of biological tissue in DC and AC circuits respectively»

Lesson № 17

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**Physical Basics of Electrotherapy with Pulse Electric Current**
the purpose of the lesson is	**to recognize electric pulse parameters and electric circuits of relaxation oscillators and to study physical principles of performance of low frequency physiotherapeutic apparatus**

Questions

1. Electric pulse and pulsed current definition and classification
2. Pulse and pulsed current parameters
3. Electro excitability of biological tissues. Strength-duration curve for stimulus of an excitable tissue. Lapicque's Equation. Rheobase. Chronaxie.
4. Electrostimulation:
   - ✓ Skeletal muscle stimulation
   - ✓ Nerve tissues stimulation
   - ✓ Cardiostimulation. Defibrillators. Pacemakers.

Practical part

1. Discussion of solution of homework tasks
2. **Laboratory work** «Studying of pulse parameters generated by multivibrator and changed by differentiator and integrator circuits»

Lesson № 18

chapter topic	**Electric and magnetic phenomena in living organisms**
lesson topic	**Magnetic field and its characteristics. Magnetic properties of matters and biological tissues**
the purpose of the lesson is	**to study properties and characteristics of magnetic field; to recognize magnetic properties of biological tissues**

Questions

1. Magnetic field and its characteristics
2. Ampere's law
3. Magnetic force acting on moving charge
4. Magnetic properties of matters. Diamagnetic materials, paramagnetic materials, ferromagnetic materials
5. Magnetic properties of biological tissues. Biological effects of magnetic field

Practical part

1. Discussion of solution of homework tasks
2. Test work

Lesson № 19

chapter topic	Knowledge control
lesson topic	**Final test**
the purpose of the lesson is	to control knowledge on the topics: ✓ Mechanical Oscillation and Wave Processes ✓ Biophysics of cell membranes ✓ Electric and magnetic phenomena in living organisms

Questions.

1. Types of mechanical deformation.
2. Stress-Strain Relationship. Hooke's Law. Young's Modulus. Typical engineering stress-strain plot.
3. Biomechanical properties of bones, muscles, blood vessels tissue, cartilage.
4. Elastic, viscous, viscoelastic media and their mechanical properties. Mechanical models of viscoelastic properties of biological tissues
5. Mechanical oscillations. Simple Harmonic Motion
6. Energy in Simple Harmonic motion
7. Damped oscillations. Forced oscillations. Resonance
8. Superposition of Oscillations. Self-oscillations
9. Compound oscillations. Fourier theorem. Harmonic content of compound oscillations
10. Harmonic analysis of medical signals
11. Waves. Types of mechanical waves. Velocity of wave propagation
12. Wave function for a sinusoidal plane wave
13. Energy of wave motion: energy flux, intensity, energy density, Umov–Poynting vector
14. Doppler effect
15. Objective sound wave characteristics (frequency, period, harmonic content) and sound wave species (musical tone: simple tone, compound tone and noise)
16. Intensity of sound wave, level of intensity in decibels, sound pressure. Threshold of hearing, threshold of pain
17. Weber-Fechner law. Subjective sound perception: pitch, loudness, and quality. Their dependence on objective sound characteristics. Equal loudness curves (Fletcher-Munson diagram)
18. Audiometry and phonocardiography
19. Ear and hearing
20. Reflection and refraction of sound wave. Specific acoustic impedance
21. Ultrasonic transducers
22. Interaction of ultrasound and biological tissues
23. Ultrasound-based diagnostic imaging technique
24. Application of ultrasound in therapy and surgery
25. Infrasound and its influence biological objects

26. The basic concepts of hydrodynamics. Ideal fluid. Steady-state fluid flow. The continuity equation, Bernoulli's law, and their usage to explain some phenomena in cardiovascular system
27. Viscosity. Newton's law of viscosity. Newtonian and non-Newtonian fluids Viscous blood properties. Determinants of blood viscosity. Fahraeus-Lindqvist effect
28. Viscosity measurement: Ostwald viscometer, Stokes' technique, rotational method
29. Work and power of the heart
30. Poiseuille's law. Hydraulic resistance coefficient
31. The elasticity of blood vessels, a pulse wave
32. Measurement of blood pressure and blood flow rate. Blood flow rate and blood pressure distribution along cardiovascular system
33. Molecular structure of liquids. Surface tension
34. Surface curvature and pressure. LaPlace's Law. Gas embolism in the vascular system.
35. Surfactant role in respiration
36. Phenomena of wetting and non-wetting. Phenomenon and physics of capillary action
37. Surface tension measurement
38. Structural organization of cell membrane
39. Physical properties of cell membranes
40. Passive transport. The main kinds of passive transport
41. Nernst–Planck equation. Fick's law
42. Active transport.
43. Membrane potential. Resting potential.
44. Nernst equation. Goldman-Hodgkin-Katz equation
45. Action potential. Stages of action potential
46. Action potential propagation in an unmyelinated axon
47. Action potential propagation in an myelinated axon
48. Electric field and its characteristics
49. Electric dipole. Electric field potential of an electric dipole. Electric dipole in electric field
50. The cardiac dipole and its wanderings
51. The concept of electrography of organs and tissues
52. Physical basics of electrocardiography. Einthoven's theory. Electrocardiogram standard limb leads (bipolar) and chest leads (unipolar)
53. The waves of ECG and their formation
54. Determination of amplitude and time parameters of the ECG.
55. Amplifiers of biopotential signals
56. Amplitude characteristic of amplifier. Amplitude distortions
57. Frequency characteristic of amplifier. Frequency distortions
58. Amplitude and frequency ranges of biopotential signals
59. Differential amplifier

60. Direct electric current. Ohm’s law. Ohm’s Law in Point (Differential) Form
61. Electrical conductivity of electrolytes
62. Alternating electric current and its characteristics
63. Resistor in an AC circuit
64. Capacitor in an AC circuit
65. Inductor in an AC circuit
66. Impedance and the phase difference between voltage and current in an AC circuit
67. Electrical conductivity of biological tissues. DC influence on body tissues. Galvanization and medicinal electrophoresis
68. AC influence on body tissues, capacitive properties of body tissues. Impedance of biological tissues. Three-element model of tissue impedance
69. Assessment of tissue vitality by means of electrical impedance dispersion
70. Rheography (impedance plethysmography)
71. Electric pulse, pulsed current definition and classification
72. Pulse and pulsed current parameters
73. Electroexcitabilityof biological tissues. Strength-duration curve for stimulus of an excitable tissue.Lapicque's Equation. Rheobase. Chronaxie.
74. Electrical stimulation of the heart
75. Electronic stimulators. The low-frequency physiotherapy electronic equipment
76. Magnetic field and its characteristics
77. Ampere's law
78. Magnetic force acting on moving charge
79. Magnetic properties of solids. Diamagnetic materials, paramagnetic materials, ferromagnetic materials
80. Magnetic properties of biological tissues. Biological effects of magnetic field

Lesson № 20

chapter topic	Electric and magnetic phenomena in living organisms
lesson topic	**Biomedical Measuring Systems**
the purpose of the lesson is	to recognize the basic principles of biological measuring, to study the physical phenomena underlying the operation of sensors

Theoretical topics

1. Structural diagram of medical and biological measuring. Electrodes for detection and biomonitoring
2. Electric conductivity of metals and semiconductors. Resistance thermometer and thermistor. Thermoelectricity. Thermocouple
3. Piezoelectric effect
4. Sensors: passive and active. Sensor characteristics
5. Different types of sensors:
   - ✓ Temperature sensors
   - ✓ Sensors of parameters of cardiovascular system
   - ✓ Sensors of parameters of breathing system

Practical part

1. Discussion of solution of homework exercises and problems.
2. **Laboratory work** «Studying the resistance dependence on the temperature of a semiconductor thermistor; calculation of temperature coefficient of resistance. Studying the resistance dependence on the length of a resistive sensor».

Lesson № 21

chapter topic	Electric and magnetic phenomena in living organisms
lesson topic	**High-frequency Electrotherapy and Electrosurgery Techniques**
the purpose of the lesson is	to study high-frequency electric and magnetic field effect on biological tissues and to recognize their usage in electrotherapy and electrosurgery

Theoretical topics

1. Physical basics of the high frequency therapy and electrosurgery
2. LC Oscillator. Technical and therapeutic circuits of apparatus for UHF-therapy
3. Influence on a biological tissue by the high frequency alternating magnetic field
4. Influence on a biological tissue by the high frequency alternating electric field
5. Influence on a biological tissue by the electromagnetic waves
6. Darsonvalization, surgical diathermy

Practical part

1. Discussion of solution of homework tasks
2. **Laboratory work** «Influence on a substance by the high frequency alternating electric and magnetic field»

Lesson № 22

chapter topic	Optical phenomena and their medical application
lesson topic	**Geometrical optics. Fiber optics. Refractometry**
the purpose of the lesson is	to study geometrical optics laws, to understand working principle of fiber optics medical instruments, to recognize the basics of refractometry and to perform refractive index measurements by Abbé refractometer

Theoretical topics

1. Geometrical optics.
2. Reflection of light. The law of reflection. Refraction of light. Index of refraction. Snell's law of refraction
3. Total internal reflection and critical angle. Fiber optics and its medical application
4. Refraction in triangular prisms
5. Refractometry
6. Dependence of refractive index of solution on its concentration. Determination of unknown concentration of solution.

Practical part

1. Discussion of solution of homework tasks
2. Test work
3. **Laboratory work** «Investigation of Dependence of Refractive Index of Sugar Solution on its Concentration. Determination of Unknown Concentration of Sugar Solution»

Lesson № 23

chapter topic	Optical phenomena and their medical application
lesson topic	**Geometrical optics. Basics of Optical Microscopy. Basics of Electron Microscopy**
the purpose of the lesson is	to study the ray optics laws, to recognize the optical structure of the human eye and to understand basic concepts in optical microscopy

Theoretical topics

1. The compound microscope
2. Magnification. Resolution of optical microscope, Abbe's diffraction limit
3. Specialized Microscopy Techniques
4. De Broglie hypothesis. Electron diffraction
5. Electron microscopy. Resolution of electron microscope
6. Scanning probe microscopy

Practical part

1. Discussion of solution of homework tasks
2. Find a solution of the tasks
3. **Laboratory work** «Magnification and Resolution of Optical Microscope»

Lesson № 24

chapter topic	Optical phenomena and their medical application
lesson topic	**Eye as an Optical System. Biophysical Basics of Human Vision**
the purpose of the lesson is	to study optical and biophysical basics of image formation in human eye, to recognize correction of imperfect human vision

Theoretical topics

1. Optical system of the human eye and accommodation
2. Imperfections of optical system of human eye
3. Eye sensitivity to light and color
4. Biophysics of visual perception

Practical part

1. Discussion of solution of homework tasks
2. Find a solution of the tasks

Problems

1. Calculate the size of the retinal image of a 10-cm leaf from a distance of 30 cm. Consider the focal length of the eye is 1.5 cm. How many times the image is less than the object?
2. Suppose the focal length of a person's eye is 3.0 cm when fully relaxed (looking at infinity). If the person's retina is 3.3 cm behind the eye lens (a nearsighted eye), what must be the optical power of the corrective lens?
3. To define eye angular resolution you may draw two parallel lines 1 mm apart on a piece of paper and tape the paper to the wall in a well illuminated room, then walk backwards from the wall until you cannot distinguish the two lines separately. Measurement of distance from the wall is approximately equal to 3.4 m. Find eye angular resolution in minutes. Using calculated value and the dimension of the eyeball ≈22 mm evaluate the order of magnitude of the dimensions of the receptor cells in the retina, on the hypothesis that two objects become undistinguishable when the light coming from them falls on the same cell.

Lesson № 25

chapter topic	Optical phenomena and their medical application
lesson topic	**Wave Optics. Polarization of Light**
the purpose of the lesson is	to study electromagnetic waves characteristics, to recognize phenomenon of polarization, its use in optical devices and in studying of biological objects

Theoretical topics

1. Electromagnetic waves and their properties.
2. Natural and polarized light. Linear and circular polarization
3. Polarizers
   - ✓ Absorptive polarizers
   - ✓ Polarization by reflection. Brewster's angle
   - ✓ Birefringent polarizers
4. Malus law. Polarizing instruments.
5. Optical activity
6. Polarimetry.

Practical part

1. Discussion of solution of homework exercises and problems.
2. **Laboratory work** «Measurement of Concentration of Optically Active Substances by Polarimeter»
3. Find the solution of the tasks

Problems

1. If the angle of incidence of unpolarised light is $tan^{-1}n$, where n is the refractive index of the glass, the reflected light is completely linearly polarised. What is the angle between reflected and refracted beams?
2. The refractive index for crown glass for red light of wavelength 660 nm is 1.52 and for violet light of wavelength 480 nm is 1.54. Calculate the difference in Brewster angle for these two wavelengths.
3. Light reflected from the surface of a material in air at an angle 56.5° to the normal is completely polarized. Calculate the angle of refraction of the glass.
4. The angle between two polarization planes of two Nicol prisms is φ=45°. What times will the natural light intensity decrease while going through a) one Nicol prism; b) two Nicol prisms?
5. Unpolarized light of intensity 6.0 Wm^{-2} is incident on a polarizer, and then transmitted light is incident on an analyser. The angle between the transmission axes of the polarizer and analyser is 60°. Calculate the intensity of the light transmitted by the analyser.

Lesson № 26

chapter topic	Optical phenomena and their medical application
lesson topic	**Stimulated Emission. Lasers and Their Medical Application**
the purpose of the lesson is	to study physical principles of lasers, to recognize properties of laser radiation, its use in therapy and surgery

Theoretical topics

1. Stimulated emission and its properties. Light amplification
2. Laser construction
3. Three- and four-level laser systems of pumping
4. Properties of laser radiation, its use in therapy and surgery

Practical part

1. Discussion of solution of homework exercises and problems.
2. **Laboratory work** «Determination of Wavelength with Diffraction Grating»

Lesson № 27

chapter topic	Optical phenomena and their medical application
lesson topic	**Absorption and Scattering of Light. Spectrophotometry**
the purpose of the lesson is	to study the laws of light absorption and light scattering, to recognize practical application of absorption and scattering of light for. spectrophotometry and nephelometry

Theoretical topics

1. Energy levels of atoms and molecules.
2. Light absorption. Beer-Lambert-Bouguer law. Absorption coefficient.
3. Transmittance. Optical density (absorbance)
4. Spectrophotometry (colorimetry). Photocolorimeter
5. Light scattering. Rayleigh scattering. Nephelometry

Practical part

1. Discussion of solution of homework tasks
2. **Laboratory work** «Measurement of Concentration of Solutions With Photocolorimeter»

Lesson № 28

chapter topic	Elements of atomic and nuclear physics
lesson topic	**Emission and Absorption of Energy by Atoms and Molecules. Luminescence. Fundamentals of Spectrum Analysis**
the purpose of the lesson is	to understand fundamentals of atomic and molecular spectrum analysis, to study the phenomenon of luminescence and to recognize their medical application

Theoretical topics

1. Bohr atomic model. Spectrum of atomic hydrogen
2. Fundamentals of atomic and molecular spectrum analysis
3. Luminescence. Stokes Law. Kasha–Vavilov Law.
4. Luminescent analysis in medicine
5. Photobiological processes
6. Photodynamic therapy

Practical part

1. Discussion of solution of homework tasks
2. **Laboratory work** «Measurement of the Visible Spectrum of Neon and Absorption Spectrum of Potassium Permanganate»

Lesson № 29

chapter topic	Elements of atomic and nuclear physics
lesson topic	**Thermal Radiation. Thermography and Thermal Imaging.**
the purpose of the lesson is	to understand wave-particle duality, to study thermal radiation laws, to recognize medical application of thermography and thermal imaging.

Theoretical topics

1. Thermal radiation and its characteristics
2. Thermal radiation laws and their quantum interpretation
3. Thermography and thermal imaging and their medical application

Practical part

1. Discussion of solution of homework tasks
2. Find a solution of the exercises

Problems

1. Define the photon mass, energy and photon momentum for red light (λ=700 nm).
2. How many photons does the radiation energy E=10 eV with λ=500 nm correspond?
3. Which temperature does the radiant emittance of a black body correspond $Re = 500\frac{W}{m^2}$?
4. What is the wave length of the maximum of the spectral density of the radiant emittance for:
   a) a human body with the temperature 37°C;
   b) an electric lamp with the temperature 1800 K;
   c) the sun with the temperature 5800 K;
   d) an atomic bomb at explosion when the temperature is 107 K.
5. Radiation emitted from human skin reaches its peak at
   $$\lambda = 9.4\ \mu m$$
   a) What is the frequency of this radiation?
   b) What type of electromagnetic waves are these?
   c) How much energy (in electron volts) is carried by one quantum of this radiation?

Lesson № 30

chapter topic	Elements of atomic and nuclear physics
lesson topic	**Electron Paramagnetic Resonance and Nuclear Magnetic Resonance Techniques for Medical Applications**
the purpose of the lesson is	to study magnetic field and its properties, to recognize magnetic field influence on a charge and current, to study magnetic properties of substances, biological and medical use of EPR and NMR

Theoretical topics

1. Electron magnetic dipole moment. Orbital magnetic dipole moment. Spin magnetic dipole moment. g-factor. Bohr magneton
2. Electron paramagnetic resonance and its medical applications
3. Nuclear Magnetic Resonance
4. Nuclear magnetic resonance imaging (NMRI)

Practical part

1. Knowledge control

Lesson № 31

chapter topic	Ionizing radiation. Fundamentals of radiation dosimetry
lesson topic	**Bremsstrahlung and Characteristic X-Radiation**
the purpose of the lesson is	to understand the basic nature of X-radiation, to study the law of attenuation of radiation in matter

Theoretical topics

1. Bremsstrahlung X-radiation nature
2. X-radiation tube
3. Bremsstrahlung X-radiation spectrum
4. Characteristic X-radiation nature. Moseley's law
5. Attenuation of radiation in matter
6. Linear attenuation coefficient, mass attenuation coefficient

Practical part

1. Find the solution of the tasks

Problems

1. The velocity of an electron is equal to 108 cm/s. It is decelerated in electric field and stopped. It emits one photon. Define the wavelength of emitted radiation.
2. Define the minimum wave length of the Bremsstrahlung X-rays if the anode voltage in the X-ray tube is 120 kV.
3. The number of X-ray photons (λ=10nm) emitted by X-ray source is 6.9×10^{12} per three second. Calculate the X-ray flux and energy.
4. In an X-ray tube the current through the tube is 1mA and the accelerating voltage is 90kV. Calculate the kinetic energy of the electrons on striking the anode assuming they leave the cathode with zero speed. Calculate the X-ray flux. The anode is made from tungsten (z = 74).
5. The ground state energy level of a fictitious element is 20 keV and that of the next state is 2.0 keV. Calculate the wavelength of the K_α line associated with this element.
6. Molybdenum K_α X-rays have wavelength 7×10^{-11}m. Find the minimum X-ray tube potential difference that can produce these X-rays and their photon energy in electron-volts.
7. Look at the diagram of an X-ray tube. How may the intensity of the X-rays be controlled?
8. The half-value thickness of a 30 keV photon in aluminium is 2.4 mm. If the initial intensity of the X-ray beam is $4.0 \cdot 10^2$ kWm^{-2}.
   What is the intensity after passing through 9.6 mm of aluminium?
   Calculate the linear attenuation coefficient of the aluminium.
   What is the intensity of the beam after passing through 1.5 mm aluminium?

Lesson № 32

chapter topic	Ionizing radiation. Fundamentals of radiation dosimetry
lesson topic	**X-Radiation medical use**
the purpose of the lesson is	to study different types of interaction of X-radiation with matter, to recognize the medical uses of X-radiation and X-ray protection techniques

Theoretical topics

1. Interaction of X-radiation with matter.
2. Physical principles of medical uses of X-radiation. X-ray imaging. X-ray therapy
3. X-ray protection techniques
4. The basics of computed tomography

Practical part

1. Find the solution of the tasks
2. Knowledge control

Test for training
"Bremsstrahlung and Characteristic X-Radiation"

1. *What types of imaging techniques expose people to X-ray radiation?*
   PET scans; CT scans; MRI scans
2. *Which material is used in protective aprons to prevent unnecessary exposure to X-radiation?*
   Plastic; lead; wood
3. *Who discovered X-rays?*
   Henri Becquerel; Wilhelm Roentgen; Marie Curie; Pierre Curie
4. *The emitter of electrons in the X-ray tube is called*
   anode; cathode; diode; anticathode
5. *Dense portions of the body (such as steel pins) show up on film as what color?*
   white; black; gray; yellow
6. *When electrons traveling in the X-ray tube strike the anode, which of the following is produced?*
   light; X-rays; heat; heat and X-rays
7. *The factor that indicates how much attenuation will take place per centimeter is known as the:*
   Mass attenuation coefficient

Linear attenuation coefficient
Decay rate
Atomic number

8. *X-rays are often referred to as photons because*
   they possess a charge
   they have mass
   they occur as small packets of energy
   none of the above
9. *When penetrating radiation is directed at a material, the radiation intensity*
   decreases exponentially with increasing material thickness
   increases linearly with increasing material thickness
   decreases linearly with increasing material thickness
   none of the above
10. *X-rays and Gamma rays have significant penetrating power due to their:*
    short wavelength; medium wavelength; long wavelength; wide range of wavelengths
11. *After traveling through two half-value layers, the incident radiation has been reduced to:*
    50%; 35%; 25%; 20%
12. *The target of an X-ray tube is often made out of tungsten because:*
    It has a high atomic mass which will result in more X-rays being generated due to atomic particle interactions
    It is an inexpensive material that is easy to machine
    It has very high thermal conductivity which makes it easy to cool
13. *Exposure to ionizing radiation can be limited:*
    With the use of shielding
    By increasing distance from the source
    By limiting the time exposed to the radiation
    All of the above
14. *On a film radiograph, an area of high density in the test component will appear:*
    Lighter than the surrounding area
    Darker than the surrounding area
    Thinner than the surrounding area
    Wider than the surrounding area
15. *Computed tomography X-ray techniques allow the test component to be:*
    Viewed in various cross-sectional slices
    Viewed from different angles
    Analyzed for chemical composition
16. *The thickness of any given material where 50% of the incident X-radiation energy has been attenuated is known as the:*
    linear attenuation coefficient; half-value layer; decay rate; mass attenuation coefficient
17. *Bremsstrahlung production of X-rays produces radiation that is composed of:*

A small number of very defined energies
A continuous spectrum of energies over some range
Radiation of only one energy
None of the above

18. *X-ray generators produce radiation through:*
Bremsstrahlung processes
K-shell emission processes
Radioactive decay

19. *Higher energy radiation will have more:*
Speed
Incident Intensity
Penetrating power

20. *The absorption of x-rays by the body depends on:*
The thickness of the absorbing materials only
The density of the absorbing materials only
The thickness and density of the absorbing materials

Lesson № 33

chapter topic	Ionizing radiation. Fundamentals of radiation dosimetry
lesson topic	**Radioactivity. Radioactive decay**
the purpose of the lesson is	to recognize the phenomenon of natural radioactive decay, to study the law of radioactive decay

Theoretical topics

1. Natural radioactivity
2. Radioactive decay. Different types of radioactive decay
3. The radioactive decay law. Half-life time. Mean life time

Practical part

1. Discussion of solution of homework tasks
2. Find the solution of the tasks

Problems

1. The symbol ${}^{A}_{Z}X$ is used for a particular isotope. If A = 14 and Z = 6,
   a) How many protons does the isotope have in its nucleus?
   b) How many neutrons does the isotope have in its nucleus?
   c) What is the element X?
2. The radioactive α-decay of uranium-234 to is written:
   $$ {}^{234}_{92}U \rightarrow {}^{A}_{Z}X + {}^{4}_{2}\alpha $$
   Identify the particle ${}^{A}_{Z}X$ that is produced.
3. Identify the product formed when the radionuclide protactinium-234 decays with the emission of a beta particle.
4. Initial mass of radioactive Co is 4 g. Find the mass of Co decayed during 216 day, if its half-life is 72 days.
5. One liter of seawater has an activity of 10 Bq.
   Approximately how many nuclei decay every day in this quantity of seawater in average?

Lesson № 34

chapter topic	Ionizing radiation. Fundamentals of radiation dosimetry
lesson topic	**Interaction of the Ionizing Radiation with Matter. Principles of Radionuclide Diagnostics and Radiation Therapy**
the purpose of the lesson is	to recognize the phenomenon of natural radioactive decay to study the law of radioactive decay, to recognize radiation detectors, to understand working principle of nuclear medicine imaging systems

Theoretical topics

1. Characteristics of interaction of the ionizing radiation with matter: linear specific ionization, linear energy transfer, mean linear range
2. Activity of a radioactive substance. Specific mass activity. Specific volume activity. Specific surface activity
3. Principles of radionuclide diagnostics
4. Radiation therapy

Practical part

1. Discussion of solution of homework tasks

Lesson № 35

chapter topic	Ionizing radiation. Fundamentals of radiation dosimetry
lesson topic	**Dosimetry of Ionizing Radiation**
the purpose of the lesson is	to study radiation doses characterized ionizing radiation and its influence on objects, to know doses interrelation

Theoretical topics

1. Absorbed dose, exposure, equivalent dose, dose rate and their units. Their interrelation
2. Effective dose equivalent
3. Collective effective dose

Practical part

1. Discussion of solution of homework tasks
2. Find a solution of the tasks
3. Test work

Problems

1. A patient of mass 70 kg receives radiotherapy. During the treatment, a tumor of mass 250 g receives 20 J of energy.
   Calculate the absorbed dose.
2. A worker in the nuclear industry receives an absorbed dose of 400 μGy from slow neutrons and an absorbed dose of 2 mGy from gamma radiation.
   Calculate the total equivalent dose received.
3. The natural radiation background at sea level is about 0.4μSv/h. In terms of mSv, what is your total radiation dose after
   a) 1 year?
   b) 70-year lifetime?
4. A Cobalt-60 source emits gamma radiation. A certain distance from this source, the equivalent dose rate is 12 $\mu Sv \cdot h^{-1}$. A thickness of 60 mm of lead is needed to reduce the equivalent dose rate to 1.5 $\mu Sv \cdot h^{-1}$.
   Calculate the half-value thickness of the lead shielding.

Lesson № 36

chapter topic	Ionizing radiation. Fundamentals of radiation dosimetry
lesson topic	**Ionizing Radiation monitoring techniques**
the purpose of the lesson is	to recognize the basic physical principles of radiation dosimetry, to understand the origin of background and man-made radiation

Theoretical topics

1. Radiation monitoring instruments. Dosimeter. Radiometer
2. Measure of exposure rate
3. Natural background radiation and man-made radiation sources

Practical part

1. **Laboratory work** «Determination of Substance Absorption Coefficient for Gamma Radiation»

Lesson № 37

chapter topic	Knowledge control
lesson topic	**Credit**
the purpose of the lesson is	to control knowledge on the topics: ✓ Electric and magnetic phenomena in living organisms ✓ Optical phenomena and their medical application ✓ Elements of atomic and nuclear physics ✓ Ionizing radiation. Fundamentals of radiation dosimetry

Credit questions

1. Structural diagram of medical and biological measuring. Electrodes for detection and biomonitoring
2. Electric conductivity of metals and semiconductors. Resistance thermometer and thermistor. Thermoelectricity. Thermocouple
3. Piezoelectric effect
4. Sensors: passive and active. Sensor characteristics
5. Different types of sensors: temperature sensors, sensors of parameters of cardiovascular system, sensors of parameters of breathing system
6. Physical basics of the high frequency therapy and electrosurgery
7. LC Oscillator. Technical and therapeutic circuits of apparatus for UHF-therapy
8. Influence on a biological tissue by the high frequency alternating magnetic field
9. Influence on a biological tissue by the high frequency alternating electric field
10. Influence on a biological tissue by the electromagnetic waves
11. Darsonvalization, surgical diathermy
12. Geometrical optics. Reflection of light. The law of reflection. Refraction of light. Index of refraction. Snell's law of refraction
13. Total internal reflection and critical angle. Fiber optics and its medical application
14. Refraction in triangular prisms
15. Refractometry. Dependence of refractive index of solution on its concentration. Determination of unknown concentration of solution
16. The compound microscope
17. Magnification. Resolution of optical microscope, Abbe's diffraction limit
18. Specialized Microscopy Techniques
19. De Broglie hypothesis. Electron diffraction
20. Electron microscopy. Resolution of electron microscope
21. Scanning probe microscopy
22. Optical system of the human eye and accommodation
23. Imperfections of optical system of human eye

24. Biophysics of visual perception Eye sensitivity to light and color
25. Electromagnetic waves and their properties.
26. Natural and polarized light. Linear and circular polarization
27. Polarizers: absorptive polarizers, polarization by reflection, Brewster's angle; birefringent polarizers; Malus law. Polarizing instruments.
28. Optical activity. Polarimetry.
29. Stimulated emission and its properties. Light amplification. Laser construction
30. Three- and four-level laser systems of pumping
31. Properties of laser radiation, its use in therapy and surgery
32. Energy levels of atoms and molecules.
33. Light absorption. Beer-Lambert-Bouguer law. Absorption coefficient.
34. Transmittance. Optical density (absorbance)
35. Spectrophotometry (colorimetry). Photocolorimeter
36. Light scattering. Rayleigh scattering. Nephelometry
37. Bohr atomic model. Spectrum of atomic hydrogen
38. Luminescence. Stokes Law. Kasha–Vavilov Law.
39. Fundamentals of atomic and molecular spectrum analysis. Luminescent analysis in medicine
40. Photobiological processes
41. Photodynamic therapy
42. Thermal radiation and its characteristics
43. Thermal radiation laws and their quantum interpretation
44. Thermography and thermal imaging and their medical application
45. Electron magnetic dipole moment. Orbital magnetic dipole moment. Spin magnetic dipole moment. g-factor. Bohr magneton
46. Electron paramagnetic resonance and its medical applications
47. Nuclear Magnetic Resonance. Nuclear magnetic resonance imaging (NMRI)
48. Bremsstrahlung X-radiation nature. Bremsstrahlung X-radiation spectrum
49. X-radiation tube
50. Characteristic X-radiation nature. Moseley's law
51. Attenuation of radiation in matter. Linear attenuation coefficient, mass attenuation coefficient
52. Interaction of X-radiation with matter.
53. Physical principles of medical uses of X-radiation. X-ray imaging. X-ray therapy
54. X-ray protection techniques
55. The basics of computed tomography
56. Natural radioactivity
57. Radioactive decay. Different types of radioactive decay
58. The radioactive decay law. Half-life time. Mean life time
59. Characteristics of interaction of the ionizing radiation with matter: linear specific ionization, linear energy transfer, mean linear range

60. Activity of a radioactive substance. Specific mass activity. Specific volume activity. Specific surface activity
61. Principles of radionuclide diagnostics
62. Radiation therapy
63. Absorbed dose, exposure, equivalent dose, dose rate and their units. Their interrelation
64. Effective dose equivalent. Collective effective dose
65. Radiation monitoring instruments. Dosimeter. Radiometer. Measure of exposure rate
66. Natural background radiation and man-made radiation sources