

**Ministry of Health Care of Ukraine
O. O. Bogomolets National Medical University**

MEDICAL AND BIOLOGICAL PHYSICS

Edited by Prof. **Alexander V. Chalyi**

*Recommended by the Ministry of Health Care of Ukraine
as a textbook for the students of higher medical
establishments of the IV accreditation level*

Third edition

Vinnytsia
Nova Knyha
2017

UDC 577.3(075.8)

BBC 28.071я73

M42

*Recommended by the Ministry of Health Care of Ukraine as a textbook
for the students of higher medical establishments of the IV accreditation level
(letter № 08.01-47/2735 by 25.12.2009)*

Authors:

A. V. Chalyi – Head of the Department of Medical and Biological Physics, Corresponding member of the Academy of Pedagogical Sciences of Ukraine, Dr. Sci. (Phys. & Math.), Professor; **Ya. V. Tsekhmister** – Deputy Rector of the National Medical University, Head of the Department of Biomedical Engineering, Dr. Sci. (Pedagogy), Cand. Sci. (Phys. & Math.), Professor; **B. T. Agapov** – Associate Professor, Dr. Sci. (Biology); **N. V. Stuchynska** – Associate Professor, Dr. Sci. (Pedagogy.); **A. V. Melenevska** – Associate Professor, Cand. Sci. (Biology); **M. I. Murashko** – Associate Professor, Cand. Sci. (Tech.); **N. F. Radchenko** – Associate Professor, Cand. Sci. (Chem.); **I. F. Margolych** – Associate Professor, Cand. Sci. (Phys. & Math.); **V. V. Pashchenko** – Associate Professor, Cand. Sci. (Pedagogy); **D. V. Lukomskyi** – Assistant Professor; **E. V. Zaitseva** – Assistant Professor, Cand. Sci. (Phys. & Math.); **E. N. Chaika** – Assistant Professor, Cand. Sci. (Phys. & Math.); **N. L. Grytsenko** – Assistant Professor.

Reviewers:

L. A. Bulavin – Head of the Department of Molecular Physics (Taras Shevchenko National University of Kyiv), Academician of the National Academy of Sciences of Ukraine, Dr. Sci. (Phys. & Math.), Professor.

N. S. Myroshnichenko – Head of the Department of Biophysics (Taras Shevchenko National University of Kyiv), Dr. Sci. (Biology), Professor.

V. I. Dotsenko – Professor of the Department of Medical Biology (National Stomatological Medical Academy), Dr. Sci. (Phys. & Math.), Professor.

L. Ya. Avrakhova – Head of the Department of Foreign Languages (National Medical University), Associate Professor.

M42 Medical and Biological Physics : textbook for students of higher medical institutions of the IV accreditation level / Chalyi A. V., Tsekhmister Ya. V., Agapov B. T. [et al.] ; Edited by A. Chalyi. – 3rd ed. – Vinnytsia : Nova Knyha, 2017. – 480 pp.

ISBN 978-966-382-639-4

The book is aimed at elucidating the most important aspects of the medical and biological physics in accordance with the program asserted by the Ministry of Health Care of Ukraine, and written for the students of higher medical institutions as well as for teachers, scientific researchers and all those readers interested in modern problems of the medical and biological physics.

UDC 577.3(075.8)

BBC 28.071я73

© Authors, 2013

© Authors, 2017

© Nova Knyha, 2017

ISBN 978-966-382-639-4

CONTENTS

PREFACE	9
MODULUS 1. Mathematical processing of medical and biological data .	12
LECTURE SECTION 1	12
CHAPTER 1.1. Mathematical methods of computing medical and biological information (principles of calculus).....	12
1.1.1. Elements of differential calculus	12
1.1.2. Elements of integral calculus	22
1.1.3. Elements of theory of differential equations.	28
CHAPTER 1.2. Fundamentals of the theory of probability and mathematical statistics	32
1.2.1. Fundamentals of the theory of probability.	32
1.2.2. Sampling method. Finding of characteristics of distribution.....	48
1.2.3. Elements of theory of correlation. Correlation and statistical dependence	50
PRACTICAL SECTION 1	52
PRACTICAL WORK 1.1. Elements of differential calculation.....	52
PRACTICAL WORK 1.2. Elements of integral calculation	66
PRACTICAL WORK 1.3. Elements of the theory of differential equations	75
PRACTICAL WORK 1.4. Elements of the probability theory.....	80
PRACTICAL WORK 1.5. Elements of mathematical statistics.....	86
MODULUS 2. Principles of biological physics	90
LECTURE SECTION 2	90
CHAPTER 2.1. Essential principles of biomechanics.....	90
2.1.1. Mechanical properties of biological tissues.....	92
2.1.2. Deformation of biological tissue	98
CHAPTER 2.2. Fluidity of viscous fluids in biological systems	100
2.2.1. Fluid viscosity	101
2.2.2. Blood viscosity.....	103
2.2.3. Viscoelastic properties of biological tissues.....	104
2.2.4. Basic equations of fluid flow.....	107

2.2.5. Criteria of mechanical affinity of flowing fluids	115
2.2.6. Pulse waves	117
CHAPTER 2.3. Mechanical oscillations.....	120
2.3.1. Harmonic oscillations and their principle parameters.....	120
2.3.2. Damped oscillations and aperiodic motion	124
2.3.3. Forced oscillations.....	127
2.3.4. Resonance phenomenon and auto-oscillations	128
2.3.5. Addition of harmonic oscillations.....	130
CHAPTER 2.4. Mechanical waves	133
2.4.1. Wave equation. Longitudinal and transverse waves	134
2.4.2. Wave energy flow. Umov vector	135
CHAPTER 2.5. Acoustics. Elements of hearing physics.	
Fundamentals of audiometry	136
2.5.1. Sound nature, its main characteristics (objective and subjective)	137
2.5.2. Weber-Fechner law.....	141
2.5.3. Ultrasound	144
2.5.4. Infrasound	146
CHAPTER 2.6. Structure and properties of biologic membranes	146
2.6.1. Passive transport of uncharged molecules.....	152
2.6.2. Passive transport of ions	155
2.6.3. Active transport.....	159
CHAPTER 2.7. Biological potentials.....	161
2.7.1. Nernst equilibrium membrane potential.....	163
2.7.2. Diffusion potential.....	164
2.7.3. Donnan's potential. Donnan's equilibrium.....	166
2.7.4. Stationary potential of Goldman-Hodgkin-Katz.....	169
2.7.5. Action potential. Mechanism of generation and propagation of nerve impulse	172
CHAPTER 2.8. Elements of dental material science	178
PRACTICAL SECTION 2.....	191
LABORATORY WORK 2.1. Measurement of hearing threshold by audiometric method.....	191
LABORATORY WORK 2.2. Study of elastic properties of biological tissues	198
LABORATORY WORK 2.3. Determination of dependence of liquid's surface tension coefficient on temperature and surface-active substances	204

LABORATORY WORK 2.4. Measurement of coefficient of viscosity	210
LABORATORY WORK 2.5. Measurement of concentration potential using compensation method	216
COMPUTER SECTION 2	222
COMPUTER PROGRAM 1. Haemodynamics	222
COMPUTER PROGRAM 2. Structure and transport properties of membranes	229
COMPUTER PROGRAM 3. Rest and action electrical potentials of membranes	244
 MODULUS 3. Principles of medical physics	 258
 LECTURE SECTION 3	 259
CHAPTER 3.1. Electrostatics	259
3.1.1. Major characteristics of electric field	259
3.1.2. Electric dipole	262
3.1.3. Dielectrics, dielectric polarization	264
3.1.4. Dielectric properties of biological tissues	268
3.1.5. Piezoelectric effect.....	270
CHAPTER 3.2. Continuous (direct) current. Conductivity of biological tissue. Alternating current and impedance of biological tissues	271
3.2.1. Characteristics of electric current	271
3.2.2. Conductivity of biological tissues and fluids.....	272
3.2.3. Action of electric current on living organism	275
3.2.4. Equation of electric oscillations	277
3.2.5. Forced electric oscillations, alternating current.....	279
3.2.6. Total resistance of alternating current circuit (impedance). Ohm's law for alternating current circuit.....	282
3.2.7. Impedance of biological tissues	284
3.2.8. Electromagnetic waves. Bias current	287
3.2.9. Maxwell's equations	289
3.2.10. Plane electromagnetic waves. Umov-Poynting vector....	291
3.2.11. Electromagnetic spectrum.....	293
CHAPTER 3.3. Magnetic field	296
3.3.1. Magnetic field in vacuum and its characteristics.....	296

3.3.2. Biot-Savart-Laplace's law	298
3.3.3. Action of magnetic field on movable electric charge. Ampere force, Lorentz force	299
3.3.4. Magnetic properties of substances	302
3.3.5. Magnetic properties of biological tissues, physical bases of magnetobiology.	306
CHAPTER 3.4. Medical electronic equipment.....	308
3.4.1. General information of medical electronic equipment (MEE).....	308
3.4.2. Classification of medical electronic equipment	309
3.4.3. MEE performance specification	310
CHAPTER 3.5. Physical principles of optical microscopy, refractometry and polarimetry	313
3.5.1. Geometrical optics.....	313
3.5.2. Ideal centered optical system.....	313
3.5.3. Optical microscopy.....	316
3.5.4. Light polarization.....	319
3.5.5. Light polarization at reflection and refraction	320
3.5.6. Polarization at double refraction in crystal.....	321
3.5.7. Light polarization at passing through an absorbing anisotropic substance	323
3.5.8. Plane-of-polarization rotation by an optically active substance	324
3.5.9. Interaction of light with substance. Light absorption.....	326
3.5.10. Light scattering	329
CHAPTER 3.6. Physical foundations of thermography, laws of heat radiation.....	331
3.6.1. Heat (temperature) radiation	331
3.6.2. Kirchhoff's law of spectral radiation	333
3.6.3. Planck's radiation law	334
3.6.4. Stefan-Boltzmann's law	335
3.6.5. Wien displacement law	336
3.6.6. Infrared radiation.....	338
3.6.7. Ultraviolet radiation.....	339
CHAPTER 3.7. Notations of quantum mechanics.....	339
3.7.1. The place of quantum mechanics in scientific system of body motion	339
3.7.2. De Broglie's hypothesis	341
3.7.3. Heisenberg's uncertainty relation	344

3.7.4. Fundamental equation of quantum mechanics – Schrödinger equation	345
3.7.5. Schrödinger equation for hydrogen atom.....	347
CHAPTER 3.8. Energy radiation and absorption	
by atoms and molecules.....	349
3.8.1. Atomic spectrum.....	349
3.8.2. Molecular spectra	351
3.8.3. Luminescence.....	355
3.8.4. Luminescence types.....	355
3.8.5. Photoluminescence. Stokes law.....	356
3.8.6. Luminescence mechanisms	358
3.8.7. Induced radiation.....	360
3.8.8. Equilibrium and inverse dependence.....	360
3.8.9. Structure and principle of laser's operation.....	362
3.8.10. Electronic paramagnetic resonance, nuclear magnetic resonance and their medico-biological application.....	363
3.8.11. Method of electron paramagnetic resonance.....	364
3.8.12. Method of nuclear magnetic resonance	368
CHAPTER 3.9. The nature and generation of X-ray beams	372
3.9.1. Deceleration X-ray radiation	374
3.9.2. Characteristic X-ray radiation, its nature	375
3.9.3. Radioactivity, its properties	377
3.9.4. Principle law of radioactive decay, half-life period, activity.....	380
3.9.5. The rules of shift, spectra specific feature at the time of radioactive decay	384
3.9.6. Exposure dose, its rate, units	387
3.9.7. Absorbed dose, its rate, units.....	389
3.9.8. Equivalent dose, its rate, units.....	391
3.9.9. Dosimeters.....	393
3.9.10. Primary physical mechanisms of interaction of X-ray radiation with substance	395
3.9.11. Primary mechanisms of radioactive radiation and particle flux effect on substance.....	399
PRACTICAL SECTION 3	403
LABORATORY WORK 3.1. Operation of electrocardiograph	403
LABORATORY WORK 3.2. Operation of rheograph.....	411
LABORATORY WORK 3.3. Study of electrical impedance of biological tissues	419

PRACTICAL LESSON. Interaction of electromagnetic field with biological tissues	425
LABORATORY WORK 3.4. Physiotherapeutic equipment operation.....	435
LABORATORY WORK 3.5. Study of microscope and measurement of microobjects	446
LABORATORY WORK 3.6. Study of solution concentration by refractometric method	450
LABORATORY WORK 3.7. Study of solution concentration by polarimetric method.....	454
LABORATORY WORK 3.8. Study of laser operation.....	460
LABORATORY WORK 3.9. Measurement of linear damping coefficient of gamma radiation	464
INDEX OF SUBJECTS	471
INDEX OF NAMES	474

Навчальне видання

Чалий Олександр Васильович
Цехмістер Ярослав Володимирович
Агапов Борис Терентійович та ін.

Медична та біологічна фізика

Підручник (англійською мовою)

Відповідальний редактор: *О. В. Марчук*
Технічний редактор: *Ю. П. Тертун*
Комп'ютерна верстка: *Г. А. Пешков*

Підписано до друку 28.04.17. Формат 60×84/16. Папір офсетний.
Гарнітура Таймс. Друк офсетний. Ум. друк. арк. 28,00. Зам. № 903.

ПП "Нова Книга"
21029, м. Вінниця, вул. М. Ващука, 20
Свідоцтво про внесення суб'єкта видавничої справи
до Державного реєстру видавців, виготівників
і розповсюджувачів видавничої продукції
ДК № 2646 від 11.10.2006 р.
Тел. (0432) 56-01-87. Факс 56-01-88
E-mail: info@novaknyha.com.ua
www.novaknyha.com.ua