FACULTY OF
MECHANICAL ENGINEERING

THE OFFER STUDIES FOR FOREIGN
STUDENTS IN THE FRAMEWORK OF THE
ERASMUS PROGRAMME:

BIOMEDICAL ENGINEERING

THE OFFER OF SUBJECTS FOR AREA OF STUDY:
BIOMEDICAL ENGINEERING

(MINIMUM NUMBER OF HOURS AND ECTS)

<table>
<thead>
<tr>
<th>Offer of Subjects in English</th>
<th>Numbers of hours</th>
<th>ECTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Automated Medical Diagnosis System</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>2. Biophysics</td>
<td>45</td>
<td>3</td>
</tr>
<tr>
<td>3. Computer Graphics</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>4. Entrepreneurship and Quality Control</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>5. Heat and Flow Problems in Biological Systems</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>6. Implants and Artificial Organs</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>7. Mechanics and Strength of Materials</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>8. Test Methods for Biomaterials</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>9. Numerical Methods</td>
<td>45</td>
<td>4</td>
</tr>
<tr>
<td>10. Programming Languages</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>11. Mobility Rehabilitation</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>12. Sensors and Non-Electrical Quantities Measurement</td>
<td>60</td>
<td>3</td>
</tr>
</tbody>
</table>
AUTOMATED MEDICAL DIAGNOSIS SYSTEMS

Course code: 6.9-WM-IB-D-2

Type of course: Compulsory

Language of instruction: Polish/English

Director of studies: Dr inż. Katarzyna Arkusz

Name of lecturer: Dr inż. Katarzyna Arkusz

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>Grade VI</td>
<td>5</td>
</tr>
<tr>
<td>Laboratory</td>
<td>30</td>
<td>Grade</td>
<td></td>
</tr>
</tbody>
</table>

COURSE AIMS:

- familiarize students with the methods of data collection used in medical diagnosis and the development of skills in the pre-processing of medical data
- familiarize students with the architecture of medical data warehouse and development of skills in the designing and application of analytical systems for medical data
- familiarize students with the methods used to build automated medical diagnosis systems and development of skills allowing the use of decision support and data mining algorithms

PREREQUISITES:

medical imaging techniques, digital signal processing, statistical methods of data analysis

COURSE CONTENTS:

Methods of data acquisition and processing for automated medical diagnosis.


methods. Medical decision support systems - case studies. Integration of decision support systems with picture archiving and communication systems.

TEACHING METHODS:
Lectures - conventional lecture, discussion
Laboratory - laboratory exercises, case studies

LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>The student can name and explain image segmentation methods, he can apply these methods to extract objects from images and compute their morphometric parameters.</td>
</tr>
<tr>
<td>K_W23</td>
<td>The student knows and can explain methods of outlier detection and missing data handling.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can name and define feature selection algorithms and he can apply these methods for medical data.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can characterize components of a data warehouse.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can design and build multidimensional data structure using star schema.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can explain how the expert system is built and he knows methods of knowledge representation.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can interpret the results of data analysis and write the report.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can name and define data mining techniques used for association and sequence discovering, clustering and classification.</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student know how to apply learned data mining methods to explore medical data.</td>
</tr>
</tbody>
</table>

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>The main condition to get a pass is positive grade in written test conducted once per semester.</td>
</tr>
<tr>
<td>K_U27</td>
<td>Grade based on laboratory classes. A passing grade in laboratory part comprises positive evaluation of reports based on each laboratory class, and preparation for classes.</td>
</tr>
</tbody>
</table>

final evaluation = 0.5 assessment of the lecture + 0.5 assessment of the laboratory.
STUDENT WORKLOAD:

Full-time studies

The student workload of 150 hours (6 ECTS), including contact hours 60 hours, consultations 15 hours, preparing for classes 30 hours, preparing for exam 15 hours, preparing of control work and reports 15 hours, reading literature 15 hours.

RECOMMENDED READING:


OPTIONAL READING:

 COURSE AIMS:  
The aim of the course is to teach the foundations of biophysics to the extent which is both necessary and useful in biomedical engineering.

PREREQUISITES:
Basic Physics Course

COURSE CONTENTS:
1) Static forces: equilibrium considerations for the human body, skeletal muscles, levers, the elbow, the hip,
2) Friction: standing and moving on an incline, friction at joints,
3) Translational motion: jump – maximum standing and running jump and vault poling, energy considerations,
4) Angular motion: running: running on a curved track, pendulum and walking, speed of running, model of walking and running,
5) Elasticity and strength of materials: longitudinal stretch and compression, spring, bone fracture: energy and impulse force considerations, injuries in car accidents, osteoarthritis and exercise,
6) Fluids: force and pressure in fluids, Pascal’s principle, hydrostatic skeleton, Archimedes’ principle, power required for floating, surface tension,
7) Motion of fluids: Bernoulli’s equation, viscosity and Poiseuille law, turbulent flow, circulation of the blood, blood pressure, control of blood flow, turbulence in the blood, arteriosclerosis and blood flow, power produced by the heart, blood pressure measurement,
8) Heat and Kinetic Energy: Heat and hotness, kinetic theory of matter, basic definitions, transfer of heat, transfer of molecules by diffusion, diffusion through membranes, the respiratory system, surfactants and breathing, diffusion and contact lenses,
9) Thermodynamics: first and second laws of thermodynamics, thermodynamics of living systems, information and the second law,
10) Heat and life: energy requirements of people, energy from food, regulation of body temperature, control of skin temperature, evaporation, resistance to cold,
11) Electricity: nervous system, electrical potential in the axon, action potential, synaptic transmission, electricity in plants, electricity in the bones, electric fish, heart as an electric device,
12) Optics: vision, nature of light, structure of the eye, accommodation, lens system of the eye, resolving power of the eye, corrective lenses,
13) Atomic physics: the atom, spectroscopy, quantum mechanics, electron microscope, X-rays, Computed Tomography, lasers,
14) Nuclear physics: the nucleus, magnetic resonance imaging, radiation therapy, food preservation by radiation, isotopic tracers, laws of physics and life.

TEACHING METHODS:
Lecture, biophysics laboratory

LEARNING OUTCOMES:
The student is able to describe the physical bases of the functioning of living organisms (K_W03, K_W08, K_W10), is able to explain the functioning of the basic systems of the human body in terms of physics (K_W03, K_W08, K_W10, K_W16). The student is aware of the limitations of the human and animal bodies following from the laws of physics (K_W03, K_W08). He or she is able to perform basic experiments of the biophysics laboratory (K_U02, K_U06).

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:
Final test, the preparation of 4 laboratory reports

STUDENT WORKLOAD:
- Participation in the lectures – 30h
- Preparation for the lectures – 15h
- Participation in the laboratory – 15h
- Preparation for the laboratory – 15h

RECOMMENDED READING:

OPTIONAL READING:
**COMPUTER GRAPHICS**

Course code: 6.9-WM-IB-P-30  
Type of course: Compulsory  
Language of instruction: Polish/English  
Director of studies: Dr inż. Przemysław Jacewicz  
Name of lecturer: Dr inż. Przemysław Jacewicz

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>Teaching hours per semester</th>
<th>Teaching hours per week</th>
<th>Semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>2</td>
<td>III</td>
<td>Grade</td>
<td>5</td>
</tr>
<tr>
<td>Laboratory</td>
<td>30</td>
<td>2</td>
<td></td>
<td>Grade</td>
<td></td>
</tr>
</tbody>
</table>

**COURSE AIMS:**  
To make students aware of contemporary computer graphics (CG) technology, including the CG applications and SDKs. Understanding of CG related terminology and basic functionalities of CG systems.

**PREREQUISITES:**  
Introduction to computer science

**COURSE CONTENTS:**  
*Fractals in computer graphics,* theory and applications.  
*Photo-realistic techniques.* Ray Tracing and Radiosity, Environmental Mapping and Image-Based Rendering. Stereoscopic rendering.
Review of available software tools for computer graphics.

METHODS OF EDUCATION:
Laboratory tasks are meant to be solved in a given time. All tasks cover design, creative use of digital media within the CG environments including CG applications and SDKs. Lecture is generally based on the given references, but it includes the most recent information from conferences and events related to CG.

LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>Learning outcomes</th>
<th>Field specific learning outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Engineering</td>
</tr>
<tr>
<td>Image processing</td>
<td>Raster imaging</td>
</tr>
<tr>
<td></td>
<td>Knowledge of image processing algorithms, raster imaging and pre-press skills of image manipulation and enhancement. DTP skills.</td>
</tr>
<tr>
<td>Vector graphics</td>
<td>CAD design</td>
</tr>
<tr>
<td></td>
<td>Knowledge of 2D and 3D image models, creative skills. CAD skills.</td>
</tr>
<tr>
<td>Scientific</td>
<td>Infographics and media design</td>
</tr>
<tr>
<td>visualization</td>
<td>Knowledge of information design and infographics. Visualisation skills.</td>
</tr>
</tbody>
</table>

Student has the following knowledge and competences

<table>
<thead>
<tr>
<th>Type of activity</th>
<th>Form of education</th>
<th>Output</th>
<th>Symbols of discipline specific learning outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>Discussion</td>
<td>Project</td>
<td>T1A_W04 T1A_K02 T1A_W07</td>
</tr>
<tr>
<td>Lab+ consulting</td>
<td>Examples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td>Discussion</td>
<td>Project</td>
<td>T1A_W07 T1A_U07</td>
</tr>
<tr>
<td>Lab</td>
<td>Examples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture+ consulting</td>
<td>Discussion</td>
<td>Project</td>
<td>T1A_U02</td>
</tr>
<tr>
<td>Lab</td>
<td>Examples</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lecture</td>
<td>Examples</td>
<td>Project</td>
<td>T1A_U07</td>
</tr>
<tr>
<td>Lab</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
VERIFICATION OF LEARNING OUTCOMES AND CONDITIONS OF CLASSIFICATION:

Lecture – classification based upon positive mark obtained during colloquium or exam in form suggested by the teacher.

Lab - classification based upon positive marks obtained during the course. Final mark is a weighted sum of all marks obtained for the given lab tasks.

STUDENT WORKLOAD:

15 two-hour labs, where students receive tasks to be done during the course, 15 two-hour lectures.

Consultations: 30 hrs lect, 30 hrs lab = 60h
Preparation: 10 h
Literature research: 10h
Preparation of report: 10h
Tasks received during the labs that require additional time (writing code, rendering animation, etc.): 25h
Preparation for colloquium or exam: 10h
Total 125h = 5 ECTS

RECOMMENDED READING:


OPTIONAL READING:


REMARKS:

Students uses at labs supplementary materials obtained from the teacher and from the internet resources.
# ENTREPRENEURSHIP AND QUALITY CONTROL

Course code: 6.9-WM-IB-P-59  
Type of course: Optional  
Language of instruction: Polish/English  
Director of studies: Dr inż. Agnieszka Kaczmarek-Pawelska  
Name of lecturer: Dr inż. Agnieszka Kaczmarek-Pawelska

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>Grade</td>
<td>4</td>
</tr>
<tr>
<td>Project</td>
<td>30</td>
<td>Grade</td>
<td></td>
</tr>
</tbody>
</table>

## COURSE AIMS:

Course has specific goals:

1. To familiarize students with the issues and challenges facing entrepreneurs in emerging markets
2. To provide an understanding of the human and organizational contexts in which young entrepreneur will be working and the skills he will need to be productive and successful
3. To explore how to put the scientific, technical and organizational knowledge learned at University to work in today organizations.

## COURSE CONTENTS:


TEACHING METHODS:
Lecture and class discussion. Homework with Business Plan preparing. Reading.

LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>In the field of technical sciences</th>
<th>Knowledge, skills, competence</th>
<th>Symbols of discipline specific learning outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>The student has a specialistic knowledge in the field of the chosen studies specialization</td>
<td>T1A_W03, T1A_W04, T1A_W05, T1A_W06, T1A_W07, T1A_W08, T1A_W11</td>
</tr>
<tr>
<td>K_W13</td>
<td>The student has a basic knowledge necessary to understand the social, economic, legal, environmental and other non-technical considerations of engineering activities, understands the application of his/her knowledge in engineering practice, knows the rules associated with safety and ergonomics</td>
<td>T1A_W02, T1A_W07</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can use a specialistic knowledge to organize the implementation of simple tasks relevant to the field of the chosen specialization</td>
<td>T1A_U12, T1A_U13, T1A_U14, T1A_U15, T1A_U16</td>
</tr>
<tr>
<td>K_K06</td>
<td>The student can think and act in a creative and enterprising way</td>
<td>T1A_K06</td>
</tr>
</tbody>
</table>

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:
The verification methods for learning outcomes are presented in the table below.

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
<th>Symbols of discipline specific learning outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W13</td>
<td>The student has a basic knowledge necessary to understand the social, economic, legal, environmental and other non-technical considerations of engineering activities, understands the application of his/her knowledge in engineering practice, knows the rules associated with safety and ergonomics</td>
<td>T1A_W02, T1A_W07</td>
</tr>
</tbody>
</table>
The student has a specialistic knowledge in the field of the chosen studies specialization

The student can use a specialistic knowledge to organize the implementation of simple tasks relevant to the field of the chosen specialization

The student can prepare and present an oral presentation concerning specific issues of the field of Biomedical Engineering

End quiz for lecture and own made Project (Business plan) presentation evaluation

For note 3 - only basic, standard knowledge from lectures
For note 4 - knowledge from readings and own experience
For note 5 - own experience, readings, participation in class discussions, use of modern methods like QFD, Prince 2 etc.

STUDENT WORKLOAD:

Student workload is about 100 hours (4 ECTS) including prepare to lessons - 60 hours, 20 hours preparing to final presentation and 20 hours participating lessons

RECOMMENDED READING:


OPTIONAL READING:

HEAT AND FLOW PROBLEMS IN BIOLOGICAL SYSTEMS

Course code: 6.9-WM-IB-P-51
Type of course: Compulsory
Language of instruction: Polish/English
Director of studies: Dr inż. Tomasz Klekiel
Name of lecturer: Dr inż. Agnieszka Mackiewicz

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per week</th>
<th>teaching hours per semester</th>
<th>Semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-time studies</td>
<td></td>
<td></td>
<td></td>
<td>Grade</td>
<td>4</td>
</tr>
<tr>
<td>Lecture</td>
<td>30</td>
<td>2</td>
<td>V</td>
<td>Grade</td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>15</td>
<td>1</td>
<td></td>
<td>Grade</td>
<td></td>
</tr>
<tr>
<td>Project</td>
<td>15</td>
<td>1</td>
<td></td>
<td>Grade</td>
<td></td>
</tr>
</tbody>
</table>

COURSE AIMS:
Students are familiar to specific language of technical physic, methods of describing real processes, can create and use models of simple fluid flows and energy transformations. Students can solve simple technical problems in bio-engineering.

PREREQUISITES:
Course of Basic Technical Physic

COURSE CONTENTS:

Project exercisers:
1. Systems of Units
2. Conservation Laws in Fluid Flows
3. Properties of Gases – Clapeyron’s Law
4. Heat Transfer
5. Energy Balance for some Processes
6. Molier Psychrometric Chart for Air Humidification
7. Combustion

Laboratory exercises:
1. Measure of Temperature
2. Measure of Pressure
3. Enthalpy of Combustion – Heating Value
4. Laminar and Turbulent Flow – visualization
5. Rheological Properties of Fluids
6. Heat Exchanger

LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>The student has a specialistic knowledge in the field of the chosen studies specialization</td>
</tr>
<tr>
<td>K_U14</td>
<td>The student can select and apply the proper calculation methods to solve simple research problems in the field of Biomedical Engineering</td>
</tr>
<tr>
<td>K_U27</td>
<td>The student can use a specialistic knowledge to organize the implementation of simple tasks relevant to the field of the chosen specialization</td>
</tr>
</tbody>
</table>

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

The verification methods for learning outcomes are presented in the table below.

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>Credit based on written test. A passing grade in the lecture part of the course is determined by three written responses to questions about the theoretical aspects of the subject.</td>
</tr>
<tr>
<td>K_U14</td>
<td>Grade based on laboratory classes. A passing grade in laboratory part comprises positive evaluation of reports based on each laboratory class, attendance and initiative on the part of the student.</td>
</tr>
</tbody>
</table>
Grade based on project. Grade on project is determined on the basis of accuracy of selection techniques and methods used and the quality of the project.

For grade course - lectures - Student must pass written quizze – enough 3 positive answers of 5 questions.
For Exercises – Student prepare correct written solution for given set of problems
For Laboratory – Grad by systematic Class participation

STUDENT WORKLOAD:
Student workload is about 100 hours (4 ECTS) including prepare to lessons - 60 hours, 20 hours preparing to exam and 20 hours participating lessons

RECOMMENDED READING:
2. A Heat Transfer Textbook, 4th edition John H. Lienhard IV, Professor, University of Houston John H. Lienhard V, Professor, Massachusetts Institute of Technology

OPTIONAL READING:
**Implants and Artificial Organs**

Course code: 6.9-WM-IB-P-27
Course type: Compulsory
Language of instruction: Polish/English

Director of studies: Prof. dr hab. inż. Romuald Będziński
Prof. dr hab. inż. Romuald Będziński

Name of lecturer: Dr inż. Katarzyna Arkusz

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>Grade</td>
<td>3</td>
</tr>
</tbody>
</table>

**COURSE AIMS:**
Challenges and opportunities in replacing of failure organs by implants or artificial organs. Issue of organs and tissues transplantation. Significance of surgery techniques for saving patients health and life. Problems in implantology.

**PREREQUISITES:**
Basics: anatomy, physiology, immunology, pathophysiology, toxicology and chemistry.

**COURSE CONTENTS:**

**TEACHING METHODS:**
Audiovisual lectures, literature analysis, students presentations, meeting/lecture with surgeon.

**LEARNING OUTCOMES:**
<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W02, K_W12</td>
<td>The student has knowledge in the field of medicine structure and organization, diagnostic and treatment methods, the basic anatomy, transplantation and implant techniques, needed to formulate and solve simple engineering tasks in Biomedical Engineering</td>
</tr>
<tr>
<td>K_U10</td>
<td>The student can use terminology relevant to the field of Biomedical Engineering</td>
</tr>
<tr>
<td>K_U06</td>
<td>The student can prepare and present an oral presentation concerning specific issues of the field of Biomedical Engineering</td>
</tr>
</tbody>
</table>

**LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:**

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W02, K_W12</td>
<td>Graduate – written verification of theoretical knowledge.</td>
</tr>
<tr>
<td>K_U06, K_U10</td>
<td>Verify of knowledge in students oral presentation concerning specific issues</td>
</tr>
</tbody>
</table>

**STUDENT WORKLOAD:**

The student workload of 75 hours (3 ECTS), including work in the auditorium 30 hours, preparing for grade 30 hours, literature analysis: 25 hours

**RECOMMENDED LITERATURE:**

4. Biomechanika Tom 5 Problemy Biocybernetyki i Inżynierii Biomedycznej.
MECHANICS AND STRENGTH OF MATERIALS

Course code: 6.9-WM-IB-P-22
Type of course: Compulsory
Language of instruction: Polish/English
Director of studies: Prof. dr hab. inż. Romuald Będziński
Name of lecturer: Prof. dr hab. inż. Romuald Będziński
Mgr inż. Ewa Paradowska

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per semester</th>
<th>teaching hours per week</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>2</td>
<td>II</td>
</tr>
<tr>
<td>Class</td>
<td>15</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Laboratory</td>
<td>15</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Course Aim:**
The aim of the course is to familiarize students with problem-solving methodology based on the laws of mechanics and analysis of the strength found in mechanical engineering.

**Prerequisites:**
General knowledge of differential calculus, integral calculus, operations on the vectors.

**Course Contents:**

**Lecture**
The basic notions and the principles of statics. Plane and spatial arrangement of convergent forces. Equilibrium plane and spatial arrangement of convergent forces. The basis of reduction of arrangement forces. The plane arrangements of strengths without friction (reduction of plane arrangement of forces, equilibrium of any plane arrangement of forces equilibrium of an arrangement consisting of rigid bodies). Friction and friction laws. Arbitrary spatial arrangement of forces. Reduction of spatial arrangement of forces. Basic notions of strength of materials. Objectives and tasks of the strength of materials. The types of loads. Types of deformations. Internal forces, de Saint Venant principle. Tension and compression of materials. Hooke's law, Young's modulus, Poisson's ratio. Principle of superposition, allowable stress, the safety factor. Statically determinate and statically

Class
Solving classes based on lectures and source materials, in two parts: mechanics (vectors, constraints, reactions, coplanar forces: concurrent force systems, arbitrary force systems, determination of resultant moment, couples of forces, calculation of values of reactions in bearings of beams, calculation of internal forces in truss members of plane trusses) and strength of materials (tension, compression, shearing, bending, torsion).

Laboratory
Main topics: methods of measurement of hardness (Brinell, Rockwell and Vickers), static tensile metals, impact bending tests, determination of the static coefficient of friction, determination of the characteristics and stiffness of springs, dynamic balancing of machine parts with balancer.

TEACHING METHODS:
Lectures with audiovisual aids. Solving classes. Working with the book. Group work in laboratory classes.

LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W08</td>
<td>The student has an elementary knowledge of engineering graphics, mechanics, the principles of workpiece design and mechanical equipment constructions, design of devices and production systems, as an engineering discipline relevant to the field of Biomedical Engineering</td>
</tr>
<tr>
<td>K_U02</td>
<td>The student can plan experiments and engineering activities, elaborate the results of testing and engineering tasks, draw conclusions, formulate and justify opinions in technical issues</td>
</tr>
<tr>
<td>K_U01</td>
<td>The student can obtain information from literature, databases and other sources, able to integrate the information, make their interpretation, as well as draw conclusions and formulate and opinions</td>
</tr>
<tr>
<td>K_K02</td>
<td>The student is aware of and understands the importance and impact of non-technical aspects of engineering, including its impact on the environment, and the responsibility for decisions consequently related with these aspects</td>
</tr>
<tr>
<td>K_K06</td>
<td>The student can think and act in a creative and enterprising way</td>
</tr>
</tbody>
</table>
LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:
The verification methods for learning outcomes are presented in the table below.

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W08; K_K02</td>
<td>Written exam. A passing grade in the lecture part of the course is determined by five written responses to questions about the theoretical aspects of the subject.</td>
</tr>
<tr>
<td>K_U01, K_K06</td>
<td>A passing grade in laboratory part comprises positive evaluation of reports based on each laboratory class, attendance and initiative on the part of the student.</td>
</tr>
<tr>
<td>K_U02</td>
<td>Positive evaluation of the test.</td>
</tr>
</tbody>
</table>

**Lecture**
- Exam

**Class**
- Grade

**Laboratory**
- Grade (received positive ratings of reports carried out laboratory)
- Evaluation of the course is getting positive ratings from all forms: Lecture, Class, Laboratory
- The final grade received by the student is the arithmetic mean of the above grades.

**STUDENT WORKLOAD:**

The student workload is 127 hours (5 ECTS), including work in the auditorium: 60 hours, exam: 2 hours, consultations: 15 hours, preparing for classes: 25 hours, revising for exam: 10 hours, revising for tests: 10 hours, preparing study reports: 5 hours.

**RECOMMENDED READING:**

1. Niezgodziński M. E., Niezgodziński T., Wytrzymałość materiałów, 1979 PWN wyd. XI.

OPTIONAL READING:
8. Rżysko J., Statyka i wytrzymałość materiałów, 1979 PWN.
**TEST METHODS FOR BIOMATERIALS**

**Course code:** 6.9-WM-IB-P-20  
**Type of course:** Compulsory  
**Language of instruction:** Polish/English  
**Director of studies:** Dr inż. Agnieszka Kaczmarek-Pawelska  
**Name of lecturer:** Dr inż. Agnieszka Kaczmarek-Pawelska  
**Mgr inż. Marta Nycz**

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per semester</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Project</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

**Course Aims:**  
The aim of the course is to acquire skills and competencies in the practical use of chemical and electrochemical methods of surface layer formation and instrumental testing methods of their properties and degradation in tissue environment.

**Prerequisites:**  
Knowledge of chemistry, electrochemistry and biomaterials.

**Course Content:**  

**Teaching Methods:**  
Conventional lectures with audiovisual aids. Working with professional literature. Individual and team work on laboratory exercises.
LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>The student has an elementary knowledge of basic methods and algorithms for testing biomaterials using electrochemical methods</td>
</tr>
<tr>
<td>K_W11</td>
<td>The student knows the basic method for selecting a set of analytical techniques to the study of biomaterials</td>
</tr>
<tr>
<td>K_U13</td>
<td>The student knows how to use the software used for electrochemical studies</td>
</tr>
<tr>
<td>K_U19</td>
<td>The student can analyze signals and interpret polarization characteristics</td>
</tr>
<tr>
<td>K_U24</td>
<td>The student is able to suggest improvements to existing technologies, is able to able to assess the usefulness of routine methods and techniques related to the scope of Biomedical Engineering</td>
</tr>
<tr>
<td>K_K02</td>
<td>The student is aware of the benefits of advanced polarization techniques and materials research in the field of medicine</td>
</tr>
</tbody>
</table>

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W11, K_W23</td>
<td>The written exam</td>
</tr>
<tr>
<td></td>
<td>A passing grade in the lecture part of the course is determined by written responses to questions about the theoretical aspects of the subject.</td>
</tr>
<tr>
<td>K_U13, K_U19, K_U24, K_K02</td>
<td>Project: Grade</td>
</tr>
<tr>
<td></td>
<td>Grade based on accuracy of selection techniques and methods the student uses and the quality of the project</td>
</tr>
</tbody>
</table>

Lecture: Exam

Laboratory: Grade

STUDENT WORKLOAD:

The student workload of 102 hours (4 ECTS), including work in the consultations: 60 hours, exam: 2 hours, preparing for grade: 20 hours, preparing a project: 15 hours, familiarization with literature sources: 5 hours.
RECOMMENDED READING:
NUMERICAL METHODS

Course code: 6.9-WM-IB-P-38

Type of course: Compulsory

Language of instruction: Polish/English

Director of studies: Dr inż. Tomasz Klekiel

Name of lecturer: Dr inż. Tomacz Klekiel

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>teaching hours per semester</th>
<th>teaching hours per week</th>
<th>Semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>15</td>
<td>1</td>
<td>II</td>
<td>Grade</td>
<td>4</td>
</tr>
<tr>
<td>Laboratory</td>
<td>30</td>
<td>2</td>
<td>II</td>
<td>Grade</td>
<td></td>
</tr>
</tbody>
</table>

COURSE AIM:

• familiarize students with the basic aspects of numerical mathematics to solve common problems,
• familiarize students with the basic algorithms to solve these tasks,
• education students' ability to use Matlab to issues of engineering calculations.

ENTRY REQUIREMENTS:

Mastery of knowledge and skills in the subject Elements of Algebra and Mathematical Analysis

COURSE CONTENTS:


**Laboratory:** Environmental engineering calculations Matlab (system resources, environmental programming, graphical tools, and editing). Floating-point arithmetic (numerical experiments, errors of calculation procedures and the accumulation and transfer of numerical instability). Solving equations (equations of nonlinear systems of linear equations, systems of a van der Monde, testing algorithms, Newton and Newtona_Raphsona). Data Processing (interpolation method, method of approximation of mean method, spectral analysis, Fast Fourier Transform). Ordinary differential equations, initial and boundary issues. Elementary finite element techniques and testing them on the basis of certain issues.

**TEACHING METHODS:**

Lecture: Lecture conventional

Laboratory: laboratory exercises and accounting

**LEARNING OUTCOMES:**

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W05</td>
<td>Student who has completed the subject understands the limitations of numerical algorithms related to floating-point arithmetic.</td>
</tr>
<tr>
<td>K_W19</td>
<td>Knows the basic numerical methods for solving nonlinear equations and systems of linear equations and differential, know the basic techniques of interpolation, approximation and numerical integration.</td>
</tr>
<tr>
<td>K_U25</td>
<td>Able to take advantage of the functionality of MATLAB environment to basic numerical, graphical representation of the results.</td>
</tr>
<tr>
<td>K_U25</td>
<td>Able to choose of these algorithms which is the most advantageous to solve a specific numerical problem.</td>
</tr>
</tbody>
</table>

**LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:**

<table>
<thead>
<tr>
<th>The reference to the effects of field of study</th>
<th>The method of checking the effect of education</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W05, K_W19</td>
<td>Grading lecture The pass of the lecture is to provide a positive evaluation of the test.</td>
</tr>
<tr>
<td>K_U25</td>
<td>Grading of the laboratory Evaluation of the laboratory is based on checking student prepare for classes and their implementation, and reports / reports resulting from the implementation of all measures to be implemented exercise.</td>
</tr>
</tbody>
</table>
Learning outcomes 1 and 2: the final test to evaluate the content of the lecture; Learning outcomes 3 and 4: Final test for assessment based on problem-solving tasks using computer and Matlab environment.

STUDENT WORKLOAD:

The student workload is 100 hours (4 credits), including contact hours: 45 hours, 15 hours consultation, preparation for classes: 15 hours, preparing to test: 5 hours, preparation of audit work, reports, reports, etc.: 20 hours, familiarization with literature sources 15 hours.

RECOMMENDED READING:


OPTIONAL READING:

PROGRAMMING LANGUAGES

Course code: 6.9-WM-IB-P-32
Type of course: Compulsory
Language of instruction: Polish/English
Director of studies: Dr inż. Katarzyna Arkusz
Name of lecturer: Dr inż. Katarzyna Arkusz

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>Lecture</th>
<th>Laboratory</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>30</td>
<td>Grade</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Full-time studies**

**COURSE AIM:**
The aim is to acquire the skills and competencies of the structured programming in C language and the basics of programming in C++

**ENTRY REQUIREMENTS:**
Basic knowledge of information technology.

**COURSE CONTENTS:**

Indicators: declaration, initialization, and a reference to the address indicated value. Solid indicators and indices for fixed: properties and application range. Pointers to functions: examples of applications. Formal parameters of the function which is a pointer to a function.

Introduction to object-oriented programming. The concept of class as an abstract data type, storage methods, encapsulation. Basics of inheritance. Polymorphism as a mechanism to support object-oriented programming.

TEACHING METHODS:

Lecture: Lecture in the form of a multimedia presentation
Laboratory: Exercises and calculations

LEARNING OUTCOMES:

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W07</td>
<td>Has ordered knowledge of the methods and techniques of programming.</td>
</tr>
<tr>
<td>K_U17</td>
<td>Able to formulating and solving tasks related to biomedical engineering, to see the system aspects, economic, legal and social with the use of computer technology.</td>
</tr>
</tbody>
</table>

LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:

<table>
<thead>
<tr>
<th>The reference to the effects of field of study</th>
<th>The method of checking the effect of education</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W07</td>
<td>Grading lecture</td>
</tr>
<tr>
<td></td>
<td>The pass of the lecture is to provide a positive evaluation of the test.</td>
</tr>
<tr>
<td>K_U17</td>
<td>Grading of the laboratory</td>
</tr>
<tr>
<td></td>
<td>Evaluation of the laboratory is based on checking student prepare for classes and their implementation, and reports / reports resulting from the implementation of all measures to be implemented exercise.</td>
</tr>
</tbody>
</table>

Lecture - provided credit is to get a positive evaluation of the test.
Laboratory - provided credit is to pass all the laboratory.

STUDENT WORKLOAD:

The student workload is 100 hours (4 credits), including contact hours: 60 hours, preparation for classes: 20 hours, preparing for test: 10 hours, sources familiar with the literature: 10 hours

RECOMMENDED READING:


OPTIONAL READING:
MOBILITY REHABILITATION

Course code: 6.9-WM-IB-P-57
Type of course: Compulsory
Language of instruction: Polish/English
Director of studies: Dr inż. Tomasz Klekiel
Name of lecturer: Dr inż. Tomasz Klekiel

<table>
<thead>
<tr>
<th>Form of instruction</th>
<th>Number of teaching hours per semester</th>
<th>Form of receiving a credit for a course</th>
<th>Number of ECTS credits allocated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>Exam</td>
<td>4</td>
</tr>
<tr>
<td>Project</td>
<td>30</td>
<td>Grade</td>
<td></td>
</tr>
</tbody>
</table>

COURSE AIM:
The aim of the course is presentation the basics of rehabilitation engineering in designing of medical equipment, rehabilitation devices and basic methods of rehabilitation.

ENTRY REQUIREMENTS:

COURSE CONTENTS:
**Lecture:** Introduction to rehabilitation engineering, history of rehabilitation, basic definitions,, the phase of the rehabilitation process. The role of rehabilitation engineering, upper limb prosthesis, prosthetic hand, forearm prosthesis, prosthetic legs, gait kinematics, locomotion, prosthetic legs, prosthetic feet, prosthetic dynamic foot, lower leg prosthesis, prosthetic thigh, hip prostheses, legs orthotics, limbs orthotics. Functional stimulation of the lower limbs, functional electrical stimulation, supply orthotic upper limbs, upper limbs orthosis, spine orthotics equipment, aids, Sensor technology in the devices for rehabilitation, rehabilitation devices, measurements of muscle tension, non-electrical measurements in medical diagnostics, sensors in modern prosthetics and orthotics. Innovative solutions smart rehabilitation devices.

**Project:** An introduction to rehabilitation engineering, analysis methods and techniques for rehabilitation of the locomotion system selected, the principles of the planning process of rehabilitation, medical consultation, conceptual design of mechatronic devices supporting the rehabilitation process of a particular condition, the assessment of solutions in terms of the effectiveness of the rehabilitation process, the technical capabilities of the device, the conditions and rules for the production of medical and rehabilitation equipment, machine control system design, selection of actuators and sensors, preparation of technical
documentation, assembly drawing machine, drawings, control algorithms, evaluation of projects.

**TEACHING METHODS:**
Lecture conventional design method, discussion, work with the literature, group work.

**LEARNING OUTCOMES:**

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>Knows the basic equipment used in the process of rehabilitation, has a basic knowledge of the development of modern techniques of rehabilitation, has information in the field of rehabilitation equipment recycling, and has a basic knowledge of the problems of people with disabilities</td>
</tr>
<tr>
<td>K_U05</td>
<td>has the ability to organize work in a project team</td>
</tr>
<tr>
<td>K_U18</td>
<td>Apply principles of safety rehabilitation equipment and prosthetic devices</td>
</tr>
<tr>
<td>K_U20</td>
<td>Able to choose a design solution in terms of cost performance, formulate a conceptual design for the chosen design of rehabilitation equipment and in accordance with a preset specification, taking into account the non-technical aspects of the design a simple device for rehabilitation</td>
</tr>
<tr>
<td>K_U24</td>
<td>Able to identify the device by its purpose, on the basis of knowledge and analysis of the functioning and indicate a device which assists the rehabilitation of selected diseases</td>
</tr>
<tr>
<td>K_U27</td>
<td>Able to find and discuss the principle of rehabilitation equipment for the assumed purpose and also has experience in the analysis of the relationship between structural and functional solution rehabilitation equipment</td>
</tr>
<tr>
<td>K_K01, K_K02, K_K03</td>
<td>Has knowledge of the importance of technical measures in the lives of people with disabilities, acquire skills and experience in teamwork and is aware of the ongoing development of rehabilitation equipment and prosthetic devices</td>
</tr>
</tbody>
</table>

**LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:**

<table>
<thead>
<tr>
<th>The reference to the effects of field of study</th>
<th>The method of checking the effect of education</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W23</td>
<td>Grading lecture – exam</td>
</tr>
<tr>
<td></td>
<td>The pass of the lecture is to provide a positive assessment of written responses to questions regarding the theoretical issues of the subject.</td>
</tr>
<tr>
<td>K_U05, K_U18, K_U20</td>
<td>Grading project classes</td>
</tr>
</tbody>
</table>
|                                               | Evaluation of the project is determined on the basis of the relevance of selection techniques and methods used and the quality of the
**K_U27** implementation of the project.

| K_K01, K_K02, K_K03 | Skills developed during the project and its various stages of consultation. |

**Lecture:** The prerequisite is to obtain a positive evaluation of the test carried out in writing form.

**Project:** credit with a grade (based on credit ratings received during the project's preparation for classes, and the final assessment for the project).

The final grade is the average of all ratings.

**STUDENT WORKLOAD:**

The student workload is 100 hours (4 ECTS), including contact hours: 60 hours exam: 2 hours, preparation for classes: 8 hours, the development of the project: 20 hours, to prepare for the exam: 10 hours.

**RECOMMENDED READING:**

1. Biomechanika i Inżynieria Rehabilitacji, Tom 5.
2. T. Bober, J. Zawadzki, Biomechanika układu ruchu człowieka.
3. Ross Ethier, Craig A. Simmons, Introductory Biomechanics.

**OPTIONAL READING:**

**SENSORS AND NON-ELECTRICAL QUANTITIES**

**MEASUREMENT**

Course code: 6.9-WM-IB-P-45

Course type: Optional

Language: Polish/English

Dr. hab. inż. Wiesław Miczulski, prof.

Main lecturer: UZ

Dr. inż. Katarzyna Arkusz

Second lecturer: Dr inż. Mariusz Krajewski

<table>
<thead>
<tr>
<th>Lecture form</th>
<th>All lectures time</th>
<th>Lecture time in one week</th>
<th>ECTS points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecture</td>
<td>30</td>
<td>2</td>
<td>IV Grade</td>
</tr>
<tr>
<td>Laboratory</td>
<td>30</td>
<td>2</td>
<td>Grade</td>
</tr>
</tbody>
</table>

**ECTS**

**Stationary studies**

3

**CEP PRZEDMIOTU:**

The aim of the course is acquisition knowledge and competences in practical use and exploitation of sensors and to measure non-electrical quantities in biomedical engineering.

**REQUIRED BASE:**

Basics: electrotechnics, electronics, physics, biology, biochemistry, metrology.

**COURSE CONTENTS:**

Course includes:

mediators first, second and third generation. Cyclic voltametry, amperometry, potentiometry. Lab-on-a-chip, dry biotests, bioreactors, non-medical biosensors applications (in environmental protection, food industry). Developments in biosensors (implanted, miniaturized)


**TEACHING METHODS:**
- **Lecture:** Audiovisual lectures, literature analysis
- **Laboratory:** Practical exercises (individual or in student group)

**LEARNING OUTCOMES:**

<table>
<thead>
<tr>
<th>Field specific learning outcomes</th>
<th>Knowledge, skills, competence</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W06</td>
<td>The student has an ordered and theoretically based knowledge of sensors, biosensors and other actuators of electrical and non-electrical quantities - applied in medicine, has basic knowledge of scientific results elaboration, knows the basic diagnostic methods and tools as an engineering discipline relevant to the field of Biomedical Engineering</td>
</tr>
<tr>
<td>K_W17</td>
<td>The student has an ordered knowledge of signals theory, in particular methods of signal filtration and digital signal processing</td>
</tr>
<tr>
<td>K_U04, K_U13</td>
<td>The student can use known analytical, simulation and experimental methods to undertake decisions in the field of Biomedical Engineering</td>
</tr>
<tr>
<td>K_U06, K_U19</td>
<td>The student can plan and carry out experiments, including measurements and computer simulations, to interpret the results and draw conclusions</td>
</tr>
<tr>
<td>K_K02</td>
<td>The student is aware of and understands the importance and impact of non-technical aspects of engineering, including its impact on the environment, and the responsibility for decisions consequently related with these aspects</td>
</tr>
</tbody>
</table>

**LEARNING OUTCOMES VERIFICATION AND ASSESSMENT CRITERIA:**

<table>
<thead>
<tr>
<th>The reference to the learning outcomes of the field of study</th>
<th>The method of the learning outcomes assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>K_W06, K_W17</td>
<td>Written exam – verification of theoretical knowledge</td>
</tr>
<tr>
<td>K_U04, K_U06, K_U13, K_U19</td>
<td>Practical verification of knowledge and skills in sensors and measurements of non-electrical quantities. Written report from every</td>
</tr>
</tbody>
</table>
K_K02 exercise with data presentation and conclusions.

**Lectures:** Grade

**Seminar:** Grade

**STUDENT WORKLOAD:**

The student workload of 75 hours (3 ECTS), including work in the auditorium 60 hours, preparing for grade 5 hours, preparing of control work and reports 5 hours, preparing for classes 5 hours.

**RECOMMENDED LITERATURE:**

2. Piotrowski J. (red.): Pomiary czujników i metody pomiarowe wybranych wielkości fizycznych i składu chemicznego. WNT, Warszawa 2009
15. Nanoscale technology in biological systems / ed. by Ralph. S. Greco, Fritz B. Prinz, R. Lane Smith.