Final state examination thematic areas within the CEMACUBE - Common European Master's Course in Biomedical Engineering for biomedical master's degree program N3921 "Biomedical and Clinical Technology" at Czech Technical University in Prague - Faculty of Biomedical Engineering

Uoint study program of the 6 European universities induded in the Erasmus Mundus program, double degree)

According to Article 7, paragraph 2 of the Dean·s directive for the implementation of bachelor and master degree study programs at the Czech Technical University **in** Prague - Faculty of Biomedical Engineering Dean sets based on proposal by the head of the Department of Biomedical Technology thematic areas listed below.

Topics are designed in accordance with the valid accreditation approved by Ministry of Education, Youth and Sports on the 29th February 2012 Ref. MSMT/6894/2012-M3.

Topics are designed as the minimum required knowledge (theoretical and practical), which are necessary for successful graduate in practice. At the end of the thematic areas the names of the mandatory courses are summarized for better orientation of students. On the basis of paragraph 3 of Article 7 of the above mentioned Dean·s Directive is mandatory for the student mentioned areas I. Thematic area Ii. is optional depending on the specialization and composition of completed subjects during the 2nd year CEMACUBE study (student has to select one specialization). During the final state examination student gets assigned min. 2 questions from each thematic area. There are also allowed issues that are directly related to the theme of Master's project (thesis) or to the curriculum of student's CEMACUBE subjects. Questions enter the committee members, or a member of the committee determined by the chairman. Answers to questions should follow immediately after entering and without a written preparation.

Thematic area I. - Fundamentals of Biomedical Engineering (mandatory - based on the subjects and competences after year 1)

Research project – structure, preparation, planning, scheduling, and controlling. Research paper – structure, preparation. lnformation sources.

Structure and function of proteins. Enzymes. Biochemistry of hormones. Metabolism of carbohydrates, lipids and lipoproteins, amino acids and proteins Biochemistry of the digestive tract, pancreas and liver biochemistry. Biochemistry of kidneys. Biochemistry of muscle, bone. Biochemistry of the nervous syslem. Biochemistry and blood clotting process. The metabolism of body fluids and ions, acid-base balance.

Overview of imaging systems, the relationship to the electromagnetic spectrum. Transfer properties of imaging systems (PSF, OTF, MTF). TV imaging systems. Fundamentals of scanning and digitization (microscopic imaging systems, TV systems, HW + SW). lnfrared imaging systems in medicine (thermal). lmaging in nuclear medicine (Anger camera). PET, SPECT. MRI. CT. Ultrasound imaging systems. Doppler systems.

Structure and function of nucleic acids DNA and RNA. Replication, transcription, translation. Protein synthesis, prokaryotic and eukaryotic gene expression. Reproduction of cells, cell cycle, cell division. Gene manipulation.

Definition of diagnostic and therapeutic medical devices. Apparatus for blood pressure measurement. Measurement of blood oxygen saturation (pulse oximetry). Electrocardiographs. Electroencephalography. Monitor of vítal signs. Pneumometry (spirometer, pneumotachograph, body composition). Medical devices for audiology, ophthalmology, optometry. Dilution methods. Electrical safety.

Biomaterials, biocompatibility. The mechanical characteristics of bones, tendons, ligaments,

muscles and cartilage. Joints, hip and knee joint - total replacement. Mechanics of walking. Mechanics of the lower extremity. Mechanics hand grip strength. Intelligent prosthesis Biomechanics of the heart and vascular syslem. Biomechanics of respiration.

Overview of the biosignals. Methods of biosignal sensing and fundamental parameters needed for the diagnosis of biosignals. Signals of the heart, brain, muscles and nervous syslem. Methods and algorithms for processing and evaluation of the most important biological (especially electrophysiological) signals, preprocessing, filtering, analysis in the time and frequency domain. Display of results, topographic rnapping.

Overview of the transport processes (Thermodynamics - equilibrium thermodynamics, total chemical potential, activities, barriers, fluxes, Fick's laws Equilibria across membranes, Nernst and Donnan-Gibbs, passive transport: free and facilitated diffusion, electro-diffusion, osmotic pressure, active transport, The Cell - structure, organization and energetics of an animal cell, Channels, carriers and pumps - classification, molecular structure, genetic manipulation, Neural signaling - neuron and the electrophysiological techniques, resting and activated membrane potential, Genesis of mechanical farce - structure, regulation and functions of muscle proteins, cardiac contraction, blood pressure and circulation, capillary transports, Transcellular transports - organization of epithelial cell layers, pathways across leaky and tight epithelia, Gas transports - partial pressure, overview of the gas transport processes, gas exchanges in the lung and in the tissues, gas transport in the blood.

Description of the procedure concerning the basic clinical examination of the patient. The manner and method of monitoring the health status of the patient.

Prerequisites (relevant subjects):
Anatomy and physio/ogy /., //., Project Proposa/ and Management, Biochemistry, /maging Systems, *Fundamente/s of Molecu/ar Biology, Medical Devices & Equipment, Biomechanics and Biomateriafs, Ethics in Biomedical Engineering, Work with lnformation Sources and Research Methodo/ogy, Biologica/ Signals, Biotransport, Fundamente/s of Pathophysio/ogy & Diagnostic Methods*

Thematic area li. - Selected topics from the Biomedical Enqineerinq (optional - based on the subjects and competences after year 2 obtained within the consortium universities specializations – detailed synopsis of below mentioned subjects are available on the www pages relevant consortium universities except of the synapsis of the Czech Technical University in Prague – FBME that are included below, **specific content of the following specializations can be adopted to the actually completed courses of the student)**

Groningen, *specialization* ***Prostheses & /mp/ant Interlace Technology***
Integrated Lab Course Biomaterials
Interface Biology
Surface Characterization
Colloid and interface science
Medical implants
Recent Developments in Biomaterials

Groningen, *specialization* ***Prostheses and /mp/ant Design***
Interface Biology
Product Design by the Finite Element Method
Robotics for IEM
Neuromechanics
Prosthetics and Orthotics

Ghent, *specialization Radiation physics & Nuclear imaging processing*
Radiochemistry
Radiobiology and radiopathology Nuclear physics
Nuclear measuring techniques
Medical dosimetry Radiological

techniques Technology cf
radiotherapy
Radiation protection and legislation
Nuclear magnetic resonance imaging technology
Advanced signal processing

Ghent, specia/ization Computational methods for medical applications

Artificial organs: technology and design
Parametric modeling and design Numerical
Fluid Mechanics Computational
biomechanics
Fluid-structure interaction
Models cf the cardiovascular syslem - advanced (OD, 1D, 30)
Project - from medical image to a numerical model and experimental validation
Multiphysics modeling

Dublin, specia/ization Tissue Biomechanics & Regenerative Medicine

Mechanics cf Cells,
Mechanics of Tissue Growth, Adaptation and Oegeneration Stem
cell, mesenchymal cell b'1ology
Tissue engineering principles
Molecular biology's techniques to analyze gene expression Fundamentals cf construct
technology
Biomaterials for scaffolds
Mechanobiology
Cardiovascular tissue engineering
Bioreactors
Orthopedic tissue engineering

Dublin, specialization Neural Engineering

Electrophysiology
Algorithmic methods for analyzing physiological signals Neural
prostheses
Neuralmodulation devices
Speech processing Biomedical
signal processing

Aachen, specia/isation Tissue engineering

Biocompatibility and biomaterials Biology
cf cultured cells
Biosafety and ethics
Fermentation technology
Bioreactors
Tissue engineering cf soft tissue, nerve tissue, bone and cartilage

Aachen, specialization /mage-guided therapy & mo/ecular imaging

Navigation and robotics Laser
surgery head and neck
Neuronavigation Laparoscopic
surgery lnterventional cardiology
Orthopedic navigation robotics
Ligans
PET and SPECT
Radiotracers
Optical imaging and molecular ultrasound Molecular
MRI and cell tracking

Aachen, specíalization Artificial Organs & lmplants

Heart assist devices Extracorporeal
liver support

Kidney engineering and clinical applications Orthopedic implants
Dental prosthetics

Prague, *specialization* ***Medica/ Instrumentation***

Electromagnetic Field in Medicine Medical
Devices & Equipment li
Design & Construction of Medical Devices/ Practical Exercises
Clinical Laboratory lnstrumentation
Equipment for Anesthesiology and Resuscitation
Laser Applications in Biomedicine

lnteractions of electromagnetic field with matter. Biological effects of electromagnetic field, safety limits. Hyperthermia, principles and technical equipment. Hyperthermia applicators Treatment planning. Hyperthermia thermometry. Microwave non-invasive thermometry.

Lung ventilators. Devices for electrosurgery. Pacemakers. Defibrillators_ Extracorporal membrane oxygenation. Hemodialysis. Drug infusion pumps. Cochlear implants. Electro-therapy, Magneto-therapy.

Biopotential amplifiers, parameters and properties (frequency bandwidth, dynamic range). CMRR - Common Mode Rejection Ratio. Galvanic isolation, filtration of biosignals,S/H – sample and hold circuits, A/D and D/A converters _ LabViewsystem support_

Principles of the optical absorption, spectrometry, polarography, chromatography, electrophoresis, isotachophoresis, mass spectroscopy, alomic absorption spectrometry and osmometry. Centrifuges and ultracentrifuges, laminar boxes, conductometers, pH meters. PCR and DNA analyzers_

Specific requirements for equipment at intensive care units (ICU) and departments of anesthesia and critical care medicine (ACCM). Blood gases, their measurement and interpretation. Principles and adverse effects of artificial lung ventilation (ALV). Conventional and unconventional lung ventilation, corresponding ventilators. Equipment for anesthesia_ Anesthetic vaporizers, their thermodynamic principles _ Humidification al ventilatory gases_ Equipment for monitoring and support of blood circulation. Monilors of vital signs.

lnteraction of radiation with tissue, overview and characteristics of lasers. Lasers in various medical disciplines - application of laser radiation in ophthalmology, dermatology, dentistry, urology, cardiology, angioplasty, neurosurgery, orthopedics, gastroenterology, otorhinolaryngology, and photodynamic therapy_ Laser safety.

Prague, *specialization* ***Modem Physica/ Methods in Biomedical Engineering***

Applied Optoelectronics in Medicine
Biophotonics
Novel Technotogies and Characterization Methods in Biomedicine
Spectroscopy in Biology & Medicine
Laser technology
Nanotechnology
lonizing Radiation Imaging
Fiber Optics for Biomedicine

Fundamental physiology of the human vascular syslem, venous and arterial hemodynamics, skin anatomy and perfusion. UV, VIS and IR spectroscopy. Fundamental optics of the eye and colour analysis. Optical parameters of biological tissue. Dispersion of light. Design of optoelectronic sensors. Camera based sensor concepts and optical imaging systems in medicine.

Overview of principles and applications in interdisciplinary region connecting disciplines of physics, optics and biology (biophotonics)_ lnteraction ol optical radiation with matter, with

tissue, basics of photobiology, bioimaging, microscopy, optical biosensors.

PVO and CVD methods for thin film creation, laser methods for thin film creation, mechanism of thin film growth, thin film characterization, applications of thin films in medicine.

Fundamentals principles of the fluorescence spectroscopy. Biological applications of fluorescence spectroscopy. Dyes used in biological fluorescence spectroscopy. Fluorescence microscopy and single molecule techniques. Biological and medical relevant applications Photodynamic therapy as fluorescence application in medicine.

Description of laser function physical principles. Classification and overview of particular types of lasers. Gas lasers - atomic, ion, molecular. Plasma lasers. Semiconductor lasers. Methods of generation of ultra-short laser impulses. Lasers for thermonuclear synthesis, and selected types of lasers for selected medical applications, Lasers for time-resolved laser spectroscopy. X-ray lasers for cell imaging.

lntroduction to nanotechnology, analytical instrumentation - scanning microscopy, electron microscopy, nanoparticles, thin films, polymeric nanocomposites, nanostructures and nanoelectronics, carbonnanostructures, biosensors, nanowires, nanomedicine, risks of nanotechnologies, methods for synthesis of nanoparticles and nanostructures, engineering of nanoparticles, present applications of nanotechnologies.

Elementary information about ion radiation sources, and ion radiation interaction with substances (of animated and inanimate nature). Radiation detectors and their characteristics. Physical principles of the methods (emission, transrnission, etc.). Detection systems, resolution, sources of errors, radiation load. Image reconstruction.

Optical liber (OF), basic parameters of OF, condition of guide, attitude of geometry and wave optics, mode structure. Optical fiber elements, OF as displaying element. OF bundles, endoscope. lntroduction to the OF sensors, spectroscopy fundamentals, intrinsic and extrinsic OF sensors, biosensors.

Prague, *specíalization* ***Medícal /maging Instrumentation***

Applied Optoelectronics in Medicine
Image Processing and Analysis
Nuclear Medicine lmaging Systems
Ultrasound and Doppler lmaging Systems
lonizing Radiation lmaging
Television, Thermovision and Endoscopic lmaging Systems
Magnetic Resonance lmaging and Impedance Tomography
Microscopy in Medicine
Fiber Optics for Biomedicine

Fundamental physiology of the human vascular syslem, venous and arterial hemodynamics, skin anatomy and perfusion. UV, VIS and IR spectroscopy Fundamental optics of the eye and color analysis. Optical parameters of biological tissue. Dispersion of light Design of optoelectronic sensors. Camera based sensor concepts and optical imaging systems in medicine.

Brightness histogram. Image acquisition from the geometrie and radiometrie point of view. Fourier transform. Sampling theorem Filtering in frequency domain. Brightness scale transformation, geometrie transformations, interpolation. Image registration. Image processing in spatial domain. Convolution, correlation. Noise filtering. Edge detection. Linear and nonlinear methods. Mathematical morphology. Image compression. Color images. Texture. Segmentation of objects in images. Objects description in images and their recognition.

Basic facts about gamma rays. Radionuclides and radiopharmaceuticals. Devices in nuclear medicine (detection, instrumentation, detectors, gamma camera imaging device parameters). Whole-body imaging, tomographic imaging systems - SPECT, PET, hybrid systems - PET /

CT, SPECT / CT. Data processing in nuclear medicine.

Introduction to ultrasound and Doppler imaging systems. Ultrasound probes and transducers, piezoelectric phenomenon. Display modes - A, M (TM), B, C, Q, and their properties. Ultrasonic probe. Linear and sector transducers - resolution, types and principles focusing of ultrasound beam. Doppler effect and its use in ultrasound imaging technique. Individua! blocks of devices and their specifications. 3D and 4D techniques using ultrasound techniques.

Elementary information about ion radiation sources, and ion radiation interac!ion with substances (of animated and inanimate nature). Radiation detectors and their characteristics. Physicat principles of the methods (emission, transm'1ssion, etc.). Detection systems, resolution, sources of errors, radiation load. Image reconstruction.

Basic blocks of television syslem. Imaging syslem - lens. Image sensor. Image and video processing. Image compression / video. Image reproduclion - display. Special elements of imaging systems. Principles of infrared imaging systems (IR). The specific configuration parameters, and IR systems parameters. Features and specifica!ions of thermovision systems. Introduction to endoscopy, endoscopic systems classification. Description, design and parameters of fibroscopic systems. Description, design and parameters of videoendoscopic systems.

Basic principles of creation, registration and processing of signals in NMR, relaxation processes and their possible influence, creating an image. Pulse spin-echo sequence, its modifications and practical use. Special pulse sequences and their use in the imaging of specific tissues. Functional magnetic resonance imaging and its methods. Parameters and properties of the specialized RF coils. Principles of EIT, its diagnostic significance. HW for EIT. Signal processing of the EIT image reconstruction, methods of mathematical evaluation of the EIT image in relation to diagnosis.

Light microscopy techniques, electron microscopy techniques. Digital bioimaging. Fluorescent microscopy, confocal microscopy and electron rnicroscopy (SEM, TEM).

Optical fiber (OF), basic parameters of OF, condition of guide, attitude of geometry and *wave* optics, mode structure. Optical liber elements, OF as displaying element. OF bundles, endoscope. Introduction to the OF sensors, spectroscopy fundamentals, intrinsic and extrinsic OF sensors, biosensors.

Supplement:

Competences after year 1

Students have basíc knowledge of:

a. Anatomy of the musculoskeletal, circulatory, digestive, respiratory, excretory, endocrine and nervous systems and general knowledge of tissues
b. Physiology of the muscular, circulatory, digestive, respiratory, sensory and nervous syslem
c. General (patho)physiologic mechanisms (inflammation, infection, immunology, repair)
d. Principles of biochemistry and cell biology
e. Bio-instrumentation; overview of diagnostic instruments, their possibilities, limitations, physical principles, the phenomena they rneasure, the rela!ion with the required information
f. Medical imaging in terms of an overview of present equipment for diagnostics, their possibilities and limitations, their physical principles, the phenomena they measure.
g. Biochemistry in terms of cell compartments; biological macromolecules; enzyme mechanisms; structure and function of membranes, antibodies, carbohydrates, lipids and proteins

Students have advanced knowledge of

h. Biomaterials in terms of an overview of potentíal materials, their properties, applications and limitations, in terms of biocompatibility and failure mechanisms.
i. Signal analysis, syslem dynamics and computational mathematics
j. Biomechanics in terms of statics, mechanics of materials (strength, stiffness, stress, deformation), dynamics (kinematics, kinetics, including gait analysis).
k. Biotransport in terms of heat transport, mass transport, biofluid mechanics.
I. Design/development; methodology, risk analysis, project management, market survey.
m. Ethics, including regutatory affairs, soclal implications.
n. Practical training in a European industry and hospitals, entrepreneurship as part of their professional development, IP.

Student skills: students are able to:

o. apply knowledge and understanding in designing newflmproved diagnostic instruments
p. apply knowledge and understanding in designing *new* or improved therapy devices.
q. make judgments, integrating medical, cultural, social and ethical insights into her/his work
r. communicate in English having *very* good command of written and spoken Janguage.
s. communicate inone ether language on a basic level, being the language of a host country.
t. co-operate with other biomedical engineers and with medical experts.
u. co-operate with international colleagues.
v. reason soundly and to critically reflect on their own and others work.

Competences after year 2

a. Students have advanced knowledge of a particular field in Biomedical Engineering (one of the specializations, offered by the consortium).
b. Students are able to apply and integrate knowledge of ha! particular field.
c. Students are able to perform a research or design project by integrating all acquired knowledge and skills, and to show appropriate behavior given the professional context.
d. Students are able to present their work in English both in writing and orally, and respond adequately to criticism.

Kladno, 5lh January 2017

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