BioCAD English Programme

Aim: computer-aided design of implantable medical devices

FRAMEWORK

European collaboration in Biomechanics and Biomimetics between : University of Lorraine (ENIM-ENSEM-Faculty of Mechanics and Mathematics, Nancy/Metz, France), Bremen University of Applied Sciences (Bremen, Germany), Gdańsk University of Technology (Gdańsk, Poland), AGH University of Science and Technology (Cracow, Poland), Poznań University of Technology (Poznań, Poland)

ADMISSION REQUIREMENTS

This program is intended for International and French students who have completed six to eight academic semesters of study (180 to 240 ECTS) at undergraduate level in Mechanical Engineering. For French ENIM students it will be for their 5th year level.

Autumn semester, 30 ECTS

Course Title	ECTS Credits	Course code
Numerical Methods Applied to Biomedical Applications	6	9KEL1M15
Biomechanical Characterization and Modelling of Biological Tissues	3	9KEL1M16
Prosthetic Device Design and Manufacturing	5	9KEL1M17
From Mechano-Transduction to Rehabilitation	1.5	9KEL1M18
The Multibody System Method Applied to the Human Body	3	9KEL1M20
Biomimetics	3.5	9KEL1M21
Biomedical Basic Knowledge	2.5	9KEL1M22
Transversal Project	4	9KEL1M19
*French as a Foreign Language**	*1.5*	
*Tronc commun management **	*1.5*	
*Tronc commun droit**	*0.5*	

** Only for International students*

*** Only for French ENIM students*

Spring semester, 30 ECTS

Research Project in Research Laboratory	30
Or Work Placement in Industry	30

CREDITS

ENIM applies the European Credit Transfer System (ECTS) to express student workload. One ECTS represents approximately 28 hours of work, which include hours of lectures, applied exercises, lab work and private study. You can earn 30 credits per semester; a full academic year is 60 credits.

INTERNATIONAL TEAMWORK

During a semester or one year, you will participate with an international group of students from various universities partners, including engineering students from ENIM, and with diverse education and cultural backgrounds. The language of instruction is English, with French as a foreign language.

STUDY PERIOD AND APPLICATION

Study period is from September to end of June. Application deadlines are April 30. A maximum of 8 international students is accommodated.

Contact International Office: enim-relinter-contact@univ-lorraine.fr ,
Academic coordinator: anne-sophie.bonnet@univ-lorraine.fr

Course title	**Numerical Methods for Biomedical Applications**
Course Code	9KEL1M15
Field of study	Mechanics, Biomechanics
Offered	Autumn
ECTS-credits	6 ECTS
Language	English
Prerequisites	Fundamentals of tensor analysis Bases of Continuum Mechanics Constitutive laws in elasticity
Teaching method	Lectures : 20 hours Applied Exercises : 12 hours Lab work : 40 hours Individual : 70 hours

Motivation:
The numerical techniques such as Finite Element Method (FEM) are indispensable to solve complicated tasks of modern design of parts, components, prosthetic solutions or modeling of thermo-mechanical behavior of biological tissues or organs.

Learning objectives

The main goals of this course are as follows:

- to understand the theoretical bases of FEM
- to be able to solve built simple FEM models in elasticity and plasticity,
- to be able to build the geometry of objects from the μCT or DICOM files,
- to execute FE simulations using general purpose software such as Marc or Abaqus or open source codes such as FEBIO- to give the physical bases of X-ray techniques
- to introduce the methods of image segmentation
- to provide practical aspects of use of μCT

Contents	**Level of competency (4)**
• Theoretical bases of FE Methods	2
• FEM in 1D, 2D, 3D elasticity	2
• Segmentation theory	3
• μCT techniques and practical aspects	2
• Biomedical applications in FE	2

Literature	*The Finite element method*, O.C. Zienkiewicz, R.L. Taylor, Butterworth-Heinemann, 2000 *Applied Finite element analysis*, L.J. Segerlind, John Wiley &Sons, 1984
Assessment	Written (2h), 2 projects
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	A.S. BONNET
More contact persons	A.S. BONNET, C. DREISTADT, T. GAJEWSKI, C. LAURENT, P. LIPINSKI, J. TARASIUK

Course title	**Biomechanical Characterization and Modeling of Biological Tissues**
Course Code	9KEL1M16
Field of study	Mechanics, Biomechanics
Offered	Autumn
ECTS-credits	3 ECTS
Language	English
Prerequisites	Continuum mechanics for solids: tensor calculus and Einstein notation, Theory of elasticity (small strains), Isotropic and anisotropic constitutive laws, mechanics of plastic strain, plasticity criteria. Basic knowledge concerning experimental tests on conventional materials.
Teaching method	Lectures : 20 hours Applied Exercises : 8 hours Lab work : 8 hours Individual : 36 hours (20h lectures, 8h AE, 8h lab work)

Motivation

A strong knowledge of the mechanical behavior of biological tissues is required to understand the clinical issues for rehabilitation and design new prosthetic solutions.

Learning objectives

At the end, the students should:

- Be able to apply the theoretical principles of the continuum mechanics to study biological tissues
- Know the composition and structure of bone tissues
- Know the mechanical properties of bone tissues (constitutive laws, ranges)
- Know the mechanical properties of soft tissues
- Know the ethical principles to conduct research on animals, human bodies and human-beings
- Understand and explain the experimental issues specific to biological tissues
- Be able to comment and write a protocol to characterize biological tissues in response to specific hypotheses

Contents	**Level of competency (4)**
• Theory of elasticity (small strains and large strains)	3
• Anisotropic elasticity	2
• Hyperelasticity	2
• Multiscale aspects of biological tissues	1
• Experimental testing in biomechanics	2
• Apparent properties of hard tissues	2
• Mechanical properties of soft tissues	2

Literature	*Bone mechanics handbook* by Cowin (ISBN 9780849391170) Skeletal tissue mechanics by Martin, Burr and Sharkey (ISBN 0-387-98474-7) *Bones* by Currey (ISBN 0-691-12804-9) *Mechanics of Biological Tissue - Part IV: Biological tissues* by Holzapfel and Ogden (ISBN-13 978-3-540-25194-1)
Assessment	Written (2h)
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	E. DE BROSSES
More contact persons	A. BALDIT, E. DE BROSSES, C. LAURENT, P. LIPINSKI

Course title	**Prosthetic Device Design and Manufacturing**
Course Code	9KEL1M17
Field of study	Mechanics, Biomechanics
Offered	Autumn
ECTS-credits	5 ECTS
Language	English
Prerequisites	CAD software Manufacturing processes Material science Dimensioning
Teaching method	Lectures: 36 hours Applied Exercises : 2 hours Lab work: 24 hours Individual: 60 hours (30 lectures, 30h lab work)

Motivation
The motivation of this module is to provide knowledge on biomaterials and manufacturing processes in order to design new medical devices.

Learning objectives
This module is composed of 4 parts: Biomaterials, Prosthetic device design; Prosthetic device manufacturing, Design project.
The aims of the module are:
Biomaterials:

- to give definition and generalities about biomaterials
- to describe more precisely the third-generation implants (tissue engineering)
- to know what a polymer is and which polymer can be used for biomaterials

Prosthetic device design:

- to give the different steps of a standard device design and patient-specific device design
- to explain regulations concerning the device design

Prosthetic device manufacturing:

- to describe processes manufacturing used for polymers
- to describe the different technologies of additive manufacturing

Design project:

- to be able to design a new device corresponding to the proposed project

Contents	**Level of competency (4)**
• Biomaterials	2
• Tissue engineering	3
• Prosthetic device design	2
• Additive manufacturing	3
• Polymer science	2
• Conventional manufacturing processes	2

Literature	*Series on Biomaterials and bioengineering Vol. 1, An introduction to biocomposites* by Seeram Ramakrishna, Zheng-Ming Huang, Ganesh V Kumar, Andrew W Batchelor, Joerg Mayer (ISBN 1-86094-425-6) *Series on Biomaterials and bioengineering Vol. 2,Life-Enhancing plastics* by Anthony Holmes-Walker (ISBN 1-86094-462-0) *Additive manufacturing technologies* by Ian Gibson, David W. Rosen, Brent Stucker (ISBN: 978-1-4419-1119-3)
Assessment	1 Written exam (WE), 1 Project (P) to obtain a Final Ass. (0.5 WE+ 0.5 P)
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	C. DREISTADT
More contact persons	A. BALDIT, A.-S. BONNET, C. DREISTADT, G.DUBOIS, X.GODOT, P. LAHEURTE, C. LAURENT

Course title	**From Mechano-Transduction to Rehabilitation**
Course Code	9KEL1M18
Field of study	Mechanicals, Biomechanics
Offered	Autumn
ECTS-credits	1.5 ECTS
Language	English
Prerequisites	Structure of bone tissues, Behavior of biological tissues, Finite Element Method
Teaching method	Lectures: 8 hours Applied Exercises: 2 hours Lab work: 8 hours Individual: 18 hours

Motivation
To propose innovative therapeutic solutions for rehabilitation, it is necessary to make the link between mechanics and biology.

Learning objectives

At the end, the students should:

- understand the evolving behavior of bone tissues
- have knowledge about the link existing between cellular activities and modifications in biological tissues
- understand models simulating bone adaptation, healing and remodeling
- know the main solutions for bone reconstruction

Contents	**Level of competency (4)**
• Introduction to adaptive behavior of biological tissues	2
• Mechano transduction and cell differentiation	3
• Bone growth, bone healing, bone remodeling	3
• Bone remodeling mechanisms	3
• Solutions for bone reconstruction	2
• Trabecular bone remodeling and structural optimization	3

Literature	*Skeletal Function and Form* by D.R. Carter, G.S. Beaupré
Assessment	Written (2h)
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	Anne-Sophie BONNET
More contact persons	BALDIT Adrien, BONNET Anne-Sophie, DE BROSSES Emilie, GANGHOFFER Jean-François, NOWAK Michal

Course title	**The Multibody System Method Applied to the Human Body**
Course Code	9KEL1M20
Field of study	Mechanicals, Biomechanics
Offered	Autumn
ECTS-credits	3 ECTS
Language	English
Prerequisites	Mechanics: Basic knowledge concerning the kinematics of rigid body, the Newton's laws applied to rigid bodies, Theological models. Anatomy: Names of the limbs, joints and bony structures. Names of the anatomical directions and planes.
Teaching method	Lectures: 18 hours Applied Exercises: 20 hours Lab work: Individual: 38 hours (18h lectures, 20h AE)

Motivation

The analysis of human motion is a method widely used in different technological fields such as for medical applications, in sport, robotics or entertainment.

Learning objectives

At the end, the students should:

- Write and solve the equations corresponding to a human motion
- Understand the usefulness of the “frame of interpretation”
- Know the hypotheses made for the analysis of human motion
- Understand the usefulness of standardization for the definition of anatomical frames
- Analyze the results of a kinematic study on human body
- Write the Newton’s laws for dynamic studies on human body
- Know the models for the determination of the body segmental inertial parameters
- Use of the kinematic data for the inverse dynamics method
- Know the physiological behavior of muscles
- Use rheological models to describe the mechanical behavior of muscles
- Understand and explain the principles of EMG and sEMG measurement

Contents	**Level of competency (4)**
• Motion analysis of human body (kinematics and dynamics)	3
• Posture and muscles	2

Literature	*Kinematics of Human Motion* by V. Zatsiorsky (ISBN-13:978-0880116763) *Kinetics of human Motion* by V. Zatsiorsky (ISBN-13:978-0736037785) *Biomechanics of the Musculo-skeletal System* by Nigg B.M. & Herzog W. (ISBN-13: 978-0470017678)
Assessment	Written (2h)
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	E. DE BROSSES
More contact persons	E DE BROSSES, W. WOJNICZ

Course title	**Biomimetics**
Course Code	9KEL1M21
Field of study	Biomimetics and Locomotion
Offered	Winter
ECTS-credits	3.5 ECTS
Language	English
Prerequisites	None
Teaching method	Lectures: 16 hours Tutorials: 4 hours Practical: 20 hours Personal: 40 hours

Motivation: Student perception of biomimetics is crucial to develop new ideas and concept to design biomechanical systems or devices.

Learning objectives:
It will start with knowledge about the development of biomimetics and its use since middle age allowing having reflection about ideas from nature.
Secondly, the students will be introduced to bio fluid mechanics applied to nature. Fundamental equations of fluid mechanics will be taught and followed by numerical application thanks to computational fluid dynamics.

Contents:
The course will give a short introduction into the field of biomimetics: What is biomimetics - and what not, the 3-criteria-definition, biology push – technology pull, application areas. Short excursion into history: from the middle age to the year 2000. The biomimetical working process (problem definition, morphologi- cal / Zwicky box, weighting of criterias, best model, plan B). Where the models / ideas came from: some biology (phylogenetics, systematics, morphology, locomotion of animals). Selection of examples from current topics in biomimetics (functional surfaces, bio-materials, ultraleight structures, fluid dynamics and MAVs / AUVs), the course will end with a short workshop”Is there an idea from nature to. . . ?”.

With various examples the introduction to bio fluid mechanics gives insight of fluid mechanical phenomena in nature which have been transferred to technical applications. To understand and to apply computational fluid dynamics the knowledge and understanding of the fundamental equations of fluid mechanics are essential. Therefore, the continuity and Navier-Stokes equations are derived. To build up a simulation case further knowledge is required about the numerical treatment of the fundamental equations. This is delivered in numerical methods in fluid mechanics. After a short introduction to Ubuntu the hands on application starts with a simple case of computational fluid dynamics which gets more complex further on. As software, the open source code OpenFOAM is applied.

Literature	*Turbulence in Fluids* (4th edition), M. Lesieur, Springer, 2008. *Analysis of Vertebrate Structure* (5th edition), M. Hildebrand and G. Goslow, 2002. *An Introduction to Fluid Dynamics*, G. K. Batchelor, Cambridge Mathematical Library, 2000.
Assessment	The Assessment consists of a project report of 3000 words, written in English. The project deals with an improvement of a fluid mechanical related technical application using biomimetic technique. Therefore, the original and the modified object are investigated by numerical fluid simulation. The object is chosen by the students.
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	BALDIT Adrien (baldit@enim.fr)
More contact persons	BALDIT Adrien, BAARS Albert, KESEL Antonia

Course title	**Biomedical Basic Knowledge**
Course Code	9KEL1M22
Field of study	Medical science, Biomechanics
Offered	Autumn
ECTS-credits	2.5 ECTS
Language	English
Prerequisites	None
Teaching method	Lectures: 24 hours Applied Exercises: Seminars and visits: 10h Individual: 24 hours (24h lectures)

Motivation:
Bases of anatomy, histology and implantology are necessary for the design of medical devices

Learning objectives

- To give engineering students basic notions about anatomy of head and neck
- To give engineering students basic notions about histology
- To give engineering students basic notions about medical imaging
- To provide clinical examples of craniomaxillofacial reconstruction
- To introduce engineering students to an understanding of dental implantology and the widening of knowledge in this discipline.
- To draw attention to the biomechanical aspects of dental implant complications.
- To introduce the engineering students to the biomedical industry

Contents	**Level of competency (4)**
• Anatomy, Histology	2
• Craniomaxillofacial reconstruction	2
• Dental implantology	3
• Seminars and visits	1

Literature	Dental Implant Prosthetics by C.E. Misch. Implant Overdentures. The Standard of Care for Edentulous Patients by J.S. Feine, G.E. Carlsson. Manual of Oral Implantology from C. Maiorana, M. Beretta M, Implant Therapy. Clinical Approaches and Evidence of Success Volume 2 by M. Nevins, J. Melloning. Tissue Engineering. Applications in Oral and Maxillofacial Surgery and Periodontics", Second Edition by S.E. Lynch, R.E.Marx, M. Nevins, L.A. Wisner-Lynch.
Assessment	1 project
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	Anne-Sophie BONNET
More contact persons	Emilie DE BROSSES, Malgorzata NATHER Narcisse ZWETYENGA

Course title	**Transversal Project**
Course Code	9KEL1M19
Field of study	Mechanics, Biomechanics, Biomimetics
Offered	Autumn
ECTS-credits	4 ECTS
Language	English
Prerequisites	Solid and fluid mechanics, biomimetics
Teaching method	Lectures: 6 hours Tutorials: 6 hours Practical: 32 hours Personal: 44 hours

Motivation

- Interest for scientific projects within a workgroup.
- Use all skills learned to fulfill a project answering a professional issue.

Learning objectives

At the end, the students should:

- be able to find information needed in scientific and technological documents,
- be able to use and apply all expertise learned in biomimetics and biomechanics,
- be able to work as a team,
- be able to manage a project.

Contents

Scientific document analysis (4h lectures / 8h tutorials) :

- Scientific articles
- Patents
- Standards

Transversal project (32h practical): Based on the overall courses done during the semester, a project is proposed to the students allowing them working as a team to answer an industrial need. All students' skills are required to work and succeed in a good and dynamic atmosphere.

Literature	Depending on the project
Assessment	2 reports and 2 presentations
Grading	According to the grading scale of ENIM
Re-examination	No
Contact person	BALDIT Adrien (baldit@enim.fr)
More contact persons	BALDIT Adrien, BONNET Anne-Sophie, DE BROSSES Emilie, DREISTADT Cynthia, FONCK-NUNEZ Marie