UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2021/2022
MASTER'S DEGREE (MSC)	BIOMEDICAL ENGINEERING
SUBJECT	ADVANCED BIOMECHANICAL MODELLING
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20909-Attivit Formative Affini o Integrative
CODE	20270
SCIENTIFIC SECTOR(S)	ICAR/08
HEAD PROFESSOR(S)	BORINO GUIDO Professore Ordinario Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	92
COURSE ACTIVITY (Hrs)	58
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**BORINO GUIDO** Thursday 11:00 12:00 Ufficio Dipartimento di Ingegneria. Sezione Strutture e Infrastrutture. Viale delle Scienze Ed. 8. I° Piano.Alternativamente sessioni on line nell'area dedicata al corso su Teams. Giorno ed orario concordato.

DOCENTE: Prof. GUIDO BORINO

PREREQUISITES	The student attending this course should know and should be able to manage the basic concepts in mathematics, linear algebra, geometry and he should have basic knowledge of continuum mechanics with special emphasis on solids and structures.
LEARNING OUTCOMES	LEARNING OUTCOMES Knowledge and understanding ability • The student at the end of the course will have additional knowledge to those imparted by the bachelor course of Mechanics of Solids and Structures. In particular he will know extended theories to the linear elastic theory to a wider context of a continuum in large displacements and large strains. Knowledge will be extended to problems of mechanical and thermomechanical modeling, including two-phase media that characterize biological materials and structures. • Capacity to apply knowledge and understanding The student will be able to set the governing equations of continuum mechanics in large displacements and large strains regime. Understanding the limitations of the traditional linear elastic theory and apply more advanced theories when needed. It will also be able to set problems related to biological materials in large displacement mastering the real meaning of specific strain measures and the corresponding stress measure. Making judgments • The student will be motivated to critical thinking and self-evaluation about: - The validity and the limits of the structural models commonly adopted with respect to the "exact" 3D problems; - The limits applicability of the structural models commonly used to describe biological materials and structures; - Levels of accuracy and correlated degree of difficulty related to modeling biomaterials and structures. Communication skills • The student will acquire the ability to communicate and express issues about the topics of the course. During the lectures and at the exercises sections considerable attention will be placed at a rigorous mode of communication, such as to enable the students to hold conversations on topics relating the advanced mechanics of mateials and structures (stress and strain measures, material constitutive parameters) or through a proper scientific terminology, and to tools of the mathematical representation of the main mechanical phenomena described. Students will encouraged to do technical discussion in public and solicited discussion among students on topics covered in the course. Learning skills • The student will learn the basics of the theory continuum mechanics of solids and structures. This knowledge will contribute to the formation of his wealth of knowledge of mechanics applied to bio-materials and structures. It is also an advanced engineering training that will allow him to continue their master engineering studies, deepening in the following courses aspects related to computational mechanics and experimental mechanics, backed up by a wealth of advanced continuous mechanics knowledge that will allow him autonomy and discernment.
ASSESSMENT METHODS	The assessment is achieved through a final oral exam, which ensures the acquisition of knowledge and skills expectations. The oral exam consists of two or three questions that tend to ascertain the student's knowledge of theoretical and applied topics discussed in lessons and exercise lectures. The exam score is awarded by a vote expressed in thirty. To pass the exam, namely to get a score not less than 18/30, the student must demonstrate a basic achievement of the goals. Objectives that are considered elementary when the student demonstrates that they have acquired a basic knowledge of the topics described in the program, is able to operate with minimal links between them, shows that they have acquired a limited degree of autonomy; His language is enough to communicate with the examiners. To achieve a score of 30/30 and laude, the student must demonstrate that he has achieved the objectives very well. The achieved goals are considered excellent when examining has gained a full knowledge of the topics of the program, demonstrating how to apply acquired knowledge , also in different / new / advanced contexts, he also expresses vocabulary competence within the specific reference language and is able to elaborate and express independent judgments based on acquired knowledge.

	The exams for non-attending students are the same to those used for attending students.
EDUCATIONAL OBJECTIVES	EDUCATIONAL OBJECTIVES The primary objective of the course is to provide advanced knowledge on the bio-mechanics of solids and structures by extending and deepening the basic knowledge developed in the three-year degree courses. The course rigorously develops the theoretical assumptions of the mechanics of the continuous focusing on the fundamental relationships: configurations, deformations, equilibrium, congruence, energy principles, constitutive equations. The course also aims to train the student in the appropriate biomechanical modeling of the elastic, thermoeleastic and two-phase media problem in a regime of finite displacements and deformations From a methodological point of view, the course is an essential junction for the engineer who wants to possess advanced solid mechanics skills before tackling strictly engineering teachings related to phenomena with complex coupled biomechanical problems to be addressed with the help of numerical techniques
TEACHING METHODS	The course program is entirely developed during lecture hours. The lectures are accompanied by exercise sections in class, in order to address students to solve specific problems of continuum mechanics based on the knowledge acquired in class.
SUGGESTED BIBLIOGRAPHY	- Franco M. Capaldi, "Continuum Mechanics: CONSTITUTIVE MODELING OF STRUCTURAL AND BIOLOGICAL MATERIALS", Cambridge University Press. 2015. ISBN: 110748099X, 9781107480995 - Marcelo Epstein "THE ELEMENTS OF CONTINUUM BIOMECHANICS" Wiley, 2012. ISBN: 978-1-119-99923-2

SYLLABUS

Hrs	Frontal teaching
3	Lecture 1.1 - Mathematics background Scalars, Vectors and Second-Order Tensors ; Eigenvalues and Eigenvectors; Spectral Decomposition of a Symmetric Tensor; Coordinate Transformation;
3	Lecture 1.2 - Mathematics background Invariants; Cayley-Hamilton Theorem Scalar, Vector, and Tensor Functions and Fields; Integral Theorems
3	Lecture 2.1 – Kinematics and Strain Tensors Configurations, Velocity and Acceleration, Displacement, Deformation Gradient; Jacobian Nanson's Formula; Homogenous Deformation, Isochoric Deformation, and Rigid Body Rotation
3	Lecture 2.2 – Kinematics and Strain Tensors Material and Spatial Derivatives; Polar Decomposition of the Deformation Gradient; Stretch Ratios Left and Right Cauchy Deformation Tensor; Green Strain Tensor; Almansi Strain Tensor; Infinitesimal Strain Tensor;
3	Lecture 2.3 – Kinematics and Strain Tensors Velocity Gradient, Rate of Deformation, Vorticity Reynolds' Transport Theorem Exercises
3	Lecture 3.1 – Statics and Stress Tensors Mass, Density, and Forces; Traction Vector; Cauchy Stress Tensor; First Piola-Kirchhoff Stress Tensor; Second Piola-Kirchhoff Stress Tensor;
3	Lecture 3.1 – Statics and Stress Tensors Maximum Normal and Shear Stress; Decomposition of the Stress Tensor Exercises
3	Lecture 4.1 – Introduction to Material Modeling Forces and Fields; Balance Laws; Conservation of Mass; Conservation of Linear Momentum Conservation of Angular Momentum; Conservation of Energy; The Second Law of Thermodynamics Summary of the Field Equations;
2	Lecture 4.2 – Introduction to Material Modeling Stress Power; Jump Conditions; Constitutive Modeling; Constitutive Modeling Principles; Principle of Dissipation; Principle of Material Frame Indifference; Material Symmetry
2	Lecture 4.3 – Introduction to Material Modeling Isotropic Scalar-Valued Functions; Isotropic Tensor-Valued Functions; Internal Variables; Thermodynamics of Materials, Elements of Heat Transfer Exercises
3	Lecture 5.1 – Elastic Material Models Finite Thermoelastic Material Model; Forces and Fields; Balance Laws; Constitutive Model; Constraints Due to Material Frame Indifference; Constraints Due to the Second Law of Thermodynamics; Hyperelastic Material Model; Balance Laws; Constitutive Model; Constraints Due to Material Frame Indifference; Clausius-Duhem Inequality; Material Symmetry; Isotropic Materials; Transversely Isotropic Materials; Incompressible Materials; Common Hyperelastic Constitutive Models; Freely Jointed Chain.

SYLLABUS

Hrs	Frontal teaching
3	Lecture 5.2– Elastic Material Models Linear Thermoelastic Material Model, Balance Laws, Constitutive Model, Clausius-Duhem Inequality, Linear Thermoelastic Constitutive Relation, Material Symmetry, Governing Equations for the Isotropic Linear Elastic Material; Uniaxial Tension Test; Kinematics; Isotropic Linear Thermoelastic Material;Incompressible Isotropic Neo-Hookean Model.
3	Lecture 6.1 – Continuum Mixture Theory Forces and Fields, Balance Laws, Conservation of Mass, Conservation of Momentum, Conservation of Angular Momentum, Conservation of Energy, Second Law of Thermodynamics, Biphasic Model, Isothermal Biphasic Model, Application to Soft Tissue, Confined Compression Experiment; Unconfined Compression
3	Lecture 6.2 – Growth Models Forces and Fields; Balance Laws, Conservation of Mass; Reynolds' Transport Theorem; Conservation of Momentum; Conservation of Angular Momentum; Conservation of Energy; Decomposition of the Deformation Gradient; Summary of the Field Equations; Constitutive Model; Uniaxial Loading; Kinematics; Governing Equation.

Hrs	Practice
3	Examples and applications of Mathematics background
3	Examples and applications of – Kinematics and Strain Tensors
3	Examples and applications of – Statics and Stress Tensors
3	Examples and applications of – Introduction to Material Modeling
4	Examples and applications of – Elastic Material Models
4	Examples and applications of – Continuum Mixture Theory