UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2023/2024
BACHELOR'S DEGREE (BSC)	ENERGY ENGINEERING AND RENEWABLE ENERGIES
SUBJECT	MECHANICS OF MATERIALS AND THEORY OF STRUCTURES
TYPE OF EDUCATIONAL ACTIVITY	B
AMBIT	50301-Ingegneria dei materiali
CODE	06313
SCIENTIFIC SECTOR(S)	ICAR/08
HEAD PROFESSOR(S)	PARRINELLO FRANCESCO Professore Associato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	9
INDIVIDUAL STUDY (Hrs)	144
COURSE ACTIVITY (Hrs)	81
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	2
TERM (SEMESTER)	2° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**PARRINELLO FRANCESCO** Tuesday 10:00 13:00 Ex dipartimento di Ingegneria strutturale

DOCENTE: Prof. FRANCESCO PARRINELLO

PREREQUISITES	The course provides for systematic use of concepts and methods of mathematics and geometry. Therefore, knowledge of mathematical analysis, geometry, linear algebra and the basic knowledge of mechanics in the Physics course is required. For the functions of one single variable, it is necessary to know limits, derivatives, integrals, Taylor series expansion and solution of differential equations with constant coefficients. For the functions of multiple variables, the knowledge of the rules of derivation and integration are required.
LEARNING OUTCOMES	Knowledge and understanding ability • The student at the end of the course will have 'knowledge of issues inherent in the mechanics of materials and structures. He will have also confidence with concepts related to the state of strain and stress, moreover, will manage linear elastic-linear constitutive relationships typical of each structural material. The student will know the main relationships that govern the response of structural systems in terms of displacements, strains and stresses. In particular, the student will be able to understand the structural response of beams subject to simple and complex external agencies. Capacity to apply knowledge and understanding • The student will be able to: classify assembled beams as structural systems with degree of hypo-, iso-, hyper-immobility (structure statically determined or undetermined). Assess and mastering the balance equilibrium equations in terms of: external and internal forces, global and local form. Assess the equilibrium of a structure, and describe it, numerically, analytically and graphically. Impose congruence and compatibility conditions for solids and structures. Know the physical and mechanical properties of solid materials such as strength, thermal and elastic stiffness. Know how to determine principal stresses and principal directions at a point and describe them, either analytically or graphically. Know how to determine the stress diagrams for a cross section of a beam (Saint Venant solid) subjected to simple and composed external load of and describe them graphically. Compute displacements, elastic and thermal deformations of the elementary structures; Determine statically indeterminate unknowns and the states of stress and displacement field of statically undetermined structures; determining critical loads and Safety condition for buckling of rectilinear rods loaded at the tip. Making judgments • The student will be motivated to critical thinking and self-evaluation about: - Validity and limits of structural modeling including the limits of the phenomenological models that characterize linear elastic behavior of materials and structures. - The conditions of applicability of structural models, which are adopted for describing actual structures; - The areas of use of the technical theory of the beam and the related criteria structural safety; - Adequacy of static structural systems, appropriate boundary conditions and optimum size and shape of beam cross sections of beam 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 to fundamentals of the discipline (state of stress and strain in solids and in structures, structural classification, the constraints reactions and conditions of maximum stress) 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 mechanics of solids and structures. He will learn the basics of the mechanical behavior of solid materials, including material properties, such as stiffness and strength. These knowledge will contribute to the formation of his wealth of knowledge of mechanics applied to solid materials and structures. These skills constitute also part of the basic engineering education that will allow to continue their engineering studies.
ASSESSMENT METHODS	Learning Assessment takes place through a final exam that ensures the acquisition of the knowledge and skills expected through two written tests (to be done without the help of notes or books), and a subsequent oral test. The student must demonstrate to master the key concepts, application and communicative skills in the course subjects. The first written exam of three (3) hours is considered automatically passed if the student has completed and passed the “in-itinere” written test at the midsemester break. The first written test (or alternatively the “in itinere” test) consists of three exercises: 1) Classification of a structure from a kinematic point of view; 2) Resolution of an isostatic structure;

	3) Representing a stress state with the Mohr Circle. The second written test lasting three (3) hours consists in the resolution of a hyperstatic structure and the verification of the most stressed sections of the structure. The first written test is considered as passed if a sufficient overall rating is achieved and allows access to the second written test. The opportunity to access the second written test is retained throughout the academic year, namely up to the next “in itnere” mid term test test. The student can opt to support the two written tests on the same day, in this case he has 4 hours of time. The second written test is passed if the total evaluation sufficient is achieved and allows access to the oral exam, within the same exam session (Summer, Winter or Extraordinary). The oral test consists of two or three questions that tend to deepen aspects of written tests and to ascertain the student's knowledge of theoretical and applied topics discussed in lessons and exercise sections. The exam score is awarded by a thirty-plus vote which also takes into account written test evaluations. To pass the exam, namely to get a score of not less than 18/30, the student must demonstrate a basic achievement of the targets. The goals achieved are considered elementary, when the student demonstrates that he has acquired a basic knowledge of the topics described in the program, and is able to operate with minimal links between them, also he shows that has 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 goals achieved are considered excellent when examining has gained full knowledge of the topics of the program, demonstrates knowing how to apply the acquired knowledge also in different / new / advanced contexts as opposed to those of teaching, expresses with vocabulary competence Also within the specific reference language and is capable of elaborating and expressing independent judgments based on acquired knowledge.
EDUCATIONAL OBJECTIVES	Primary objective of the course is to provide the basic knowledge of the mechanics of solids together with elements of the theory of structures, developed specifically refered to the application in the field of chemical engineering and materials. In the formulation of the theoretical assumptions (mechanics of continuum solids and beam theory) focus on fundamental relations: balance laws, compatibility relations, principle of virtual work, constitutive equations. In view of applications, the beam theory is widely developed in a specific part of the lecture course; while, in parallel, the Exercise course develops the numerical-applied aspects of simple structural systems. From a methodological point of view, the course is as an essential hub among the basic scientific courses (mathematics, geometry, physics and rational mechanics) employing the same formal rigor, and the subsequent courses more closely related to engineering design and strength check of materials and structures. Final verification develops according to a written exam and to an oral interview in which the student must demonstrate that he has mastered the basics concepts and he has achieved an adequate level of knowledge of the specific topics. The student must also demonstrate that he is able to use independently the tools provided in solving simple problems but paradigmatic of structural cases. The learning mechanism is based on direct involvement of students in practical exercises held in the classroom.
TEACHING METHODS	The course program is entirely developed during lecture hours. The lectures are accompanied by exercises sections in the class in order to guide students to solve specific problems of Mechanics of the structures based on the knowledge acquired in class. At least once, it is planned a visit to the Laboratory of Structural Engineering to show students some tests on materials and structures.
SUGGESTED BIBLIOGRAPHY	• L. Gambarotta, L. Nunziante, A. Tralli, Scienza delle Costruzioni, McGraw-Hill, 2003, EAN: 9788838666971 • C. Polizzotto, Scienza delle Costruzioni, Ed. Cogras, 1985 (Appunti del corso). • F.P. Beer, R.R. Johnston. J.T. DeWolf, Meccanica dei Solidi, McGraw-Hill, 2006, ISBN: 8838663246 • M. Capurso, Lezioni di Scienza delle Costruzioni, Pitagora, 1995, , ISBN: 8837100477 • E. Viola, Esercitazioni di Scienza delle Costruzioni, Pitagora, 1988, ISBN: 8837106653

SYLLABUS

Hrs	Frontal teaching
2	A. THEORY OF STRUCTURES 1A. Introduction Themes and purposes' of mechanics of materials and structures

SYLLABUS

Hrs	Frontal teaching
3	2A. Rigid systems Kinematics, admissible configurations, Euler's theorem; Constraints, Static and kinematic multiplicity. Classification; Reaction of constraints; Cardinal equations of statics; Principle of virtual work and equilibrium conditions
2	3A. Beam systems Kinematic classification of structures; static classification (structure statically determined or undetermined and the concept of kinematic degree of lability). Stresses for structures formed by beams, Work and Energy, Principle of Virtual Work
2	4A. Geometry of Areas Moments of the first order, the transport theorem, center of gravity, moments of the second order, the central ellipse inertia. Analysis of simple and complex sections
3	5A. Resolution of isostatic structures Reactions of internal and external constraints. Axial Force, Shear Force and Bending Moment characteristic diagrams. Application of the principle of virtual work for searching reactions and stresses.
2	6A. Technical theory of Beams Features of stress and deformation for beams in bending. Equations of equilibrium for indefinite inflected beams and boundary conditions. Planar cross section conservation hypothesis and congruence equations. constitutive relationship for bending beams.
2	7A. Resolution of statically indeterminate structures Method of forces and redundant unknowns, Internal work, Muller-Breslau Method.
6	B. MECHANICS OF DEFORMABLE SOLIDS 1B. Statics Continuum solid. global balance laws, defining stress vector; the stress vector decomposition, normal and tangential component; Cartesian components of the stress and the stress tensor; Symmetry of the stress matrix; Cauchy Theorem; Directions, planes and principal stresses; Invariants of the stress matrix; Classification of states of stress (cubic, cylindrical, hydrostatic) Plane state of stress, normal stress component and maximum shear stress. Mohr circle representation, indefinite equations of equilibrium and balance equations on free boundary.
3	2B. kinematics Deformations and continuity bond; Analysis of the deformation in the neighborhood of a point (linearization); Decomposition of the vector displacement gradient; Strain tensor; longitudinal strain, angular (sliding) and rigid motion; volumetric and deviatoric deformation; principal strain and principal strain directions; triaxial state of deformation plane and uniaxial state of deformation. compatibility equations
3	3B. linear elastic constitutive relations Homogeneous and isotropic solids; Uniaxial Test and linear elasticity. Longitudinal elasticity modulus (Young modulus), Shear modulus and Poisson's ratio; Constitutive equations in direct and inverse mode; Effect of temperature variations; orthotropic solids; linear elastic problem and Navier equations.
1	4B. Elements on the failure criteria Brittle and ductile materials; Criterion of maximum principal stress; the maximum strain criterion; Criterion of Tresca and von Mises.
3	C. THE DE SAINT VENANT PROBLEM FOR BEAMS 1C. Generality Problem of de Saint Venant; 3-D and 2-S beam systems with straight axis; cross section and stress characteristics; Equations of congruence and balance.
2	2C. Axial Force Uniform strain and stress state, Uniform temperature variations. Axial Compliance and Stiffness, equilibrium differential equation and boundary conditions, Examples of isostatic beams and statically indeterminate systems
3	3C. Simple bending Theory of Navier-Bernoulli; deformation state and flexural curvature. Cross section stress distribution and neutral axis; Bending Compliance and Stiffness; differential equations of equilibrium and boundary conditions; differential equation of the elastic line; Elements of composite beams.
2	4C. Combined Axial force and bending moment Simple and composed Axial force and bending; Cross section stress distribution and neutral axis collocation; Analysis on section with one or two axis of symmetry.
2	5C. Biaxial Bending and Combined Axial Force and Biaxial Bending Axial force applied at a generic point of the cross section. Stress distribution and neutral axis; central core of inertia of a section.
2	6C. Shear Force Tangential stresses and shear force; Equilibrium and state of deformation in a cross section of a bar; Combining shear force and bending moment, Jourawsky equation; Shear stiffness and compliance; stress safe design of sections with simple and double axis of symmetry.
2	7C. Torque Kinematics of the deformation of beams with polar symmetry section; Distribution of shear stress; Torsional stiffness and compliance. Twist angle. Analysis of beams with thin-walled cross section and Bredt equation;

Hrs	Practice
2	A. STRUCTURAL ANALYSIS 1A. Exercises and applications on the Rigid structural Systems Kinematics, admissible configurations, Euler's theorem; Constraints: static, kinematic multiplicity and related classification; Reaction of constraints; Cardinal equations of statics; Principle of virtual work for the equilibrium conditions
6	2A. Exercises and Applications on Beam Systems Kinematic classification of structures; static classification. Stresses, Work and Energy, Principle of Virtual Work
2	3A. Exercises and applications on geometry Areas Moments of the first order, transport theorem, center of gravity, moments of the second order, the central ellipse of inertia. Analysis of simple and complex cross sections
6	4A. Solution of statically determined structures Reactions of internal and external constraints, Axial force, Shear Force and Bending moment diagrams. Application of the principle of virtual work the determination of constrain reactions and stress at a section.
1	5A. Exercises and Applications on Beams Differential equations of equilibrium for indefinite inflected beams and boundary conditions. Hypothesis of plan cross section conservation and compatibility equations.
6	6A. Solution of statically undetermined structures Force method and redundant unknowns. Internal Work, principle of virtual work, energy theorems: Clapeyron, Betti and Maxwell. Applications and solution of statically undetermined structures
2	B. MECHANICS OF DEFORMABLE SOLIDS 1B. Exercises and Applications of Statics of continuum stress vector; the stress vector decomposition, normal and tangential component; Cartesian components of the stress and the stress matrix; Directions, planes and principal stresses; Invariants of the stress matrix; State of plane stress, normal stress and maximum shear, Mohr representation.
2	C. THE DE SAINT VENANT PROBLEM FOR BEAMS 1C. Exercises and Applications for beams subject to Axial Force. Uniform state of strain and stress. Uniform temperature variations, Axial Compliance and stiffness. Equilibrium differential equation and boundary conditions, Examples of statically determined and undetermined beams Truss structures.
2	2C. Exercises and Applications for beams subject to simple bending Theory of Navier-Bernoulli; strain state and bending curvature, stress distribution and neutral axis; Bending compliance and stiffness. Differential equations of equilibrium and boundary conditions; differential equation of the elastic line; Composite beams; Elements of the Timoshenko theory; Applications to simple restrained beams statically either determined or undetermined.
1	3C. Exercises and applications for beam subjected to combined axial force and bending moment In-plane bending; Stress distribution and neutral axis; stress analysis and safe design for sections with two or one axis of symmetry.
2	4C. Exercises and Applications for beams subject to Biaxial Bending and Combined Axial Force and Biaxial Bending. Stress distribution and neutral axis; central core of inertia of a section, Analysis and safe design of sections.
2	5C. Exercises and applications for beams subject to Shear force tangential stress and shear force; Equilibrium and state of deformation of the cross section; Approximate solution of Jourawsky; Shear Compliance and Stiffness; Safe deign of sections with single and double axis of symmetry.
2	6C. Exercises and applications for beams subject to torsion Beams with polar symmetry cross section; Distribution of strains and shear stresses; Applications to beams; Analysis of beams with thin-walled cross section and report Bredt equation.