UNIVERSITÀ
DI PARMA

Dipartimento di Ingegneria dei Sistemi e delle Tecnologie Industriali - DISTI
Department of Engineering for Industrial Systems and Technologies (DEIST)

Nonlinear Continuum Mechanics

Graduate Course (20 hours)

First semester 2025/2026

Venue: University of Parma, Parco Area delle Scienze, Parma

Lecturer: Gianni Royer Carfagni (gianni.royer@unipr.it)

The purpose of this course is to show how the non-linear analysis of structural elements subject to external actions cannot be reduced to simply checking a box on a drop-down menu in a commercial software such as Abaqus. Far from being exhaustive, I intend to present the basic principles that make it possible to acquire, at least, the nomenclature commonly used in non-linear structural mechanics. I hope that, after attending the course, the student will be able to make a more conscious use of the great computing capacities available today which, unfortunately, are too often abused. The topics that will be covered are summarized below.

Preliminaries. Euclidean space, points, vectors, tensors. Scalar product of vectors. Tensor product. Trace operator. Inverse of a tensor. Orthogonal tensors. Rotations. Oriented area and cross product of vectors. Volume and triple product of vectors. Determinant of a tensor. Symmetric and skew tensors. Green Theorem and transformation of surface integrals in volume integrals.

Analysis of the deformation. Actual and deformed configuration. Deformations defined by mappings. Homogeneous deformation. Pure deformations. Rotations. Polar decomposition theorem. Plane deformations. Infinitesimal deformations.

Stress and balance laws. Forces. Contact forces. Euler separation axiom. Principle of local action. Simple materials. Cauchy's theory and the definition of stress. Conservation of mass. Piola transformation. Balance of linear momentum. Balance of angular momentum. Cauchy stress tensor. First and second Piola-Kirchhoff stress tensors.

Work of deformation. Work done by the external forces. Rate of change of kinetic energy. Work expended to deform the body. Work conjugation of the Cauchy, first and second Piola-Kirchhoff stress tensors, with the corresponding measures of deformations.

Constitutive equations. General forms of the constitutive equations. Principle of determinism. Material frame indifference. Restrictions on the form of the equations. Correspondence with the molecular theory. Constitutive symmetries. Specialization to infinitesimal deformations.

Credit Requirement - Seminar Lecture: Students earn course credit by successfully presenting a lecture on an instructor-assigned research paper. This paper will delve into advanced topics connected to the course subject matter.