



**Graduate course**

# **Nonlinear Material Mechanics**

**November 15<sup>th</sup> – 17<sup>th</sup> 2023**

**November 22<sup>th</sup> – 24<sup>th</sup> 2023**

**Hosted by:**

**Faculty of Engineering Technology  
University of Twente**



**UNIVERSITY OF TWENTE.**

## General

This course is an initiative of the Dutch graduate school Engineering Mechanics. The course is part of the 3TU Engineering Mechanics training programme for PhD students. As part of this programme a series of graduate courses is organized, related to the following research themes:

- Computational and Experimental Mechanics of Materials
- Structural Dynamics and Control
- Reliability and Optimization
- Linear and Nonlinear Material Theory

## Objective

Reliable simulation tools in engineering and design require accurate material models. Nonlinear material behaviour plays an essential role in many applications of engineering mechanics. The engineering response of materials essentially results from the physics and mechanics of their underlying microstructure. The distinction between materials science and mechanics is becoming more and more diffuse. Multi-phase structures, voids, grains, interfaces and the presence of additional phases play an intrinsic role. Using proper knowledge from mechanics and advanced computational tools one can reach an improved understanding of the mechanical behaviour and properties of commonly applied and new materials.

This course focuses on a presentation of the fundamental aspects of the modelling of nonlinear material behaviour. It includes large deformations and solution techniques. Applications include e.g. metals and multi-phase brittle and granular materials.

Attention will be given to kinematics, stress and balance laws, thermodynamics, hyperelasticity, plasticity, anisotropy, multi-phase materials, phase transitions and damage. On the numerical side, nonlinear solution techniques, higher order continua, and discontinuous models will be introduced. In addition to continuum theory and methodology, also particle methods and the micro-macro transition from particle methods to continuum theory will be introduced.

## Local organization

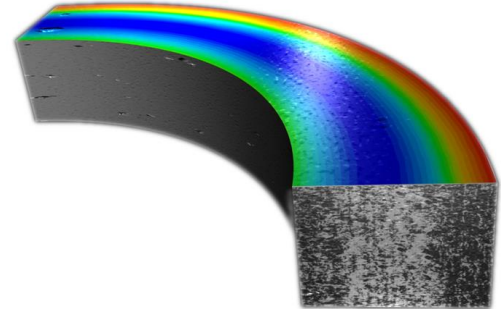
The course is organized by the *Nonlinear Solid Mechanics* group and the *Multi-scale Mechanics* group, University of Twente, faculty of Engineering Technology, and the *Computational Mechanics* group, Delft University of Technology, Department of Civil Engineering and Geosciences.

Organizing committee:

- Ton van den Boogaard
- Stefan Luding
- Bert Sluys

## Lecturers

- Ton van den Boogaard (UT)
- Remko Akkerman (UT)
- Stefan Luding (UT)
- Vanessa Magnanimo (UT)
- Semih Perdahcioğlu (UT)
- Bert Sluys (TUD)
- Thomas Weinhart (UT)
- Celal Soyarslan(UT)



## Contents

- Vectors and tensors
- Kinematics (material coordinates, deformation & strain tensors, polar decomposition)
- Force and stress, Balance laws
- Fundamental concepts of constitutive equations (thermodynamics, frame indifference, elasto-viscoplasticity, yielding and hardening)
- Multi phase materials (phase transition, TRIP, composites, anisotropy)
- Plasticity models and continuum damage models (yield functions, damage loading functions, tangential formulation, return mapping, locking)
- Higher-order continua (non-local, gradient models, micro polar models)
- Deformation mechanics in composite laminates, extreme anisotropy and intraply shear locking
- Particle Methods (particle systems, molecular dynamics for particle systems, smooth particle hydrodynamics for continuum systems)
- Depth-averaged models (applied to granular systems)
- From Particle Systems to Continuum Theory (micro-macro transition methods, plastic flow models, higher order continua, advanced theories)
- Nonlinear solution techniques (Newton-Raphson methods, convergence criteria, Load-, displacement-, arc-length-control)
- Discontinuous models (weak/strong models (GFEM/XFEM), continuous-discontinuous models)

## Lecture notes

Lecture notes will be distributed during the course.

## Prerequisites

Basic undergraduate courses in Mathematics, Materials science, Mechanics of materials, Continuum Mechanics and the Finite Element Method.

## Location/date

The course will take place at the University of Twente in two modules of three days each, i.e. November 15th – 17th and November 22th – 24th 2023, respectively. The course language is English.

## Fee/Registration

The course is free for registered members of the graduate school Engineering Mechanics and for the research members of the contributing research groups. The course fee for non-EM members is € 250 for PhD students and € 1000 for other participants. The fee includes lunch and coffee breaks, but does not include lodging and other meals. Participants will receive an invoice after accepted registration. Participants need to register via our website <https://engineeringmechanics.nl/courses/> **before November 5<sup>th</sup>, 2023**. Members of the Graduate School Engineering Mechanics receive priority in case of over-subscription.

## Further information

On the content of the course:

Dr. Javad Hazrati

E-mail: [j.hazratimarangalou@utwente.nl](mailto:j.hazratimarangalou@utwente.nl)

On the organization of the course:

Ms. Tjerkje Dijkstra-van der Veen

E-mail: [t.j.dijkstra-vanderveen@utwente.nl](mailto:t.j.dijkstra-vanderveen@utwente.nl)

Further information about the educational programme and other activities of the Graduate School on Engineering Mechanics can be found at: <https://engineeringmechanics.nl/courses/>

