PX912-15 Multiscale Modelling Methods & Applications II

20/21

Department
Physics
Level
Taught Postgraduate Level
Module leader
James Sprittles
Credit value
15
Module duration
10 weeks
Assessment
60% coursework, 40% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

N/A.

Module web page

Module aims

To provide students with a firm foundation in the macroscopic modelling of fluid flows and solid deformation in order to describe a phenomenal range of natural and technological processes. Classical approaches to formulating and solving the equations of continuum mechanics will be covered, but our primary focus will be to explore and understand recent approaches to developing classes of macroscopic models that are connected to an underlying microscopic description via multiscale techniques.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

The following syllabus is a superset of what can be covered in this module. The majority of Sections 1,2,4 will be covered whilst the topics for Sections 3 and 5 are intended vary year-to-year (Exemplars are provided).

1. Foundations of Continuum Mechanics (4 lectures)
   (a) physical properties of materials
   (b) continuum approximation
   (c) Eulerian/Lagrangian descriptions
   (d) vectors and tensors
   (e) theory of deformation
   (f) stress and deformation measure
   (g) conservation of mass
   (h) equations of motion/linear momentum balance
   (i) principle of virtual work

2. Classical Fluid Mechanics (4 lectures)
   (a) Viscous incompressible Newtonian fluids
   (b) interfacial dynamics
   (c) boundary conditions, initial conditions
   (d) dimensionless parameters
   (e) general concepts of thermodynamics
   (f) energy equations
   (g) computational fluid dynamics

3. Recent Developments in Multiscale Fluid Mechanics - Topic Flexible (4 lectures)
   Example 1: From Kinetic to Continuum for Gas Microflows
   (a) introduction to the Boltzmann equation
   (b) Grad's method of moments
   (c) Chapman-Enskog expansions
   (d) connection to and derivation of macroscopic models
   Exemplar 2: Secondary Continuum Limit for Particulate Flows
   (a) motion of single particles within Stokes flow, fundamental solutions
   (b) ensemble averages for dilute suspensions
   (c) emergence of non-Newtonian behaviour
   (d) method of fundamental solutions for microflows
   Exemplar 3: Thermal Fluctuations in Fluid Flow
   (a) introduction to fluctuating hydrodynamics
   (b) Landau-Lifshitz Navier-Stokes
   (c) simplified configurations
   (d) computation of SPDEs

4. Classical Solid Mechanics (4 lectures)
   (a) general theory
   (b) linear elasticity, displacement formulation, derivation of Navier-Lame equation, boundary conditions (Neumann, Dirichlet, mixed)
   (c) simple configurations
   (d) weak form of BVP
   (e) discretisation and FE solution

5. Recent Developments in Multiscale Solid Mechanics - Topic Flexible (4 lectures)
   Exemplar 1: Incorporating Microstructure
   (a) mean-field approaches
   (b) heterogeneous multiscale methods
   (c) separation of scales, localisation, homogenisation
   (d) Representative Volume Element (RVE), periodic boundary conditions
   (e) nested approach

Learning outcomes

By the end of the module, students should be able to:

- It is expected that by the end of this module students will be able to understand the foundations of continuum mechanics and derive the classical governing equations of fluid and solid mechanics.
- It is expected that by the end of this module students will be able to appreciate the relationships between different modelling frameworks.
- It is expected that by the end of this module students will be able to engage with cutting-edge topics in the multiscale modelling of materials.
- It is expected that by the end of this module students will be able to develop and apply appropriate computational methods to solve real world phenomena.

Indicative reading list

D.J. Acheson, Elementary Fluid Dynamics
G. K. Batchelor, An Introduction to Fluid Dynamics
P.A. Kelly, Mechanics Lecture Notes: An introduction to Solid Mechanics. University of Auckland, 2019 (online).
G.A. Holzapfel, Nonlinear Solid Mechanics: a continuum approach for engineering, Wiley, 2010.

Subject specific skills

It is expected that by the end of this module students will be able to:

understand the foundations of continuum mechanics and derive the classical governing equations of fluid and solid mechanics

appreciate the relationships between different modelling frameworks

engage with cutting-edge topics in the multiscale modelling of materials

develop and apply appropriate computational methods to solve real world phenomena

Transferable skills

Coding, problem solving, writing

Study

Study time

Type	Required
Lectures	10 sessions of 2 hours (13%)
Supervised practical classes	10 sessions of 2 hours (13%)
Private study	40 hours (27%)
Assessment	70 hours (47%)
Total	150 hours

Private study description

Reading set material, preparation for projects.

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group D

	Weighting	Study time
Fluids Project	30%	30 hours
On Section 3 (Multiscale Fluids). Each of which will contain a computational component.		
Solids Project	30%	30 hours
On Section 5 (Multiscale Solids). Each of which will contain a computational component.		
Viva Voce Exam	40%	10 hours
On core material. 30 minutes long.		

Feedback on assessment

-\tWritten annotations on submitted projects\r\n-\tVerbal discussion during viva voce exam\r\n-\tWritten summary of viva performance

Past exam papers for PX912

Availability

Courses

This module is Core for:

- Year 1 of TPXA-F344 Postgraduate Taught Modelling of Heterogeneous Systems
- Year 1 of TPXA-F345 Postgraduate Taught Modelling of Heterogeneous Systems (PGDip)