

LTCC Advanced Course

Title: Continuum Mechanics Beyond Newtonian Fluids (extended)

Basic Details:

- Core Audience: first-year app.
- Course Format: Continuum Mechanics Beyond Newtonian Fluids (extended)

Course Description

Keywords:

continuum mechanics, viscoelasticity, biological complex fluids, non-equilibrium mechanics

Syllabus:

We cover the following topics in each block:

1. Fluid Mechanics:
Reynolds number, Stokes equation, Green's functions for point forces, force-dipole solutions, and boundary effects
2. Solid Mechanics:
displacement and strain, linear elasticity, surface point-force and stress solutions, and bending of elastic beams
3. Viscoelasticity:
Maxwell and Kelvin-Voigt models, stress relaxation, creep response, and oscillatory shear and complex modulus
4. Active Fluids:
introduction to active matter, active stress in constitutive law, active polar and nematic systems, and spontaneous flow instabilities
5. Active Solids:
strain-stress work cycles, non-reciprocal response, odd elasticity, and mechanical waves and instabilities

Recommended reading:

- [1] D. Tong, *Fluid Mechanics* (Cambridge University Press, 2025).
[2] P. M. Chaikin & T. C. Lubensky, *Principles of Condensed Matter Physics* (Cambridge University Press, 1995).
[3] The Provided Electronic Lecture Notes

Additional optional reading:

- [1] L. D. Landau & E. M. Lifshitz, *Fluid Mechanics*, 2nd edition (Butterworth-Heinemann, 1987).
[2] L. D. Landau, E. M. Lifshitz, A. M. Kosevich & L. P. Pitaevskii, *Theory of Elasticity*, 3rd edition (Butterworth-Heinemann, 1986).
[3] J. D. Ferry, *Viscoelastic Properties of Polymers*, 3rd edition (John Wiley & Sons, 1980).

[4] M. Fruchart, C. Scheibner & V. Vitelli, *Odd Viscosity and Odd Elasticity*, **Annu. Rev. Condens. Matter Phys.** **14**, 471–510 (2023).

[5] M. C. Marchetti, J. F. Joanny, S. Ramaswamy, T. B. Liverpool, J. Prost, M. Rao & R. A. Simha, *Hydrodynamics of Soft Active Matter*, **Rev. Mod. Phys.** **85**, 1143–1189 (2013).

Prerequisites:

Students should be familiar with vector calculus, ordinary and partial differential equations, and basic fluid mechanics or continuum mechanics. Some prior exposure to tensor notation would be useful but is not essential.

Format

No of discussion/problem sheets (typically 4 for extended courses, and 1 for intensive courses, with solutions): Four problem sheets; one for each block.

Electronic lecture notes (these are strongly encouraged, as they will form the core of the individual study of the students): Electronic lecture notes will be provided in advance.

Necessary support facilities: None

Necessary software requirements for computing facilities: None

Lecture/computer session/tutorial/discussion split (hours of each): 1 hour lecture plus 1 hour problem solving for each block

Lecturer Details

Lecturer: Dr. Cheng-Tai Lee

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