Course Overview. A journey through soft materials—from everyday foams and gels to polymer networks and interfacial dynamics. We develop the conceptual and mathematical foundations to understand why soft matter behaves so differently from hard solids and liquids.

Course Goals

- Develop a basic understanding of key concepts in Soft Condensed Matter
- Recognize parallels and differences between Soft Matter and 'Hard Matter' systems
- Engage critically with publications and seminars (assessed in final presentations)
- Learn how to contribute to Open Source Science (mid-course assignment)

Course Structure (Lectures + Bridges)

- Lecture 1: **Different Faces of Soft Condensed Matter** – What is soft matter, why is it soft, and how do we measure softness?
  - **Bridge 1.5: The Taylor–Culick Paradox** – Resolving a century-old paradox through proper energy accounting and momentum conservation
  - **Homework Solutions: Lecture 1** – Self-assessed questions with model answers
- Lecture 2: **Viscosity and Momentum Diffusion** – Viscosity as an emergent property from kinetic theory; the no-slip condition; continuum momentum transport
  - **Bridge 2.5: From Newton's Laws to Conservation Equations** – Microscopic particle dynamics to continuum momentum balance and Cauchy stress
- Lecture 3: **Soft Matter Instabilities** – Pattern formation through instability mechanisms: Rayleigh–Plateau, Kelvin–Helmholtz, Rayleigh–Taylor, Faraday waves, Rayleigh–Bénard–Marangoni, Saffman–Taylor fingering, and viscous coiling. Understanding how competing forces select characteristic length scales and how to harness instabilities for fabrication.
- Lecture 4: **Soft Matter Singularities** – Finite-time singularities, contact lines, and the mid-course open-science assignment
- Lecture 5: **Elastic, Viscous, and Viscoelastic Behaviour** – Constitutive response, mechanical analogues, and relaxation times
- Lecture 6: **Rheology** – Measuring softness and interpreting time-dependent response
- Lectures 7–8: **Student Presentations** – Paper-led synthesis and discussion
  - **Presentation Paper Topics** – Paper choices, preparation process, and assessment criteria

Administrative Information

Course Details

- Format: Six one-hour lectures plus one two-hour presentation session (8 contact hours)
- Homework: Short self-assessed questions at the end of each lecture (model solutions provided)
- Office Hours: Announced at the start of each course run, or by appointment via vatsal.sanjay@durham.ac.uk
- Assessments:
  - Mid-course: Open Source Science contribution (40%, after Lecture 4), with feedback before the final assessment
  - Final: Student presentation (60%, final course session)
- Grading: Mid-course assignment (40%), final presentation (60%)

Key Learning Outcomes

By the end of this course, you will be able to:

1. Identify soft matter in everyday materials and explain what makes it “soft”
2. Explain the microscopic origins of soft material properties (entropy, surface tension, weak interactions)
3. Compare and contrast soft and hard condensed matter using scaling arguments and dimensional analysis
4. Apply continuum mechanics to soft matter problems (flows, instabilities, deformations)
5. Interpret rheological data and connect microscopic structure to macroscopic behavior
6. Critically read soft matter research papers and engage in scientific discussion

How to Use These Lecture Notes

- Start here: Read **Lecture 1** for foundational concepts and examples
- Work through systematically: Each lecture builds on the previous one
- Try the homework: Self-assessment questions reinforce key ideas
- Use the references: Further reading suggestions at the end of each lecture
- Engage with videos and figures: Visual examples illustrate abstract concepts

Recommended Prerequisites

- Physics: Mechanics (Newton's laws, energy, momentum)
- Mathematics: Calculus (derivatives, integrals), linear algebra basics
- Chemistry: Basic atomic/molecular structure, thermodynamics concepts

No prior knowledge of soft matter or materials science is required.

Textbooks & References

This list will be populated as we go through the course

Primary References

- de Gennes, P.-G. (1979). *Scaling Concepts in Polymer Physics*. Cornell University Press. **Amazon UK**
- Oswald, P. & Pieranski, P. (2005). *Nematic and Cholesteric Liquid Crystals: Concepts and Physical Properties Illustrated by Experiments*. Taylor & Francis.
  - **DOI: 10.1201/9780203023013**
  - Detailed experimental and theoretical treatment

Modern Overviews

- Tom McLeish, *Liquid Crystal Polymers* (Oxford University Press, 2018) — contemporary soft matter overview **Link**

Research Journals

- *Phys. Rev. Fluids* (APS)
- *J. Fluid Mech.* (Cambridge)
- *Soft Matter* (Royal Society of Chemistry)
- *Langmuir* (ACS)

Contact & Support

Instructor: Vatsal Sanjay Email: **vatsal.sanjay@durham.ac.uk** Office Hours: Announced at the start of each course run, or by appointment.

Have questions? Come to office hours or send an email — I'm here to help!

Metadata

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