Non-Newtonian fluid mechanics (M24)

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The relationship between the stress applied to a material and its kinematic response is known as its rheology. It is common in fluid mechanics to assume a so-called Newtonian rheology, in which stress and strain rate are linearly related. This assumption is inaccurate for many fluids; attempting to model, predict and understand the wealth of more complex constitutive behaviour that is exhibited by these materials makes up the field of *non-Newtonian fluid mechanics*. Many fluids we experience on a daily basis are non-Newtonian: ketchup, mayonnaise, shampoo and shaving foam all exhibit complex constitutive behaviour encompassing elasticity, plasticity, ageing and jamming. Geophysical and biological materials are also commonly non-Newtonian in character: lava, mud, sand, blood, and mucus, for example, all behave in ways that are not well described by a simple Newtonian rheology.

This course will introduce the mathematical framework for continuum modelling of non-Newtonian fluids in different contexts. After a general introduction to the fascinating and varied phenomenology exhibited by these materials, the course will cover a selection of topics including:

- Non-linear 'generalised-Newtonian' fluids;
- Viscoplastic fluids;
- Viscoelastic fluids: linear and non-linear models; convective derivatives;
- More complex rheology: memory effects; granular media; mechanics of suspensions;
- Flow problems involving non-Newtonian fluids; physical and geophysical modelling with non-Newtonian fluids.

By the end of this course, students will be equipped with the skills necessary to carry out independent research in academic or industrial fields involving complex fluids and rheology.

Prerequisites

Undergraduate viscous fluid mechanics, vector calculus and mathematical methods.

Literature

1. Barnes, H.A., Hutton, J.F. and Walters, K. *An Introduction to Rheology*, Elsevier 1989.
2. Tanner, R.I. *Engineering Rheology*, 2nd edition. OUP 1999.
3. Bird, R.B., Armstrong, R.C. and Hassager, O. *Dynamics of polymeric liquids, vol.1*, 2nd edition. Wiley 1987.

Additional support

Four examples sheets will be provided, with associated examples classes. There will be a revision class in the Easter Term.