Non-Newtonian Fluid Mechanics (M16)

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Standard courses in fluid mechanics are concerned with the dynamics of Newtonian flows. In the Newtonian limit, viscous stresses depend linearly on the instantaneous deformation rate of the fluid. However, in many instances relevant to industry as well as natural and physical sciences, a wide variety of fluids display non-Newtonian behaviour. In fact, we are all familiar with these fluids in our daily life. For example, in the kitchen, while water and olive oil are Newtonian, mayonnaise and ketchup are non-Newtonian fluids. Similarly, in the bathroom, toothpaste, shampoo and shaving cream are materials which can be made to flow like liquids but also share many properties with elastic solids. Most biological fluids are also non-Newtonian, in particular blood. In this course, we give an introduction to the mathematical modelling of flowing Non-Newtonian fluids.

After introducing the experimental phenomenology of non-Newtonian flows, we will present the mathematical frameworks to tackle:
(i) Generalised Newtonian fluids with instantaneous but nonlinear stress-deformation responses;
(ii) Linear viscoelastic fluids that have a memory of their past deformation;
(iii) Nonlinear viscoelastic fluids displaying normal stress differences and resistance to extension;
(iv) Yield-stress fluids that can only deform if applied stresses exceed critical values;
(v) Viscoelastic instabilities.

Throughout the course, mathematical modelling will be motivated and compared with experiments. At the end of the course, students will be equipped with the necessary skills to carry out independent research in complex fluids and rheology relevant to a wide range of scientific problems, for both fundamental research and industry.

Pre-requisites

Undergraduate fluid dynamics, vector calculus and mathematical methods.

Literature

1. National Committee for Fluid Mechanics Film on "Rheological Behavior of Fluids" at: `http://web.mit.edu/hml/ncfmf.html`
2. F. A. Morrison (2001) Understanding Rheology, Oxford University Press.
3. R. B. Bird, C. F. Curtiss, R. C. Armstrong, and O. Hassager (1987) Dynamics of Polymeric Liquids, Vol. 1: Fluid Mechanics, 2nd ed, Wiley.

Additional support

Three examples sheets will be provided and three associated examples classes will be given. There will be a revision class in the Easter Term.