Math 451 - Methods of Applied Mathematics II

Spring 2015

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Textbook:
There is no mandatory text for this section. The following books and materials will be used:
1. D.J. Acheson, Elementary Fluid Dynamics, Oxford Applied Mathematics and Computing Science Series, 1990, ISBN-13: 978-0198596790 (available in the library or from the instructor).
2 K. W. Morton and D. F. Mayers, Numerical Solutions for Partial Differential Equations: An Introduction, Cambridge, 2005, ISBN-13: 978-0521607933j (available in the library or from the instructor.)
3. Selected research articles (to be provided by the instructor).

Grading policy:

Projects and presentations through the semester: 70%
Final report and presentation: 30%

Course Outline

Theoretical, computational, and experimental research:

Instabilities in two-phase flow of complex fluids

Overview: Two-phase flow in Hele-Shaw geometry (flow in the gap between two plates) will be considered. This flow may become unstable leading to pattern formation. The focus of the class will be exploring the nature of the instabilities leading to pattern formation and their mathematical description for flows of Newtonian fluids, liquid crystals, and shear-thinning fluids.

Theoretical component:
(1) Navier-Stokes equations in viscous regime; simplifications in Hele-Shaw geometry using consistent asymptotic expansion;
(2) Understanding of the concept of instability in a two-phase flow; discussion of Saffman-Taylor instability;
(3) Introducing and implementing the concept of linear stability analysis;
(4) Discussing modifications of linear stability analysis due to non-Newtonian (shear thinning) behavior on instability development.
(5) Discuss the formulation of Hele-Shaw limit for liquid crystal flows.
(6) Discuss influence of electric field on instabilities in Hele-Shaw flow of liquid crystals.

Computational component:
(1) Finite difference based methods for solving linear and nonlinear elliptic problems;
(2) Boundary integral methods for solving linear elliptic problems;
(3) Applications of the numerical methods (1) and (2) to Saffman-Taylor instability;
(4) Development of diffusion-limited aggregation (Monte-Carlo type of simulations) approach to simulating Hele-Shaw flow of two fluids; applications to Newtonian, liquid crystal, and shear-thinning flow configurations.

Experimental component: Carrying out experiments involving an air or water bubble spreading into (1) viscous fluid (glycerin); (2) nematic liquid crystal with and without electric field, and (3) shear-thinning fluid such as corn starch. Discuss the issues involved in carrying out controlled, reproducible experiments and quantify the error bounds. Interpret the results in the context of the theoretical and computational results.