The Hele-Shaw Cell

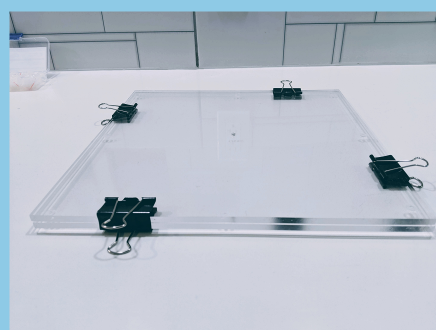
Note: This is not a full project, just the outline of an idea. Use it as a starting point, but go further, be more complete and careful.
You're expected to do your own literature search on the topic.
Ask questions, find the answers.

Description: A Hele-Shaw cell is formed by two close-spaced plates with fluid confined between them. This makes for an essentially two dimensional flow, and the close spacing of the plates ensures the flow is very viscous (very low Reynolds number). A key experiment with a Hele-Shaw cell involves pumping a second fluid into the gap, leading to instabilities in the interface between the fluid, called "radial fingering" or "fractal viscous fingering." This experiment gets you to reproduce these instabilities and perform some analysis on them.

References: T. Maxworthy, *Physical Review A*, Vol. 39, No. 11, June 1989; Lincoln Paterson, *Journal of Fluid Mechanics*, Vol. 113, December 1981; Stephen Morris, Advanced Physics Laboratory, U. of Toronto, 2018 (www.physics.utoronto.ca/~phy326/fvf).

Suggested Materials

Two clear acrylic sheets (12"x12" or similar)
Large syringe and tubing
Nylon washers/spacers
Binder clips
Vegetable oil or similar
Camera (high speed preferable, but a smart phone will do)
Tracker Video Analysis and Modelling Tool (physlets.org/tracker)



Use the binder clips to secure the two acrylic sheets, with thin spacers between. One sheet has a hole drilled in the centre for the syringe to deposit fluid.

Vegetable oil was pumped into the space between the sheets, and then air was slowly pumped in to form the fingers.

Basic Analysis: The growth of the instabilities were measured by first tracking the size of one particular finger (Figure 1) and then by counting the number of fingers that appear as a function of radius r of the instabilities (Figure 2). In this linear regime, the growth rate slowed down as the instabilities grew, as expected.

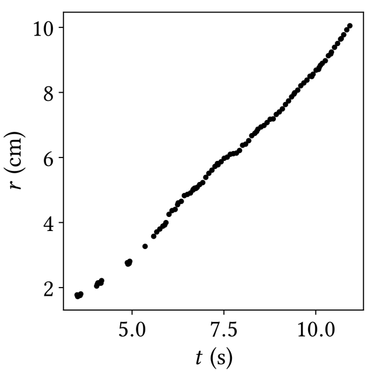


Figure 1 - Length of one particular finger r as the instability grows.

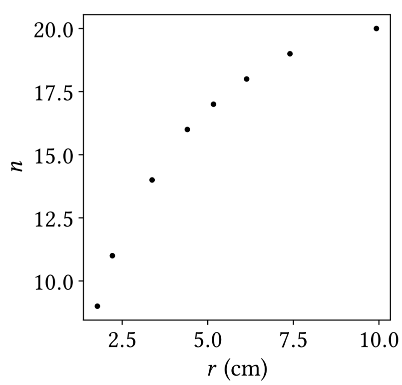
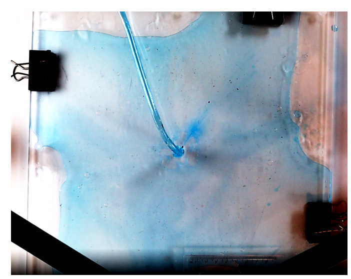
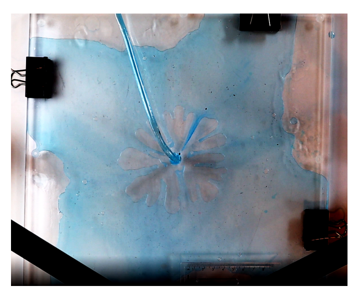
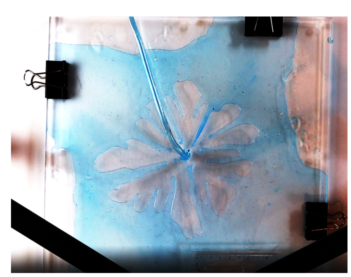


Figure 2 - Number of fingers n as the radius of the instability grows.







Further Work

This is a well studied experiment and there are numerous things to do beyond this quick demonstration. Try different fluids. Try different pressures and spacing. Calculate the Reynolds number of the flow as well as the capillary number. If you have a high speed camera, increase the pressure so that the instabilities become strongly nonlinear. What else can you measure and what else has been predicted in the literature?