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Stokes' Law Exercise for "Rocks and Minerals"

In this exercise students determine the velocity of different kinds and sizes of particles through different kinds of fluids. I designed this activity to serve several purposes. One purpose is to help students understand how sediments settle out through fluids (sorting, graded bedding). Another is to give students to apply a range of basic quantitative skills.

I use this exercise in my Rocks and Minerals course. This is a 200-level (second-year) course that is required for Earth Science majors and minors, and Physical Geology is the only prerequisite for this course. The number of students in the course is usually around 20, and I have students do the activity in groups of four.

I begin by asking the students to consider what factors will affect how fast a particle will fall through a fluid. They brainstorm with each other in their groups for a few minutes, and then I ask each group to contribute one of their ideas to a brief class discussion (think-pair-share techniques). Each group then formulates a formal hypothesis to test. Later on, these hypotheses and the students' subsequent observations will help the class to collectively come close to "deriving" Stokes' Law. They usually come up with something like "velocity of settling is directly proportional to particle density and diameter, and inversely proportional to fluid viscosity." They may or may not use these terms, but I introduce them (or remind the students of them) as we go through our discussion.

Different groups of students choose different fluids for their settling experiments. I use water, corn oil, corn syrup, and honey. I have particles of varying diameters and densities available for the students to use. Basically they time how long it takes a given particle to travel a fixed distance through a column of fluid (large graduated cylinder). They make measurements, record data, make graphs of their data, and compare data sets between groups.

I lead the students in a discussion about controlled variables, errors in measurement, experimental design limitations, accuracy and precision, and a little bit about statistics. We also talk about the importance of units and unit conversions, and of making graphs to help us make better sense out of the data. For example, when looking at a graph of particle diameter versus settling velocity for a given mineral in a given fluid, is there a correlation? Is it a positive or negative correlation? Is it linear or non-linear? If non-linear, what might the mathematical relationship be instead and how could we find out?

After we "derive" Stokes' Law qualitatively/semi-quantitatively, I give them the full equation and ask them to pick at least one of their data points and compare the measured settling velocity to the velocity they calculate with the equation (given values for fluid viscosity and density). I also ask them to pick at least one other data point, and assuming their measured settling velocity is correct, calculate the viscosity of the fluid (given fluid density). This gives them an idea of how accurate their measurements were.

During another class period, after the students have written up the lab report for this activity, I have them use Stokes' Law to estimate how long it would take a crystal of olivine 1 cm in diameter to settle to the bottom of a basaltic magma chamber that is 10 meters in its vertical dimension. I give them tables of data for liquidus and solidus temperatures for different magma compositions, for viscosity of magmas of different compositions as a function of temperature, for density of magmas of different compositions as a function of temperature, and for density of olivine as a function of olivine composition. I ask them to justify the values that they choose to use. This helps them see that solving problems isn't always strictly "plug and chug" with one exact answer. There is plenty of opportunity to discuss order of magnitude estimates and significant figures, and students get lots of practice with unit conversions.