# Material Behavior at Rest and in Motion

### General notes on weekly assignments

Some of what you do each week will be used much later. The general idea is to give you hands-on experience answering questions that require your own observations to be integrated with lecture materials and with readings. I'd like you to do today's assignment for Friday in the usual way. I will give a grade, but I will not record it. The idea is to give you experience in what to expect (and to get you started on thinking about material properties, a thread that we will pick up again much later). *Think about the difference between a property of a material versus characteristics of a flow of that material. Note that granular material, liquids and gases can flow. Begin to think about how flows of liquids and granular materials (e.g., in an hour glass) differ both qualitatively and quantitatively. Does an hour glass slow down as "time runs out?"* We will not deal much with gases, but be aware that much of what you learn about behavior of water when it flows also applies to air when it flows. As you probably recall, however, a gas expands to fill its container.

### Today's questions/assignments

## Background

Loosely, the angle of repose is the maximal angle that a free surface (not locally confined or supported by some other structure) at rest will hold with respect to a horizontal plane that is perpendicular to the gravity vector. Determine angles of repose for liquid water at the air-water interface, for a solid, for dry sand in air, for dry spheres in air, and for spheres and sand completely under water. An estimate within 10˚ is precise enough.

Water is a peculiar material in many ways. Materials can adhere to other materials or cohere with molecules of their own kind. Glue (an adhesive) by definition is good at sticking to materials of other kinds. To do its job, glue must also be cohesive, *i.e.*, stick to itself so the glued items do not come apart because of a failure in the glue layer. You have all observed water. On a newly waxed car, it beads up (sticks to itself more than to the wax). You have seen a meniscus many times, but which way does it curve? An upward concave curve (smile shape) indicates that it sticks to glass better than to itself, whereas an upward convex curve (like the one that you see on top of a mercury column) indicates that it sticks to itself better than to its container. Glass is a pretty good analog for the naturally occurring, silica-based minerals that dominate Earth geology, so you should also learn from your observations how sand and water interact at some scale under some circumstances.

Consider how granular materials vs. fluids resist forces. What happens when you pound sand? Does water react the same way? Do both media resist slow movements in the same way?

Armed with your observations of angles of repose under air and water, wet a pile of sand. Hint: You have no doubt done this before. What is the angle of repose of wetted sand under air? Now try it with a bucket of wet *vs*. dry gravel.

Assignments are due at 1700 Friday, 5 September, by *e*-mail.

## Assignment

Summarize the information that you have on angles of repose for the two- and three-media cases. Explain the reasons for the differences. You know (after the afternoon lecture) how a Newtonian liquid transfers shear stress at low *Re*. Do you think that a granular medium will transmit shear in the same way (*i.e.*, with a no-slip condition at its interface with a flat plate will it show a linear velocity gradient)? Consider doing some simple experiments to answer this question, including a rough plate to make sure that force is transmitted to the first layer of grains. Tune your thinking by feeling the force needed to pull a vertical rod out of a beaker of syrup versus sand. The purpose of this exercise is literally to give you a feel for how viscosity works in liquids by making you think about a less familiar (granular) material.