Lab Objective:	Differentiate between the various fine earth fraction texture classes; determine soil limitations based on soil texture; learn the various soil structure types *Goal 1: define the size classes of sand, silt, and clay; explain the unique properties of each particle type* *Goal 2: Use textural triangle to determine texture class and percentages of one type of soil particle given the others.* *Goal 3: Utilize a mechanical settling method to approximate soil particle size distribution; use hand texturing methods to determine appropriate soil particle size distribution.*
Content Overview:	In terms of controlling the processes that occur in a soil, one of the biggest determinants after soil moisture would be soil texture. Parent material and mineralogy will go a long way in dictating the beginning texture of a soil – soil forming from sandstone will have a sandy texture; lacustrine deposits are most often silty or clayey; granite, with its large mineral crystals, weathers to coarse sandy material; basalt, with fine mineral crystals, will weather to a fine textured soil. As soils weather, they tend to develop and accumulate clay, so that the soil formed from granite 50,000 years ago is rich in clay today (assuming there is enough moisture in that 50,000 years to drive this process). Clayey soils are often called “heavy”, because they are hard to pull a plow through. They tend to stay wetter longer because they hold water in their smaller pores (more on this in the soil water lab). Some clays shrink when they dry and swell when they get wet; this makes a bad foundation for a house or road due to potential for cracking. But the small nature of the clay particle also makes it a great retainer of nutrients – many plant nutrients are positively charged ions (cations) and most clays are negatively charged and therefore retain the cations (cation exchange capacity, CEC). Some clay is essential for retaining nutrients – a sandy soil will tend to have nutrients leached away because it lacks CEC. The stickiness of clay also makes it hold together, resisting erosion and aggregating the soil. The small pore spaces also provide habitat for various microorganisms. Sandy soils generally don’t hold water well and drain quickly. From a grower’s perspective, these soils can be droughty and have low nutrient status. Silty soils hold and yield water to plants, but when they dry up they can blow away or else they are easily washed away because they are neither as heavy as sand nor as sticky as clay. For determining soil texture we can use the adage “the bigger they are the faster they fall. Bigger particles (sand) settle out of water faster than smaller particles (silt and clay). In fact, some clay particles are so small that many times, they will never settle out (due to atomic level Brownian Motion). This size settling was put into theory by Sir George Stokes in 1851 (Stokes Law encyclopedia entry). Essentially Stokes determined that in a viscous fluid (like water), an object will fall at a rate that is controlled by the radius of that object. Stokes was using smooth balls in his work; while soil particles typically are neither round nor smooth we stick with this assumption for our calculations. If you’ve been lucky enough to float in the ocean you may have noticed that floating is easier there than in a swimming pool. That is because ocean water has salts dissolved in it which makes the water more dense. If you know the density and volume, you can

determine the amount of dissolved material (density equals mass divided by volume).

Mixing up soil in a water column will do the same thing, create a more dense fluid. If we start with a known amount of soil, say fifty grams, we know the amount of material in the water. The density at that point is the result of 50 grams of soil. At this point, Stokes' Law comes in to play as the density will decrease as first sand, then silt, and, possibly, clay settle out. Since clay, silt, and sand have specific size ranges, we should be able to bracket the time period required for it to fall a specific distance in water.

Based on Stokes' Law, we can calculate that the smallest sand particle, at 0.05 mm (United States Department of Agriculture (USDA) size class) will take ~44 seconds to fall 10 cm in a column of water. The smallest silt, at 0.002 mm, will take 7.7 hours. Clay can take even longer or may never settle out. In a soil testing lab, after the sand and silt have settled, we add a chemical that will clump the clay back together (flocculate) or put the suspension in a centrifuge to settle out the clay. If we measure the density of the fluid at 44 seconds, the density is due to silt and clay since the sand is settled out. If we measure after 7 hours, the density is due to the clay. But how to measure density of a fluid? Enter the hydrometer.

The hydrometer on the left shows the weighted bottom and scale. On the right, the hydrometer floats in water. Not that the water level is at the zero mark on the hydrometer, indicating pure water.

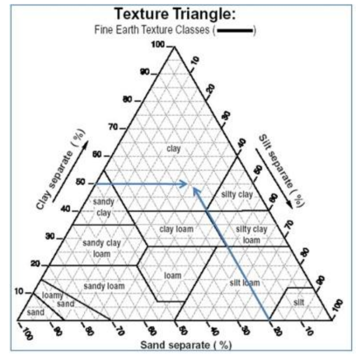
A hydrometer is a calibrated instrument that floats in fluid and, depending how high it floats, gives a density reading. A calibrated instrument for soils gives a reading of grams. That is "grams left in suspension." In clean water, the hydrometer reads zero. When 50 grams of soil are added, the hydrometer floats higher and reads 50 grams. As material settles out, the hydrometer sinks and the readings get closer to zero. If there is clay in the sample, the hydrometer will likely never get to zero because the clay will not all settle out. You will construct a hydrometer for testing your samples.

The last thing to know is how to communicate soil texture as a language. We will be using the USDA breaks to place the solid components of soil into the following groupings:

Clay:	< 0.002 mm
Silt:	0.002 to 0.05 mm
Sand:	0.05 to 2 mm
Gravel:	2 to 75 mm
Cobbles:	75 to 250 mm
Stones:	250 to 600 mm
Boulders:	> 600 mm

Soil texture is based only on the sand, silt, and clay. However, it is important to realize that if you have gravels, cobbles, etc. in your soil, they will have a profound effect on the properties and behaviors of that soil.

The proportions of sand, silt, and clay in a sample determine the texture class and together they add up to 100% for a sample. Numeric values of texture are written sand% - silt% - clay% (e.g. 20-30-50 is 20% sand, 30% silt and 50% clay). Once you have at least two of the percentages (e.g. sand and clay) you can find the third (100% – [sand + clay] = silt). A triangular graph, called the texture triangle, allows you to follow the lines to determine the texture class (see right, a full sized version is included as a handout). You read the percents in the direction of the angle of the axis labels. In the image, the blue arrows follow the 20% sand and 50% clay lines to where they converge. At that point on the graph, the silt value is 30%. The texture class here is clay**.** If clay content of our sample was 10% instead, the clay and sand lines would converge in the silt loam area and show a silt content of 70%.



From the United States Department of Agriculture

You'll notice that for each texture class (there are twelve) there is a range of possible clay, sand, or silt percentages. The texture class reports the dominant characteristics of the texture. Anything that ends with "clay" is a clayey soil. A silty clay is a clay with a noticeable presence of silt. Loams are the texture classes where none of the three particle types dominate; however, a sandy loam has a noticeable sand presence while a clay loam has noticeable clay.

**most soil hydrometers are calibrated for tests at 68 degrees F (20 degrees C). Slight adjustments are needed when suspension temperatures are above or below the calibration temperature*
***Organic matter should be oxidized prior to determination of soil texture and carbonates removed – both of these soil components may result in an overestimation of clay*

Definitions:

Soil Texture:

Sand:

Silt:

Clay:

Fine earth fraction:

Hydrometer:

Stokes Law:

Materials:

• Camera • Graduated cylinder • Permanent marker • 2 soil samples from Kit	• • Scale • Week 1 Soil samples • Dixie cup (or light container	• Straw • Tape or paper clip • Water

Exercise: **Creating a hydrometer**

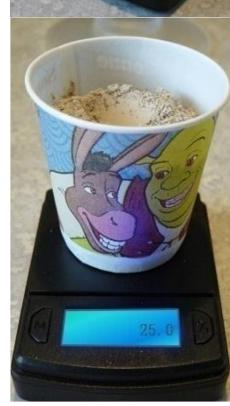
You will need a plastic straw (the bigger the better), some salt and tape

1) Make at least two folds in one end of the straw and tape or clip the folds in place. Pinch the tape to make sure it will be water resistant.
2) Pour a teaspoon or so of salt into the straw.
3) Fill the graduated cylinder close to the top and slowly lower the straw-hydrometer into the water. It should float with only a few inches out of the water. If the hydrometer sticks too far out add more salt to the straw. If it sinks, you'll have to start over!
4) When it floats where you want, pull it out while placing a thumb or finger on the straw where the water line was. Mark the straw at this location (you may have to dry it some to get the marker to work). When the straw is dry, extend the mark all the way around the straw. This is your pure water hydrometer reading (zero grams of "stuff" in the water).

Hydrometer Tests

Now we will do some calibration to the hydrometer and use it to qualify our sample textures. Have all your supplies at hand. Read this through first before starting.

1) Turn on the scale and press the left button (M) so that the letter to the right of the numbers is g (for grams).
2) Place the Dixie cup on the scale and press the tare button (button on the right with a T on it. This "tares out" or zeros out the mass of the cup so the scale reads zero (see picture).
3) Spoon into the cup 25 grams of lab Kit sample 1 (baggie of soil with no number). Be careful not to spill soil on the scale. Mark inside the cup where the soil fills it to.
4) Fill the graduated cylinder with water to the 220 mL mark. Carefully pour the sand into the cylinder (use a paper funnel if you need to).
   QUESTION: Describe how the water and soil mixture turn out. What is the new volume on the cylinder?
5) Now spoon into the cup 25 grams of Lab Kit sample 2 (has #2 on the baggie). Make a mark where this soil fills the cup to.
   QUESTION: Was there a difference in how much of each soil type was required to get to 25 g? Why (in your



opinion)?

6) Gently add sample 2 to the suspension in the cylinder.

Question: What level is the hydrometer at now? Why did the volume change?

7) Important!! Have a watch or clock with a second hand handy so you can time yourself. Our goal is to get the soil mixed (next step) and the hydrometer into the mixture and settled (not bobbing) within one minute of the end of mixing.

8) Cover the top of the cylinder with a piece of plastic wrap and then your hand to keep the plastic in place and invert the cylinder about ten times to mix the soil with the water (we are trying to easily mix the sand/clay/water without spilling and making a mess).

9) Immediately after your last inversion, put the cylinder down and gently place the hydrometer into the suspension. One minute after you stopped shaking, pull out the hydrometer and mark where it was sitting in the water (just do a dash this time, not a full circle). Ideally the pure water circle should be above this mark (see picture).

QUESTION: What does this new line represent with respect to "Stuff" in the water?

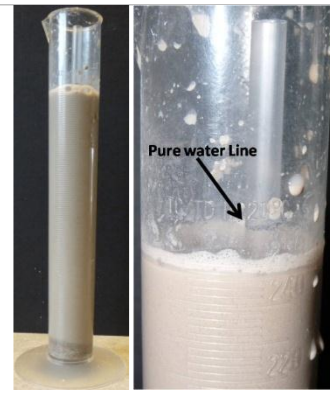
10) Remove the hydrometer (it will leak and change the buoyancy, so it needs to come out). Set the cylinder aside for a few hours (4 to 7) then come back and look. Place the hydrometer back in and measure where it is reading. Describe the appearance of the cylinder. Gently slosh it around, what happens in the clay layer.

QUESTION: Describe the soil suspension after a few hours. Looking from the outside at the lower part of the cylinder, how does the material look? What did the hydrometer do compared to the one-minute reading?

11) Clean out the cylinder – don't drain it into the sink because 1) it could cause a clogging issue and 2) that is perfectly good soil/water that can be put outside.

12) Using one of your dried, cleaned and possibly sieved soil samples from Lab 2, load fifty grams of soil into a new 220 mL of water and repeat the experiment. You don't need to do this for all three samples, one will suffice. (the hydrometer when placed in the clean water should read at zero again)

QUESTION: How did your collected sample compare with our "fabricated" sample? Describe what you observed.



Hand Texturing

As a skilled soil scientist, you will be able to differentiate soil texture by using your hands. Clay is sticky (can make ribbons), silt is smooth (like baby powder), and sand is gritty (like sand paper). Use the accompanying flow chart to do a hand texture analysis on your collected samples from week 1, filling out the table on the Turn In Sheet. On the course webpage are some streaming videos demonstrating how to hand texture (not the best quality but they will do the trick for now). Read the flow chart then come back here to look at these tips:

1) start with the hand that you DON'T write with. It's going to get dirty and so will your pencil and paper. Once the soil is wet up, then switch hands to do the ribbon – if you've got soil stuck to your wet-up hand the ribbon will stick there too and you'll never get it. It's easier to add more water than to take it away, so add water in small amounts.
2) this is an extremely individualized experience – every person has their own style, there is no "right way" as long as you are consistent (and correct) with your estimations.
3) the ribboning part is what helps determine clay content – you are generally first classing the soil into a loam, clay loam, or clay class (see diagram).
4) the grittiness or smoothness relates to sand content and silt content, respectively. Once you put the soil in a loam, clay loam, or clay (the vertical separations on the textural triangle), you need to determine if it "needs" a sandy or silty adjective. Have the textural triangle handy. For example, to say something is a sandy clay loam requires almost 50% sand. That's a lot. Same goes for calling something silty.

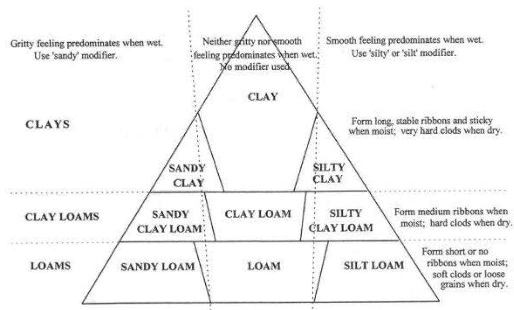


Diagram showing the approximate breakdowns of soil texture classes. From bottom to top, the dominant change is an increase in clay, going from loam, to clay loam, to clay. On the right or left are greater proportions of sand or silt, which are used as adjectives on loam, clay loam, or clay. (From the USDA)

5) try to estimate the clay %. A clay loam ranges from 27% clay to 40% clay. A 2.5 cm ribbon would be around the 27% line; a 5 cm ribbon would be near the 40% line. BTW, 2.5 cm is just about an inch.
6) the ribbon lengths are not set in stone but rather serve as a guide. Also, ribbon each soil multiple times to get a feel of the average ribbon.
7) have fun.

You have two Lab Kit soil samples. You should wet these up and practice ribboning; I will provide you with texture values for these so you can calibrate your method.

Record the textures for your Lab Kit and Lab 2 samples in the table on the Turn In Sheet. You will need to take pictures of the ribbons you were able to make for each soil sample.

Study Questions:

1) How can you relate the visual results of the hydrometer experiment to real world natural processes (think about you inverting the hydrometer as approximating running water)?
2) Very likely, at the end of the experiment that used one of your soil samples, there was

	still "stuff" floating in the suspension and possibly on top. What is it? If we had a true hydrometer, how would this impact your calculations? 3) The clay in the first hydrometer test should have sloshed around when you moved the cylinder after a few hours. How come it is not a solid layer like the sand at the bottom?
Report Items:	• Lab 6 turn in sheet (includes hydrometer calculations and datasheet for your hand texturing) and answers to the questions scattered throughout the experiment (there are 6) • **Required for end of term report:** Photos of hydrometer after construction, in the pure water, in the sample soil suspension, and in the Lab 2 soil sample • **Required for end of term report:** Photos of the ribbons of all three samples • Include, if you want, photos of the clay ribbon if you do one
Extra Background Information:	