KEY: POROSITY AND PERMEABILITY #1

Experiment #1 - Determining the Porosity of Soil Materials

1. Define porosity.

*The amount of pore space in soil, sediments, and rock is called **porosity**, which can also be defined as the percentage of a material's total volume that is taken up by pores.*

2. If not done already, obtain clear plastic cups or empty soda pop bottles. You will be filling cups with various types of soil material; your teacher will inform you on how many cups to make and the contents of those cups. Possible contents of the cups are as follows:
    - Gravels (aquarium gravel works)
    - Coarse sand (playground sandbox sand)
    - Fine sand (garden sand)
    - Clay (if available, possibly from soils around your home or from a stream bank)
    - Mixture of Gravel and Sands
    - Mixture of Coarse and Fine Sands

3. Using a beaker, measure out the same volume of the **DRY** soil material for each cup. Record this volume.

    ______ mL of soil material in each cup

4. Fill out the first 2 columns in the chart below. You will predict which soil material will have the highest porosity and rank them from highest porosity (1) to lowest porosity.

Contents of cup – all with same volume of material	Predicted rank for highest porosity (have 1 = highest)	Volume of water soil material holds (pore space) (mL)	% porosity	Rank of porosity for cups (have 1=highest)

5. Fill a small volume graduated cylinder with water, noting the initial amount of water in the cylinder. You need to keep track of how much water will use in the next step.

6. For this step, your goal is to pour just enough water into the cup's soil material to fill all of the pore spaces in between the soil particles, but you do not want to overfill the container. Pour water from the graduated cylinder into the cup of soil material. Keep pouring water in as long as the soil absorbs it. As soon as any water starts to puddle or remain on top of the soil material, do not add any more water. In fact, if water remains on the surface and does not get absorbed, use an eyedropper to carefully suck off the surface water and *place it back into the graduated cylinder*.

7. Based on the water remaining in your graduated cylinder, determine how much water you used to fill the pore spaces in the cup's soil material. This is the volume of pore space. Record this value in the data table.

8. Now determine and record the % porosity using the formula below for each other sediment cups in the chart.

$$\% \text{ porosity} = \frac{\text{Volume of pore space}}{\text{Total volume of sediment}} \times 100$$

9. Repeat steps 5-8 for any additional cups of material.

10. Once the data table is complete, review your predicted rankings. Did you correctly predict which sediment type had the highest porosity? Why were you correct or why were you wrong?

Many students will hopefully predict the cups of gravels. Usually the larger the consolidated (well sorted) grain size, the better the porosity (aquarium gravel). If the materials are poorly sorted (lots of different sizes) then it reduces porosity because smaller grains fall between larger grains, reducing space and flow paths (gravel and sand; sand and clay mixture). Surprisingly, clay can have high porosity too because clay has a greater surface area than sand, therefore, more water can remain in the soil.

11. If you were to dump out only the water from your cup, keeping the sediments, and then try this experiment again, why would your porosity likely decrease for this second trial?

Because water (a film of water that exists around soil particles called hygroscopic water) will have been retained in the cups of soil. The water "sticks" to the soil particles because of cohesion and adhesion, common properties of water. This water that is already in the soil sample will decrease the porosity for the second trial.

KEY: POROSITY AND PERMEABILITY #2

Experiment #2 - Determining Permeability of Soil Materials

1. Define permeability.

Permeability is the measure of how easily water flows through soil or rocks, so it depends on the size of the pore space and how well connected they are to one another. It is often defined as pore interconnectedness and the unit of measurement is usually distance (cm, m, or ft.) per time (second, minute, day). Permeability can also be referred to as hydraulic conductivity.

2. If not done already, obtain clear plastic cups or empty pop containers with holes in the bottom. If no holes, poke numerous holes in the bottom of each using a thumbtack or metal dissecting probe. Keep the approximate number of holes equal between all cups. You will be filling cups with various types of soil material (possibly the soil material used in *Experiment #1 – Determining Porosity of Soil Material)*; your teacher will inform you on how many cups to make and the contents of those cups. Possible contents of the cups are as follows:
    - Gravel (aquarium gravel works)
    - Coarse sand (playground sandbox sand)
    - Fine sand (garden sand)
    - Clay (if available, possibly from soils around your home or from a stream bank)
    - Mixture of Gravel and Sands
    - Mixture of Coarse and Fine Sands

3. Fill cups with the same volume of the various types and sizes of sediments. They do not have to be dry.

4. Fill out the first 2 columns of the chart below.

Contents of cup – all with same volume	Predicted rank for permeability (drainage) of cup (have 1=fastest)	Amount of time for water to drain through soil (min)	Actual rank of permeability (drainage) of cups (1=fastest)

5. Pour equal amounts of water (your teacher will determine this amount) into each cup and allow them to drain over an empty catch container/beaker. Keep track of how long it takes for all of the water to drain through the sediments – this should be the point when water stops dripping from the bottom of the cup. Record this time in the data table.

6. Repeat this procedure for any of the other cups of material. Fill in data table accordingly.

7. Once all cups have been tested. Rank the cups with highest permeability (quickest to drain) to least permeability (slowest to drain). Did you correctly predict which cup had the highest permeability? Why were you correct or why were you wrong?

   Usually the larger the consolidated (well sorted) grain size, the better the permeability (aquarium gravel). With this sediment size, there is plenty of connectedness of pore space, allowing the water to drain out of the soil sample quickly.

8. Did the soil materials with higher porosity also tend to have higher permeability? Were there any exceptions to this correlation?
   Well sorted gravel and sands had high porosity and also had high permeability. There was an exception to the above mentioned correlation - clay / silt can have high porosity because these small soil particles have a greater surface area, therefore, more water can remain in the soil. However, clay/silt has bad permeability. The connectedness between clay particles is low and clay tends to retain water (because of the greater surface area again), slowing gravitational flow downward.

9. Why are both porosity and permeability of the soil/rock layers important factors to consider if you wanted to drill a groundwater well to obtain drinking water for your home?
   Because you want to drill into a soil/rock layer that has good porosity so that it can hold more water for you to use. You would also want there to be decent permeability in your soil/rock layers because you need to be able to draw the water up into the well, and if there is no connectedness of the pore spaces then this will be harder to do.

10. Based on your experimentation, what type/s/ of soil/rock material would you want to drill into to obtain a sufficient groundwater supply? Why?
    You might want a sand/gravel mix, poorly sorted. This has good porosity (not the best though) and good permeability (not the best though). Digging into well-sorted gravel or sand can also be good because of the high porosity, but you might have to dig a deep well because the high permeability will allow water to readily drain downward and deeper due to gravity.

11. If you had two cups for the permeability experiment, each with the same amount of the same type of sand, but one cup's sand was wet and the other cup's sand was dry, which cup would drain quicker? Why?

    When the sand is wet, the water attached to the soil particles will slow the flow of water through the sample because it is closing up some of the interconnectedness of pore space. Also, the cohesive properties of water, water likes to "stick" to other water molecules, trying to keep water from draining through the soil sample.