

MODELING POROSITY, PERMEABILITY, AND CAPILLARITY

The ways in which water enters and flows through the **groundwater system** depends greatly in the size of the soil particles. You can investigate the effect of **particle size on porosity, permeability, and capillarity** in soils using beads and test-tubes.

Porosity refers to the amount of space within the ground (or other volume) that could be filled by water or air. **Permeability** refers to how easily water could flow through the space. **Capillarity** describes how water or other fluids can adhere to the sides of the container—you're familiar with this property from soda rising above the surface in a drinking straw.

If you experimented with a physical model, you could measure how much water can be added to a container, how easily it flows, and whether it displays capillarity. But much of what you would observe may still be puzzling—until you use a **mathematical model** to help make the patterns more understandable.

A 'mathematical model' uses equations to represent what happens in 'real' processes and events. One of the most important, and complex, examples of using mathematical models are the unbelievably complex sets of equations that are constantly solved by some of the world's largest computers to create weather forecasts. In this activity, we will use relatively simple algebraic equations to determine the volume of space in a "soil sample" occupied by particles and water.

Any mathematical model must begin with **assumptions**—guesses about the conditions in which the processes and events occur. So we will begin by assuming groundwater movement occurs within a cubic box that is 10 cm by 10 cm by 10 cm.

For all problems: show your work, include proper units,
and place your answer inside a box.

Q1. What is the volume of the imaginary box?

Next, imagine that there are just two differently sized beads (sediment particles), one with a diameter of 2.0 cm and the other with a diameter of 0.2 cm.

Q2. What category of sediment does each fall into, according to the *Earth Science Reference Tables*?

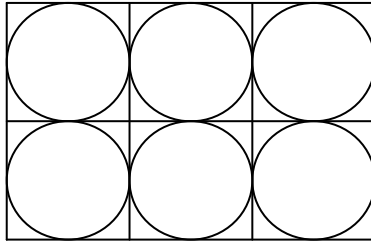
The 2.0-cm beads would represent _____ and

the 0.2-cm beads would represent _____.

Assume first we fill two of our imaginary boxes with beads of just one size. How can we compare their porosities, permeabilities, and capillarities? Before we start our calculations, predict what you expect to find in this situation by completing these sentences.

1. Compared with the larger beads, the porosity of the smaller beads would be _____.
2. Compared with the larger beads, the permeability of the smaller beads would be _____.
3. Compared with the larger beads, the capillarity of the smaller beads would be _____.

First, we need to calculate how many beads of that volume could fit inside the imaginary box. To simplify the problem, we'll imagine that they are packed as if they were inside boxes:



Q3a. What would be the volume of a 2.0-cm cube?

Q3b. What would be the volume of a 0.2-cm cube?

Now, calculate how many beads of each size could fit into the 10-cm x 10-cm x 10-cm box.

Q4a. How many of the 2.0-cm beads fit into the box?

Q4b. How many of the 0.2-cm beads fit into the box?

Next, we need to calculate the volume of each sized sphere.

$$\text{volume of a sphere} = \left(\frac{4}{3}\right) \pi r^3 \quad (\text{"r" is the radius})$$

Q5a. What is the volume of the 2.0-cm bead?

Q5b. What is the volume of the 0.2-cm bead?

OK, since we know how many beads of each size would be in the box and the volume of each sphere, we can calculate the volume of space occupied by the particles by simple multiplication:

Q6a. What volume is occupied by the 2.0-cm beads?

Q6b. What volume is occupied by the 0.2-cm beads?

Q6c. What can you conclude about the **porosity** of the box when it is filled with beads of similar shape packed in the same way, but having different sizes? Does this match your prediction? Explain.

Permeability is greater when a fluid can move through a larger opening. (Think of people walking through a doorway or a hallway or a large room.)

Q7. What can you say about the relative permeability using these two sizes of beads? Does this match your prediction? Explain.

Capillarity is greater through tubes that have smaller diameters. (The smallest blood vessels are called capillaries, and are so narrow that blood cells must line up to pass through them.)

Q8. What can you say about the relative capillarity using these two sizes of beads? Does this match your prediction? Explain

Q9. Predict what would happen to the porosity, permeability, and capillarity if you were to put beads of both sizes into the 10-cm x 10-cm x 10-cm box. Explain your predictions.

Q10. Finally, make **bar graphs** to represent the relative porosity, permeability, and capillary patterns in this mathematical model.

Porosity

Permeability

Capillarity

2.0-cm

0.2-cm

2.0-cm

0.2-cm

2.0-cm

0.2-cm