MiSP Permeability and Porosity Worksheet 1 L1

Name ______________________________ Date _____________

Water Movement Through the Ground

Introduction:

You have learned about **permeability** and **porosity**. **Porosity** is a measure of the empty space that is potentially available for water storage in a geologic material. It is the *percentage* of empty space in a given volume of material. **Permeability** is the *rate* at which moisture passes through a material.

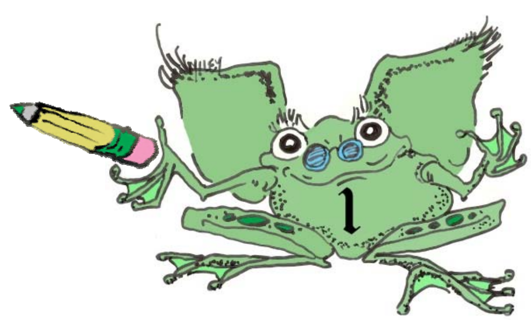
It was demonstrated that different substances may have different permeability rates. Permeability changes with the particle size of the substrate. The materials used in the demonstrations may not have been homogeneous/well-sorted substances (made up of particles that are all the same size). Information about sorted particles can be used to predict the results of many different mixtures. In this experiment we will use beads of three different particle sizes to model Earth materials. (Your teacher may choose to use sand or other well-sorted materials instead.)

Problem or Question:

How will particle size affect porosity, permeability, and water retention?

Materials:

- Plastic column setups (columns, stoppers/tubes/clamps, support rod and clamp[s])
- Plastic beads: 3 mm, 5 mm, 12 mm
- Water
- Beaker
- Graduated cylinder
- Timer



Procedures: *Do the following procedures three times (once for each bead size):*

___ 4 mm beads ___ 7 mm beads ___ 12 mm beads

☐ 1. Place **300 ml** of sorted bead particles in a plastic column. Write the **bead particle size** (mm) on the data chart (row 1).

☐ 2. Measure the **height in cm of the bead particles** in the plastic column. Enter this information on the data chart (row 2).

☐ 3. Measure 100 ml of water in a graduated cylinder. Pour about 50 ml of water into the plastic column while someone times the interval between the time when the water ***first*** touches the top of the bead particles and the time when the ***first*** water reaches the bottom of the cylinder. Enter **the time needed for water to travel down the length of the column** on row 3 of the data chart.

☐ 4. Calculate the **rate of flow (permeability)** by **dividing** the **height** of the bead particles (row 2) in the column by the **time** recorded in row 3.

$$\text{permeability (cm/sec)} = \frac{\text{Distance the water moved (height of particles in cylinder [cm])}}{\text{Time for water to travel from top to bottom of the column (sec)}}$$

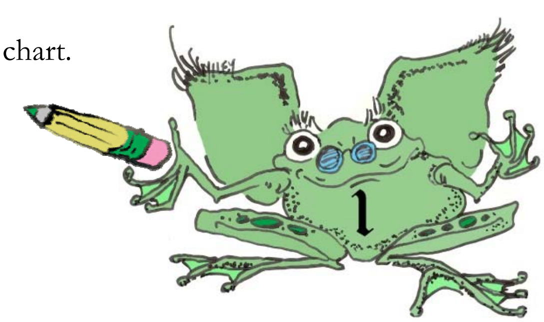
WORK SPACE:

4 mm beads

7 mm beads

12 mm beads

☐ 5. Enter the results of your calculations on row 4 of the data chart.



Volume of Pore Space

☐ 6. Continue to SLOWLY pour water into the column, small amounts at a time, until the water is just up to the top of the bead particles.

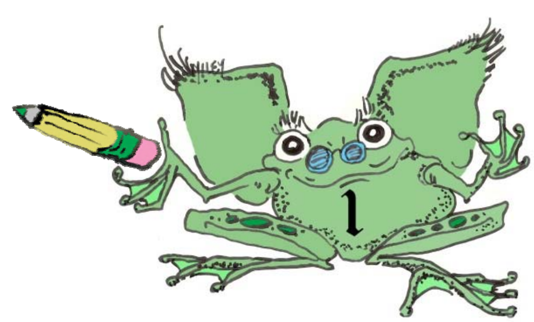
☐ 7. On row 5 of the data chart, record the total amount of water it took to just cover the beads. (This amount equals 100 ml minus the amount remaining in the graduated cylinder.) This is the **volume of pore space**.

WORK SPACE:

4 mm beads

7 mm beads

12 mm beads



Water Retention

☐ 8. To determine the amount of water retained by the particles, drain the water into a dry beaker by opening the hose clamp. Measure the volume in a graduated cylinder and enter the amount on row 6 of the data chart.

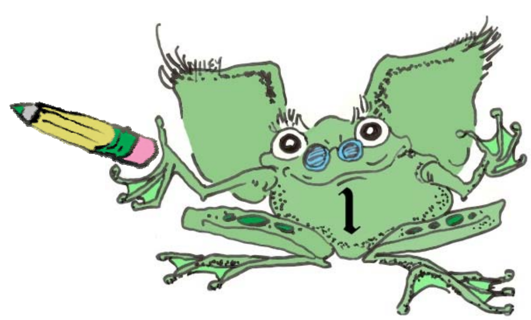
☐ 9. Determine the **water retained** (water remaining in the column after draining) by subtracting the amount of water drained into the beaker (row 6) from the amount of pore space found in row 5.

WORK SPACE:

4 mm beads

7 mm beads

12 mm beads



Porosity

☐ 10. Calculate the **percent of pore space** (**porosity**) by dividing the **volume of pore space** (row 5) by the **total volume of particles** (step 1 – 300 ml). Enter the % on row 8 of your data chart.

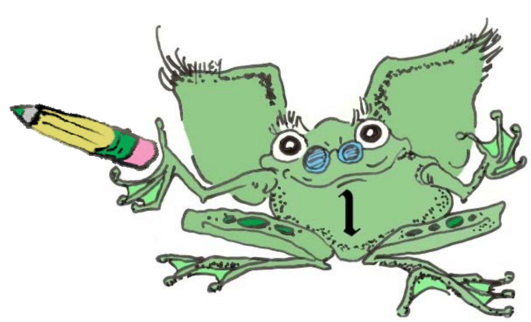
$$\text{Porosity (\%)} = \frac{\text{volume of pore space}}{\text{total volume of particles}} \times 100$$

WORK SPACE:

4 mm beads

7 mm beads

12 mm beads



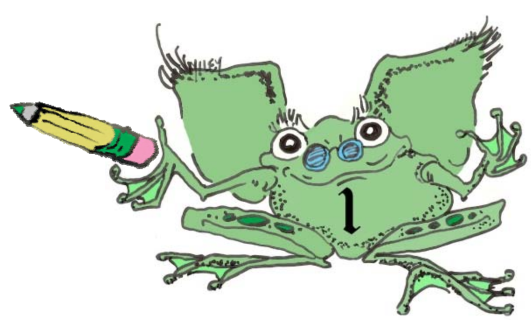
Record your data: (data chart)

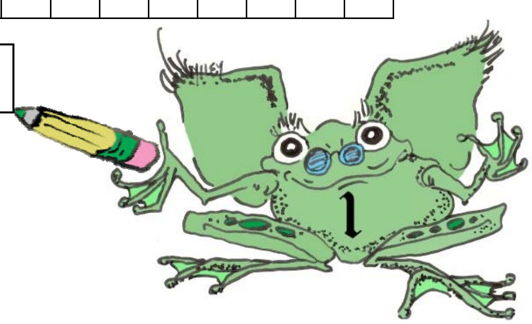
ROW 1	BEAD PARTICLE SIZE (mm)	4	7	12
2	HEIGHT OF BEAD PARTICLES IN COLUMN (cm)			
3	TIME NEEDED FOR WATER TO TRAVEL DOWN THE LENGTH OF THE COLUMN (seconds)			
4	RATE OF FLOW (PERMEABILITY) cm/sec			
5	WATER REQUIRED TO FILL PORES — VOLUME OF PORE SPACE (ml)			
6	WATER DRAINED FROM THE COLUMN (ml)			
7	WATER RETAINED IN THE COLUMN (ml) Row 5 – Row 6			
8	PERCENT PORE SPACE (POROSITY) $\frac{\text{Row 5}}{\text{300 ml}} \times 100$			

Graph your data: Permeability

Graph the data on the next page to show the relationships between particle size (mm) and permeability (cm/sec).

- Label the *x*-axis.
- Label the *y*-axis.
- Connect the data points by drawing a straight line between them.
- Draw a best-fit line with a different color.





Permeability Discussion Questions:

1. Look at the graph for permeability. As the bead particle size increased, what happened to the permeability (cm/sec) (the rate of the downward movement of the water)?

   ____

   ____

2. Which of the three different sizes of bead particles had the greatest (fastest) permeability? Why does water in a column with that size of bead travel faster than in columns with the other two sizes?

   ____

   ____

3. Use the graph to predict the permeability in plastic columns with 9 mm and 14 mm beads:

   a. 9 mm ______________________________ cm/sec

   b. 14 mm ______________________________ cm/sec

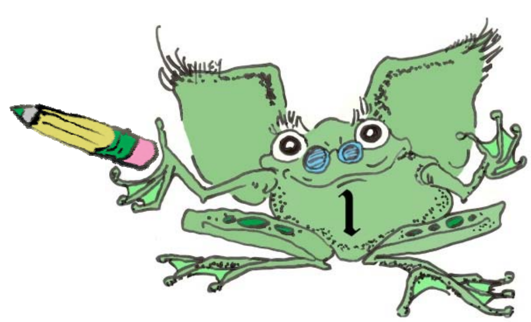
4. If an athletic field has very small particles in the upper soil, what will be the effects on:

   a. runoff? ____

   ____

   b. time of infiltration of rainwater that falls on the field? ______________________

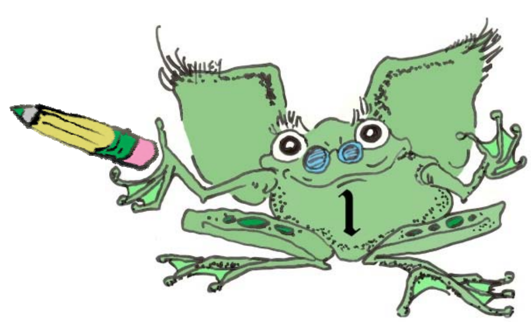
   ____

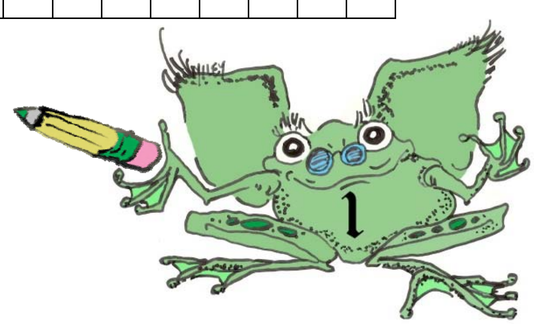


Graph your data: **Water Retention Graph (the amount of water retained)**

Graph the data on the next page to show the relationships between particle size (mm) and the water retained (ml).

- Label the *x*-axis.
- Label the *y*-axis.
- Connect the data points by drawing a straight line between them.

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Water Retention Discussion Questions: (amount of water retained)

1. Look at the graph for water retention. As the bead particle size increased, what happened to the water that was retained in the column?

   ____

   ____

2. Describe the "shape" of the lines you drew between the three data points. Does it look as though the data forms a line, some sort of curve shape, or something else?

   ____

   ____

3. Water is retained in a porous material because it "sticks" to the surface of the particles in the material. Which of the three different sizes of bead particles retained the most water? Why is more water retained in a column with that bead particle size than in columns with the other two sizes? (Remember that the beads were all made from the same material.)

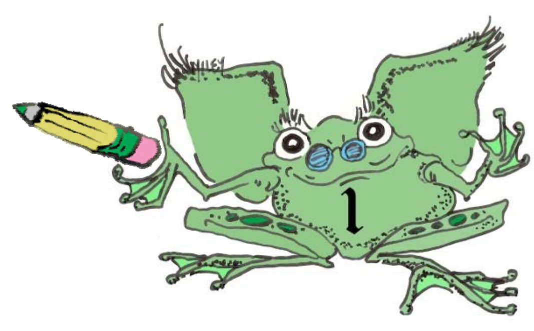
   ____

   ____

4. Use the graph to predict water retention in plastic columns with 2 mm and 9 mm beads:

   a. 2 mm ____________________ ml

   b. 9 mm ____________________ ml



5. Farmers and gardeners want to have water retained in their topsoil (the soil just below ground level) after rain or sprinkler water soaks in. Why do farmers want water retained in the topsoil?

____

____

6. What soil particle size (small, medium, or large) would be best for that?

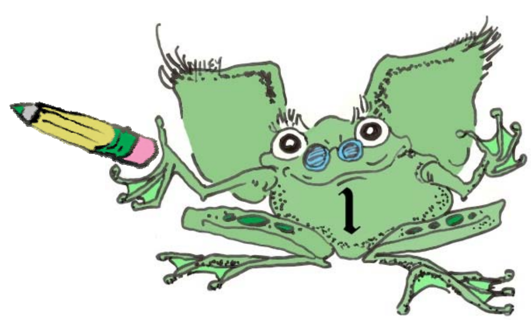
____

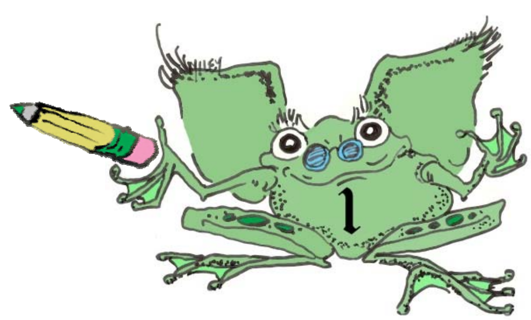
____

Graph your data: Porosity

Graph the data on the next page to show the relationships between particle size (mm) and porosity (%).

- Label the *x*-axis.
- Label the *y*-axis.
- Connect the data points by drawing a straight line between them.
- Draw a best-fit line with a different color.

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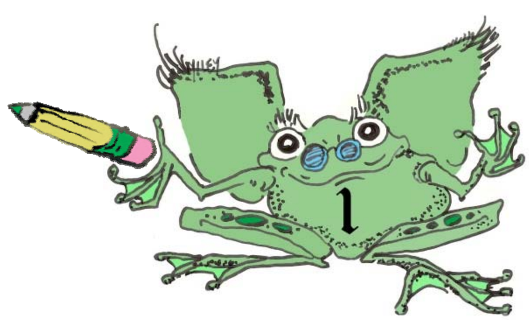
Porosity Discussion Questions:

1. Look at the graph for porosity. According to your data, as the bead particle size increased, what happened to the porosity? Look at the lines connecting the data points and the best-fit line.

2. Careful experimentation will usually produce data that tells us that no matter what size of well-sorted particles (like the bead particles in this lab) is used, the porosity will be the same. Does your data agree with that predicted outcome? Be specific.

3. Why do different sizes of beads in columns have the same porosity?



4. Using the information in 1b and your data, what is the porosity of beads in a plastic column with the following sizes? Explain your answers.

   a. 9 mm ______________________________ %

   b. 14 mm ______________________________ %

____

____

____