

MiSP Permeability and Porosity Worksheet 1 L3

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.

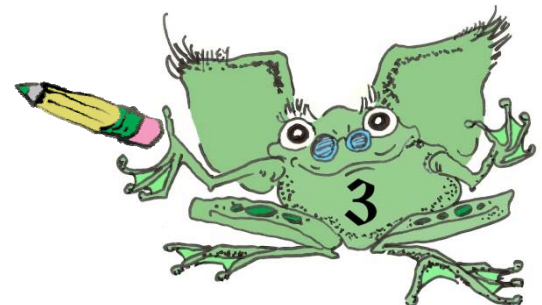
It was demonstrated that different substances may have different permeability rates. Permeability changes with the particle size of the substrate. The materials used in the demonstrations may not have been homogeneous/well-sorted substances (made up of particles that are all the same size). Information 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.

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

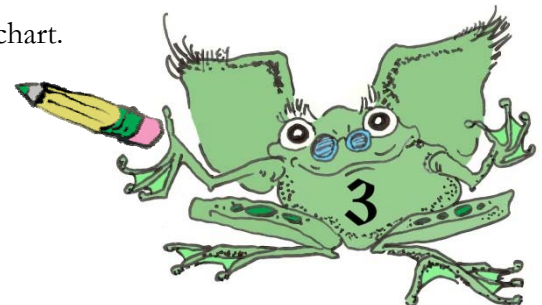
WORK SPACE:

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

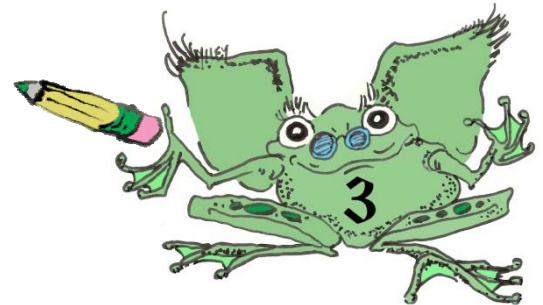
- 6. Continue to SLOWLY pour water into the column, small amounts at a time, until the water is just up to the top of the bead particles.
- 7. On row 5 of the data chart, record the total amount of water it took to just cover the beads. (This amount equals 100 ml minus the amount remaining in the graduated cylinder.) This is the **volume of pore space**.

WORK SPACE:

4 mm beads

7 mm beads

12 mm beads



Water Retention

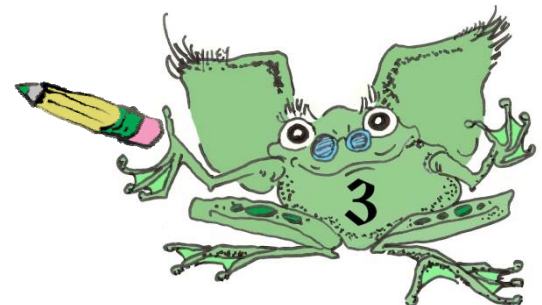
- 8. To determine the amount of water retained by the particles, drain the water into a dry beaker by opening the hose clamp. Measure the volume in a graduated cylinder and enter the amount on row 6 of the data chart.
- 9. Determine the **water retained** (water remaining in the column after draining) 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.

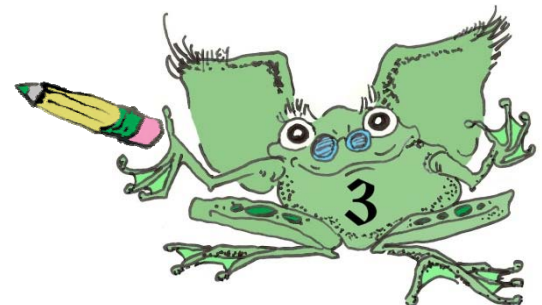
$$\text{Porosity (\%)} = \frac{\text{volume of pore space}}{\text{total volume of particles}} \times 100$$

WORK SPACE:

4 mm beads

7 mm beads

12 mm beads



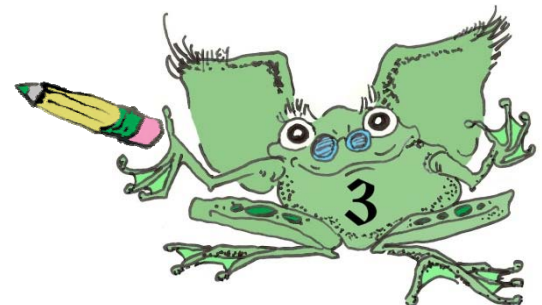
Record your data: (data chart)

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) $\frac{\text{Row 5}}{300 \text{ ml}} \times 100$			

Graph your data: Permeability

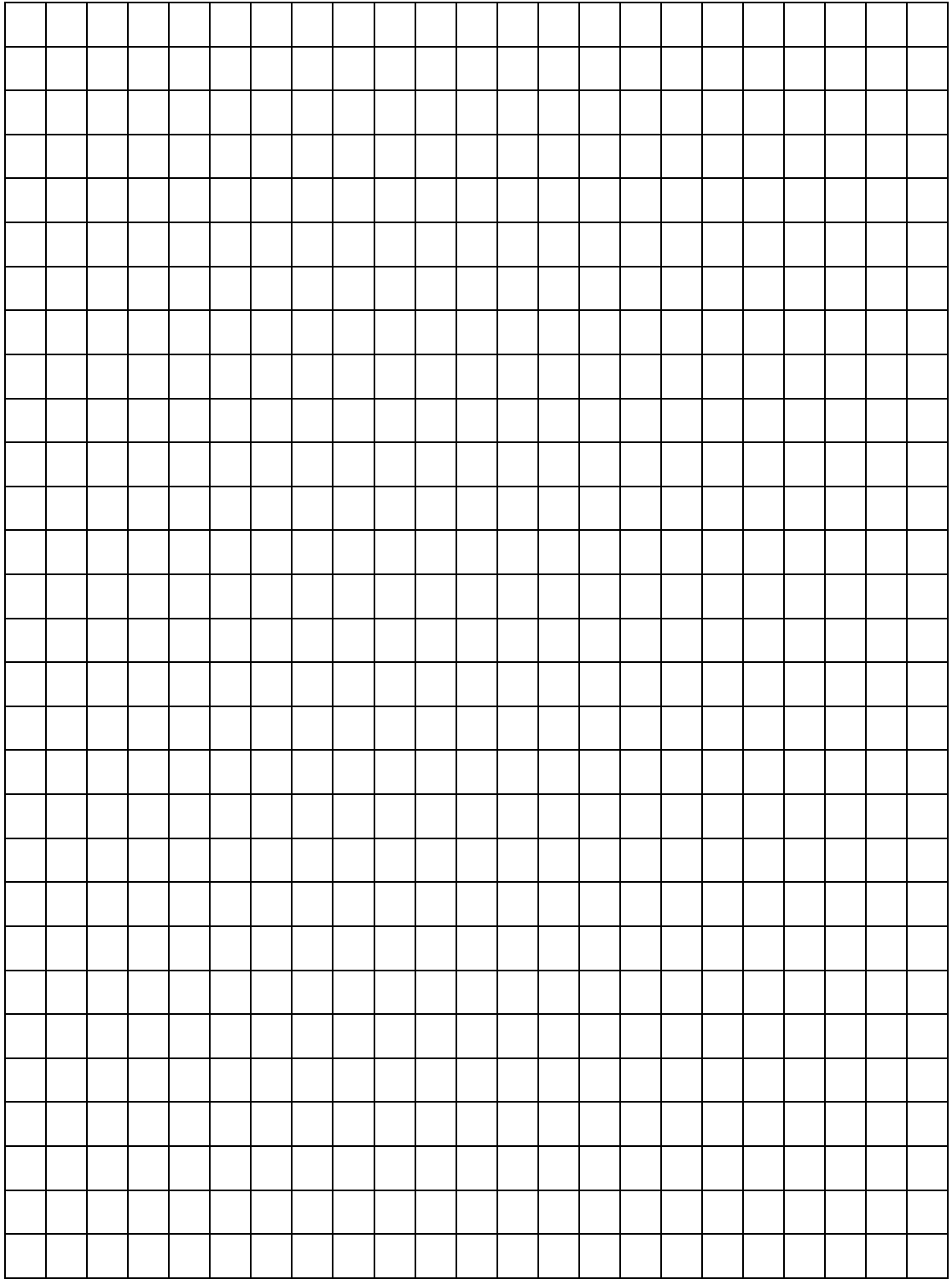
Graph the data on the next page to show the relationships between particle size (mm) and permeability (cm/sec).

- 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.

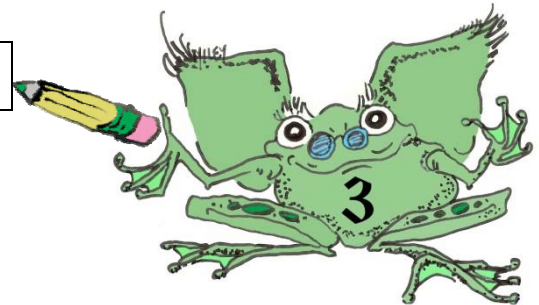


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Permeability Discussion Questions:

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:

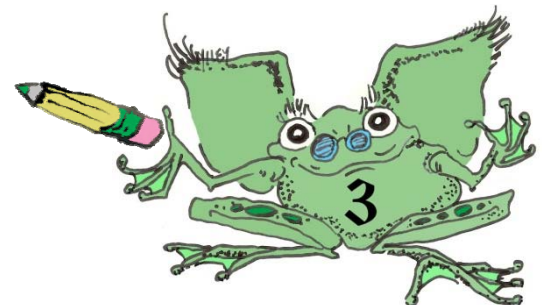
a. 9 mm _____ cm/sec

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? _____



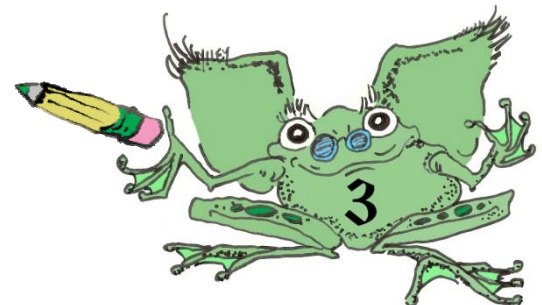
5. Use the best-fit line on the permeability graph to compare the changes in permeability when there is an increase in bead particle size by calculating the unit rate of change (slope). (*When you use a best-fit line, the ordered pairs to determine slope must be from the best-fit line, not from the data chart.*)

$$\text{Unit Rate of Change} = \frac{\Delta \text{Permeability (cm/sec)}}{\Delta \text{Bead Particle Size (mm)}} = \frac{\Delta y}{\Delta x} = \frac{(y_2 - y_1)}{(x_2 - x_1)}$$

Ordered Pair used for calculation (x_1, y_1) (x_2, y_2)	Δ Permeability (cm/sec) Δy	Δ Bead Particle Size (mm) Δx	Unit Rate of Change (slope) $\Delta y / \Delta x$

6. What is the sign (positive/+ or negative/-) of the unit rate of change (slope)? What does that tell you about the relationship between bead particle size and permeability?

7. If a student did the bead particle experiment and then *increased* the size of the bead particle she used by 2 mm, by how many millimeters would the permeability change? Would it be an increase or a decrease?



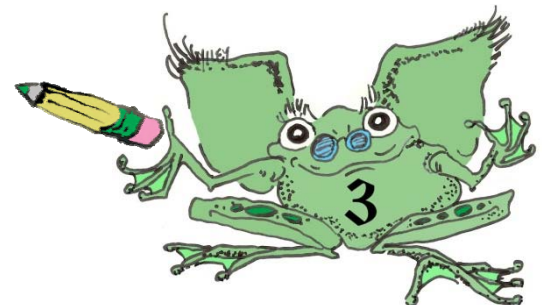
8. Determine the y -intercept for the permeability graph best-fit line. Use the equation for a line to calculate the y -intercept. The equation for a line is

$y = mx + b$, where m is the unit rate of change (slope) and b is the y -intercept

Y-Intercept
$m =$
Ordered pair $(x, y) = (\underline{\hspace{1cm}} , \underline{\hspace{1cm}})$
$y = mx + b$
Solve for b :

9. On the basis of the unit rate of change (slope) that you calculated above and the y -intercept, write an equation for the best-fit line on the permeability graph. Remember that the equation for a line is $y = mx + b$ and m is the unit rate of change (slope) and b is the y -intercept.

Equation – Best-Fit Line - permeability graph



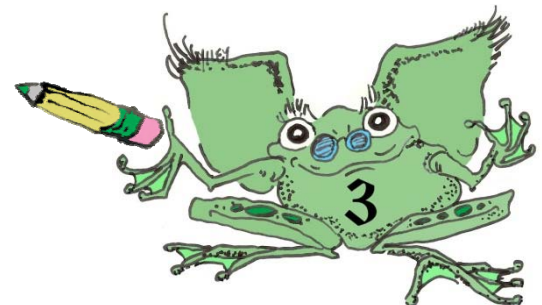
10. Use the equation you determined above to calculate the permeability of bead particles of sizes 1.3 mm and 14.1 mm. Show your work.

Bead Particle Size (mm)	Permeability (cm/sec)
$x = 1.3$	$y =$
$x = 14.1$	$y =$

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

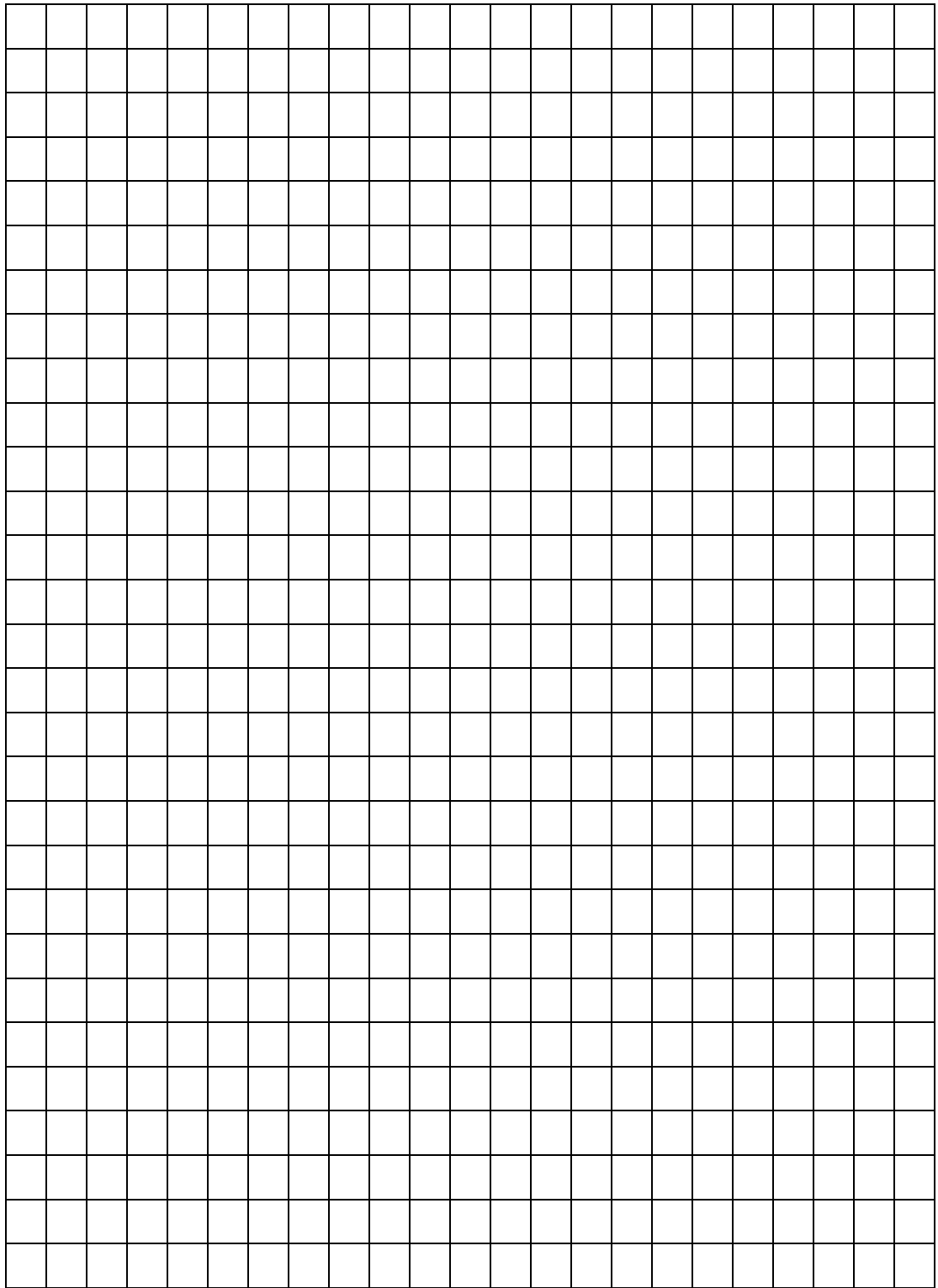
Graph the data on the next page to show the relationships between particle size (mm) and the water retained (ml).

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

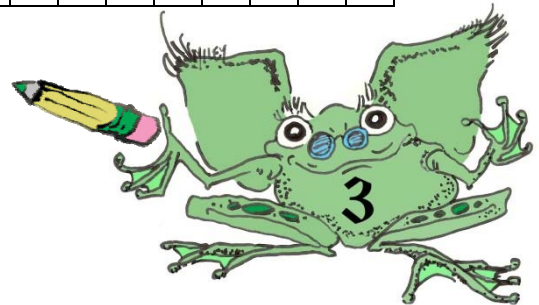


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Water Retention Discussion Questions: (amount of water retained)

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?

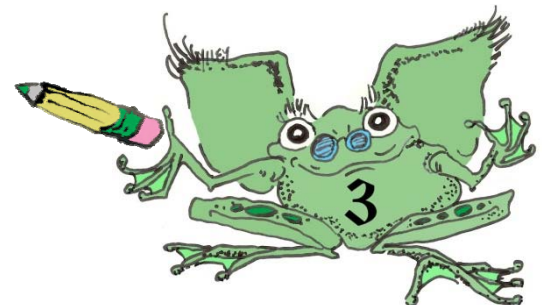
2. Describe the “shape” of the lines you drew between the three data points. Does it look as though the data forms a line, some sort of curve shape, or something else?

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?

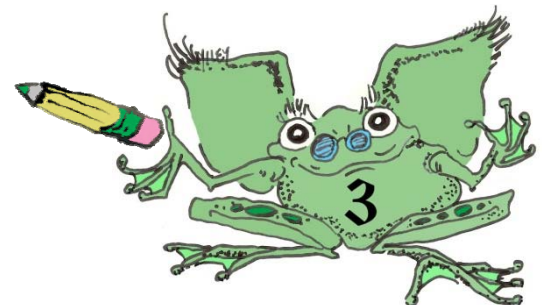
7. The formula for the unit rate of change for lines on the water retention graph would be:

$$\text{Unit Rate of Change} = \frac{\Delta \text{Water Retained (ml)}}{\Delta \text{Bead Particle Size (mm)}}$$

What would be the sign (positive/+ or negative/-) of the unit rate of change (slope) of the lines on the water retention graph connecting the data points

- a. between 4 and 7 mm? _____
- b. between 7 and 12 mm? _____
8. Which line would have the greatest (number/absolute value) unit rate of change (slope)?

The line between 4 and 7 mm / The line between 7 and 12 mm *circle one*

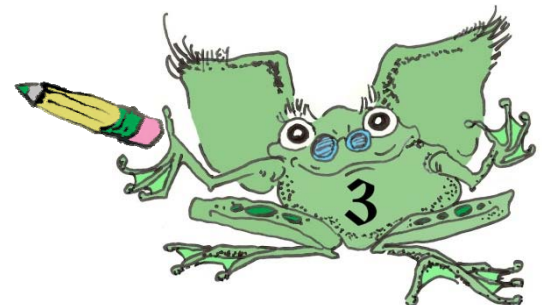


9. You have used linear equations in math and science to help analyze data. Linear equations ($y = mx + b$) of the lines between 4 and 7 mm, between 7 and 12 mm, between 4 and 12 mm, and even of a best-fit line using all three data points would not be useful to calculate predicted water retention in columns with beads less than 4 mm or more than 12 mm. Why not?

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.

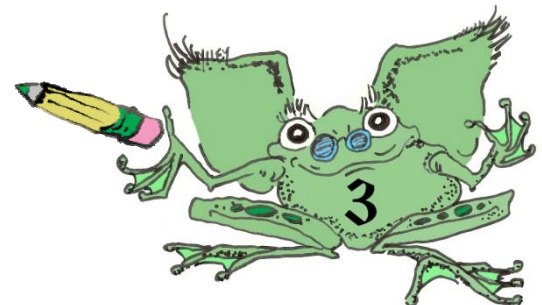


Porosity Discussion Questions:

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.

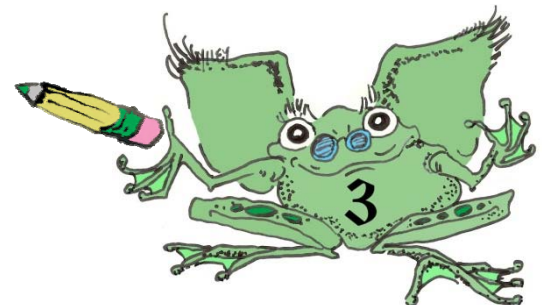
a. 9 mm _____ %

b. 14 mm _____ %

5. The formula for the unit rate of change (slope) for the porosity graph is

$$\text{Unit Rate of Change} = \frac{\Delta \text{Porosity (\%)}}{\Delta \text{Bead Particle Size (mm)}} = \frac{\Delta y}{\Delta x} = \frac{(y_2 - y_1)}{(x_2 - x_1)}$$

If beads of all sizes have the same porosity (all would have the same value for y), what would be the unit rate of change (slope) of bead size and porosity data? Explain.



6. Refer to the data chart and the porosity graph. What is the porosity of 4 mm beads?

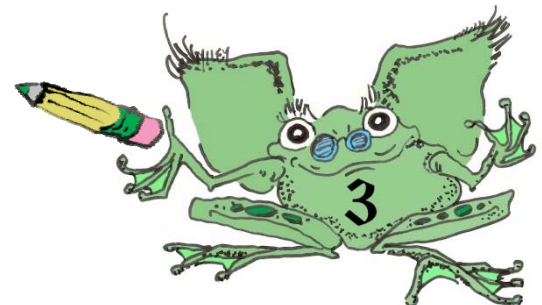
_____ %

All sizes of beads should have the same porosity. (The graphed line should be horizontal because all the different x 's / bead sizes would have the same value y 's / porosity %.)
Therefore, the y -intercept would be the same value as the y value (porosity) when $x = 4$ mm.

Y-Intercept (same porosity $x = 4$ mm)

7. On the basis of the unit rate of change that you calculated above and the y -intercept, write an equation for a horizontal porosity line through the 4 mm data point on the graph.

Equation



8. Use the equation above to calculate the expected porosity of bead particles of sizes 1.3 mm and 14.1 mm.

Bead Particle Size (mm)	Porosity (%)
1.3	
14.1	

