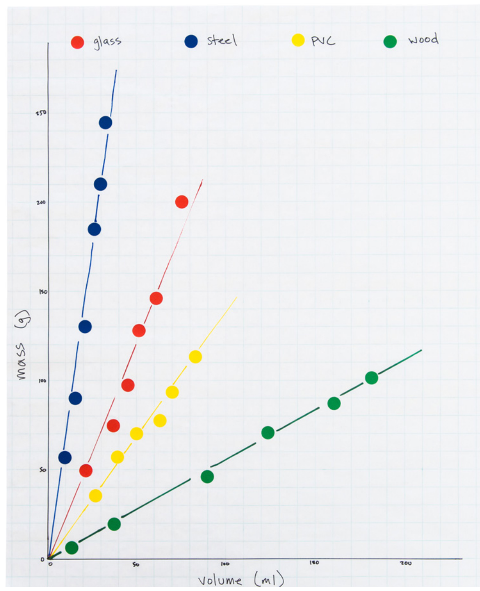


Plot the Dot

Graphing can be a slippery slope to understanding.

Scientists develop their descriptions of the world by collecting data. Graphs can reveal patterns that lead to a deeper understanding of phenomena. In this Snack, data collected from ordinary objects reveals a constant in nature.

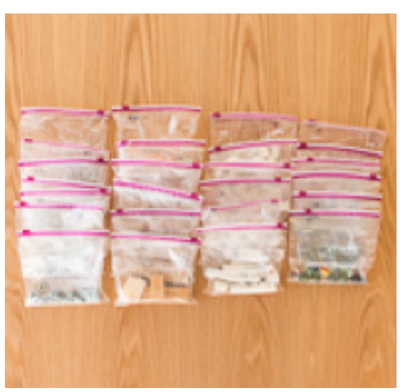
Tools and Materials

- Glass marbles
- Small pieces of wood
- Steel washers or nuts
- Small pieces of PVC
- 24 quart-size (liter-size) sealable plastic bags
- Digital balance
- Marker
- Assortment of graduated cylinders or measuring cups (Note that the volumes of the bagged samples will be determined by water displacement, so the containers must be big enough to hold the samples in each bag, plus some water)
- Water

- Pencil or skewer
- Paper towels
- Large piece of graph paper for plotting data
- Ruler or straight-edge
- Six sets of 3/4-inch-diameter circular labels in four different colors
- Optional: one additional set of 3/4-inch-diameter circular labels in a fifth color

Assembly

1. Place different amounts of marbles in six separate plastic bags. The exact number of marbles in each bag isn't critical, but they should all be different, and the total mass should not exceed 250 grams in any one bag. Use a marker to number the bags 1 through 6 so you can keep track of the samples.
2. Do the same for the wood, washers, and PVC, creating six bags of each type of material, and each with different amounts of a single sample. Continue numbering the bags, from 7 on. When you're done, you should have 24 numbered bags containing different amounts of different materials: glass, wood, steel, and PVC.



To Do and Notice

Record your data

Make a table to record the mass and volume of the contents in each of the 24 bags.

Find the mass of each sample

Use the digital balance to find the mass (in grams) of the contents in each bag. To do this, you can find the mass of the entire bag and then subtract the mass of the plastic bag (assume it's 5 grams), or you may use a more refined technique if you wish. Record the results in your table.

Find the volume of each sample

Use a method called water displacement to find the volume (in milliliters) of each bag's contents. Partially fill a graduated cylinder with a known amount of water. Take the objects out of one bag, place them in the water, and note the new volume in the graduated cylinder. The difference is the volume of the objects you added in. Note the results in your table, blot the objects dry with paper towels, and then return them to their plastic bag. Move on to the next bag until you've found the volume of all 24 samples.

As you work, be sure the objects are completely submerged. If there's not enough water, start over with more. If an object floats, gently push it down with a pencil or skewer until it's just below the surface. Try not to push the pencil into the water too far—you don't want to add its volume!

Create a graph of the results

Set up a graph on a large piece of paper with mass along the x-axis and volume along the y-axis. Scale the axes so the largest masses and volumes you measured will fit on the graph.

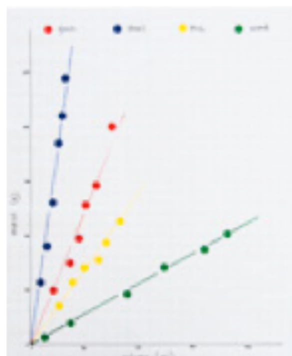
Assign a label color to each material (such as red for glass, blue for steel, yellow for PVC, green for wood), and stick a label at the appropriate mass-volume coordinates on the large graph for each of your samples. Do you notice a pattern in the data?

Use a ruler or straightedge to draw the best straight line through the dots that represent each of the four materials on the graph. Use 0,0 as the starting point of each line (when mass is zero, volume is zero).

What's Going On?

In this Snack, you're working with objects made of four different materials: glass, steel, wood, and PVC. The properties measured here—mass and volume—are examples of ***extrinsic properties***, since they aren't specific to a given material, but instead depend on other factors. Here, mass and volume both change depending on the quantity of the material. That means each sample bag has a different place on the mass-volume graph since they all contain different amounts of different materials.

The purpose of collecting data is to help us understand the world in a systematic way. Graphing is a valuable way to organize data since it can often help you determine a pattern. You may have noticed the pattern that appeared in your graph when you used colored dots to represent different materials. Even though each bag had a different number of objects in it, the dots for each material should have lined up.



The fact that a line appeared means there is something constant about the material. This constant can be found by determining the slope of the line you drew through the points. The slope represents the increase in mass for a given increase in volume. The fact that this is constant means that it is an ***intrinsic property*** of the material—something that doesn't change, regardless of the quantity of the material. This property, represented by the ratio of the mass of an object to its volume, is so important that it has a special name: ***density***. Your data shows that the density of a specific material at a given temperature is constant.

Going Further

Find the mass of six different volumes of water, with the largest volume not exceeding 200 mL. Plot these values onto the graph with dots of a new, fifth color, and draw a best-fit line through the dots. What do you notice?

The density of water at room temperature is 1g/mL, so the best-fit line should be close to the line $y = x$. Objects that sink in water (such as steel, glass, and PVC) have larger densities, and their data should have greater slopes than the water-sample line. Objects that float (such as wood) have smaller densities, and the slopes of their data will be less than the water-sample line.

Teaching Tips

This Snack is a powerful way to show students ***why*** we graph. Rather than teaching density by starting with an equation, we recommend having students realize that density is a property they can discover by collecting and graphing data.

In a large class, have small groups of students take the data for a single sample of each material. You can easily increase the number of samples to get students into smaller groups. Combine this data on a large graph that represents the class data so students can see how their data fit together. Having students put the number of the bag on their sample dot can help keep track of which dot represents which group.