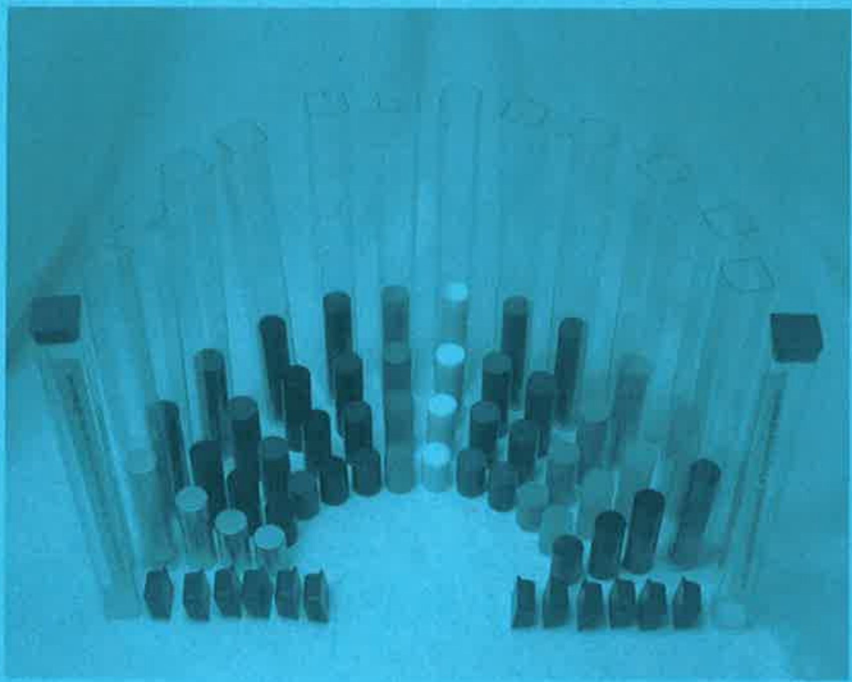
DN4X12

INSTRUCTIONS AND EXPERIMENTS
for the

Density / Slope Class Set



48 Density Specimens Arranged as
4 each of 12 Materials

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Notes to the Teacher

This is a class set of 48 density specimens, organized as 12 sets of 4. A given tube contains specimens of a particular substance. This set guides students to discover the idea of density as a mathematical concept, and to discover that density is a constant for a given substance.

Students determine the mass and volume of four material samples. As the graph will show, the data is not random, but follows a clear pattern: The data points from the material fall on one straight line.

The line has a constant slope, which may be calculated. When a mathematical constant is discovered as a result of scientific experiments, it is often given a name. The constant slope in this experiment is called *density* -- the slope of the line from the material data is the *density* of that type of material

Mathematically, the investigation above parallels exactly the experiments with the Speed of the Bubble Tube set, also available from many Science Education suppliers.

You may also use the set for authentic or performance tests of students' abilities in determining length measurements, mass, volume, and density.

Finally, the specimens serve as examples of substances of industrial importance. Some are familiar, while others are not commonly seen, or are not usually recognized when they are. Some information is given for each substance at the end of this manual.

The volume of the material specimens may be found either by immersion in water in a graduated cylinder, or by measurement with a metric ruler and calculation, using formulas for the volumes of geometric solids. A balance is used for finding mass.

The following are the densities of the included items in ascending order. The densities of the materials may be less consistent than implied by the number of significant figures given. This is particularly true of the wood samples, which may readily vary by 0.06 from the values given. All values are in units of g/cm^3.

0.77	Maple	1.23	Polyurethane
0.90	Polypropylene	1.32	Phenolic
1.03	Polystyrene	1.37	Polyvinylchloride (PVC) (2 colors)
1.15	Polyamide (Nylon)	2.2	PTFE (Teflon)
1.17	Acrylic (2 colors)	2.71	Aluminum

Safety

Please teach and expect safe behavior in your classroom and lab. Safety considerations call for supervision of students at all times, safety eyewear, no horseplay, and immediate reporting to the instructor of accidents or breakage , among others.

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LAB: Graphs and the Relationship between Mass and Volume

This lab shows how mass and volume are related. It also demonstrates how graphs can connect ideas from science and math.

Safety

Follow proper lab behavior rules, such as wearing safety glasses. Ask your teacher if you do not know these rules, or do not understand them.

The materials and equipment used in this lab are precisely made, and are expensive if lost or damaged. Please treat them with care. Return the material samples in the tubes, as you received them.

Items Needed

- A balance for determining mass
- A 100 *ml* graduated cylinder, *or* a metric ruler and calculator for finding volume
- 4 samples *of the same material*, furnished in square plastic tubes. (Your group may need to share and exchange these items with other groups. You will only need one sample at a time.)
- One or more lab partners, as your teacher directs

Procedure

Choose one of the samples, and find its volume and mass as accurately as possible. Enter your data into the table. Include units of measurement as part of your data. Your teacher may ask you to enter additional information into the notes column.

Then exchange samples with another group and repeat the above. Do this for all 4 samples. Remember to use four different samples *of the same kind of substance.*

For each of the samples, you now have a pair of numbers: its volume, and its mass. For each of these pairs, plot a point on the graph. Make the point neatly and accurately. Identify the data point by drawing a small circle around it.

When all four points have been plotted, use a pencil or erasable pen to draw a "best-fit line." Remember that a best-fit line is one that represents the pattern of the data. The pattern should be a straight line, so use a ruler or straight-edge. We should not expect the data points to all fall exactly on the line. It may be that none of them will. This is because all measurements contain uncertainty. The line should go through the point (0, 0). (Can you explain why?)

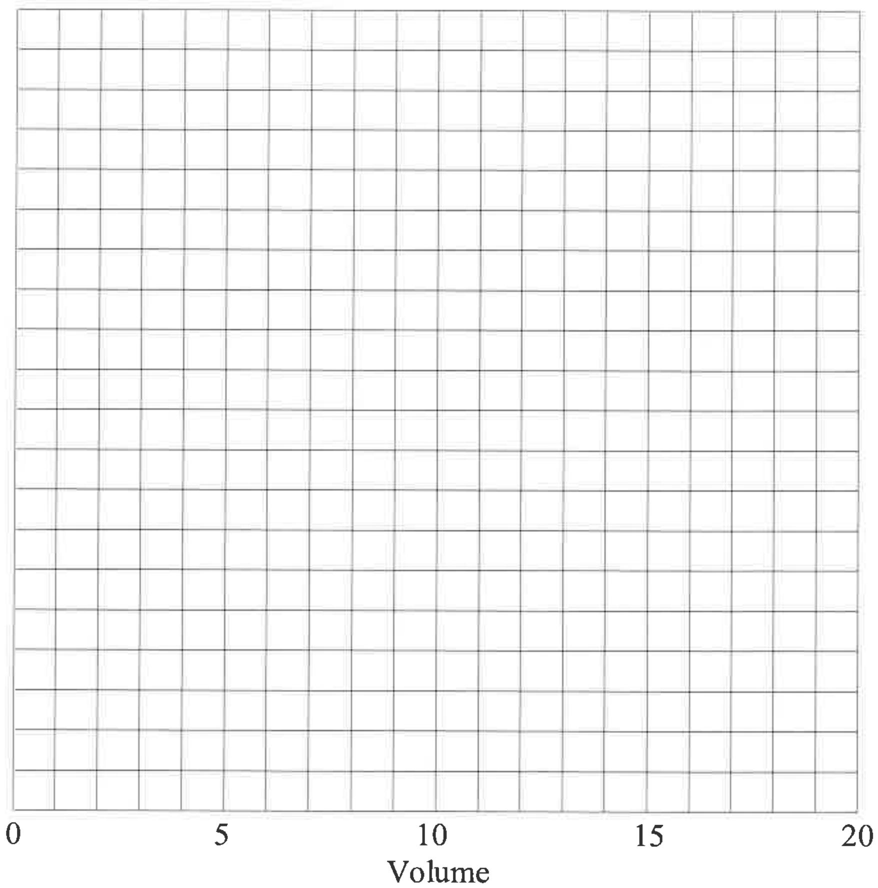
It is expected that the data points may not fall *exactly* on the best-fit lines. However, if any points fall *far* from the lines, the basic measurements should be rechecked for mistakes.

Your instructor may want you to repeat the above for 4 samples of a different substance.

LAB: Graphs and the Relationship between Mass and Volume…

Substance type:____________________________

Volume	Mass	Notes



LAB: Graphs and the Relationship between Mass and Volume
Questions:

In the field of math, we often use the word "slope" when we want to use numbers to say how steep something is. Slope is defined as Rise divided by Run. Rise is a vertical measurement, and Run is a horizontal measurement.

The best-fit line for your substance was a straight line going upward at an angle from the point (0,0). We can calculate the slope of this line by choosing two points on the line, finding the rise and run, and dividing.

1. Find the slope of the graphed line from the data for the material samples. Follow these steps:

a) Mark two points on the line, and label them "A" and "B." The points should be on the line, and far apart. Try to choose points that will make it easy to read the volume and mass measurements.
b) Point "A" corresponds to a volume of ________, and a mass of ________.
Point "B" corresponds to a volume of ________, and a mass of ________.
c) Use your answers from part "b" above to calculate the rise and run:
Rise = ______________ minus ______________ = ______________.
Run = ______________ minus ______________ = ______________.
(Did you remember to include units of measurement in your work above?)
d) Now calculate the slope:
Slope = Rise divided by Run = ____________.
(Do not forget to include units of measurement)

All parts of a straight line have the same, constant slope. When a mathematical constant is discovered as the result of scientific experiments, it is often given a name. The slope you have just calculated is called the *density of that material.* It is a property of the material in general; not just of some particular piece of that material.

The slope of each of these graphs was computed from the rise and run between two points. You could have chosen the point (0,0) as one of the points to simplify your arithmetic, although that was not necessary to find the correct answer. Then the rise would be an amount of mass, and the run would be the corresponding volume. This leads to the formula:

Density = Mass / Volume

One of the purposes of this experiment was for you to discover this formula by experiment, instead of merely reading it in a textbook. This experiment shows that when you find the density of an object made of a particular substance, such as aluminum, you have found the density of all objects made of that substance. While it is not necessary to graph many mass and volume measurements to find density, graphing does tend to "average out" small measurement errors, and to give a more accurate result.

Material descriptions

Following are the materials represented in this set, by color. Note that in some cases two different colors are in fact the same substance.

Black 1.15

Polyamide (Nylon): This is termed an "engineering plastic" due to its properties that allow its use in demanding applications such as machine parts, etc. It is tough through a wide range of temperatures, it is strong, and it has low coefficient of friction when in contact with steel and other metals. Drawn into fine fibers, it is used in textiles. The natural color is white. These samples have been colored black.

Dark Brown 1.32

Phenolic: This is one of the earlier plastics discovered, and is different in that it is a thermosetting plastic. Most other plastics, such as nylon, are thermoplastics—they may be heated and shaped, and when cooled retain their new form. This may be done repeatedly. Thermosetting plastics are formed at elevated temperatures, but during the forming process undergo chemical changes that do not permit them to soften a second time when heated again. Phenolic is hard but brittle, and is normally reinforced to give it better properties. Fillers include wood fibers, glass fibers, fabric, or paper. These samples are reinforced with paper. Phenolics are widely used as insulators in electrical appliances.

Light Tan 0.77

Over the past decades, significant reforestation has begun occurring in many areas of the United States. Maple, a common hardwood, is widespread in some of these forests. Maples are responsible for much of the bright red foliage seen in the autumn. The finer grades are valued for furniture, flooring, and finish carpentry, while the poorer grades are used for industrial purposes such as pallets for transporting goods. Some species are "tapped" to make maple syrup. Wood is somewhat porous, and will soak up water and change density. These specimens have been treated with a compound to close the pores at the surface to make it "waterproof". These specimens have been selected to have nearly the same density, but wood, being a natural mixture of many substances, has variable properties.

White 2.2

Poly tetrafluoroethylene (PTFE, TFE, or Teflon): This polymer has a variety of interesting properties, including resistance to extreme temperatures, very low coefficient of friction, non-stick characteristics, and resistance to almost all chemicals. These samples are its natural color, white. "Teflon" is a trademark, like *Xerox* and *Kleenex*.

Red Translucent, Green Translucent 1.17

Acrylic: This plastic can be made extremely transparent, and is used for windows, drinking glasses, and a wide variety of other items. It is naturally colorless. These samples have been colored red or green, and are translucent.

Purple, Gray 1.37

Polyvinylchloride, (PVC): This plastic is produced in very great amounts for a variety of purposes, including water pipes, chemical tanks, hardware items, etc. It is naturally colorless and transparent, but is commonly pigmented to make it more resistant to UV light, which has an adverse effect on many plastics. These samples are purple or gray.

Metallic Silver 2.71

Aluminum: Although this metallic element is quite active chemically, the thin oxide coating that quickly forms on its surface is impervious to air or water. This protects it from further corrosion. While mostly aluminum, these samples are actually an alloy containing a small percentage of other elements, including less than one percent each of magnesium, copper, iron, and silicon.

Red Opaque 0.90

Polypropylene: This plastic is a lower cost polymer which is produced in very large quantities for a variety of common uses, including food containers, toys, etc. Polypropylene has good chemical resistance, but has low strength and poor performance at temperature extremes. Its appearance in its natural state is a milky translucent white. These samples have been colored red.

Yellow 1.23

Polyurethane: This is an *elastomer*, or artificial rubber-like material. A wide variety of elastomers have been developed for purposes of chemical resistance, temperature resistance, and strength. Different formulations have different degrees of hardness. These samples are yellow, which is a color coding used in industry to designate its hardness.

Orange 1.03

Polystyrene: This is a low cost polymer which tends to be brittle. It is often injection molded, blow molded, or vacuum formed to make low cost articles. It may also be foamed for insulation for buildings or disposable cups. Styrofoam, which is a trademark, is an example. This plastic may readily be made in a crystal clear form, or colored. This sample has had additives to make it an opaque orange.