

ERROR ANALYSIS – DENSITY of SPHERICAL BEADS

In this lab, we will measure the density of a set of spherical glass beads. Each group will use 20 beads of the same type. The diameter of each bead will be measured with a caliper, and used to calculate the volume of the bead. The mass of each bead will be measured with a scale. The density of each bead will be calculated as the ratio of mass to volume. These values will be used to calculate an average density and a density variation.

Then the entire set of 20 beads will be treated as one unit. The total mass will be measured with the same scale. The total volume will be measured with water inside a graduated cylinder. These two numbers will also be used to calculate the density of the set of beads. We will compare the two values and see if they agree.

Uncertainty: The caliper will measure the bead diameters only within a range of uncertainty. The scale will measure the bead masses and the total mass only within a range of uncertainty. And the cylinder will measure the total volume only within a range of uncertainty. Therefore we cannot expect to have absolutely precise numbers for the density of the beads, and we cannot expect perfect agreement between the two values, even if the density of the beads is perfectly uniform.

Variation: In addition, there is a real variation in the shape and size of the beads, and perhaps in the density of the beads. We will see this variation by doing some statistical analysis on the numbers we measure. In the end, we will see variation in the diameter, mass and density of the beads. However, if the variation of each quantity is smaller than the uncertainty in that quantity, we can conclude that the quantity (diameter, mass or density) is uniform for the beads. This is true, whether we consider the actual variation and uncertainty, or the percent variation and uncertainty. IS THE DIAMETER UNIFORM? IS THE MASS UNIFORM? IS THE DENSITY UNIFORM?

Density results: We will state our results in the form of a density value and a range based on both the measurement uncertainties and the measured density variation: $\rho \pm \Delta\rho$. We will do this for the individual bead measurement data, and for the bulk measurement data. We will compare the two to see if the ranges overlap. If they do overlap, we can conclude that there is agreement as to the average density of the beads. If they do not overlap, then our measurements are inconclusive, and we do not have a good value for the density of the beads. DO THE TWO DATA SETS AGREE?

Checking for systematic errors: Sometimes a lab group is doing something that, unbeknownst to them, biases their measurements in a definite direction. For example, all their mass values might be too large for some reason. In this case we say there is a systematic error in the data. This effect can be hard to discern. One way to see if this is happening is for a second group to repeat the measurements using the same beads, but with their own equipment. If time allows then, after each group has made all the measurements with a set of 20 beads, they should swap beads with another group, repeat the measurements, and compare results. DO THE TWO LAB GROUPS AGREE?