# Measurements

**Objective:** To measure the volume of different solid objects, calculate the density of the objects, and find the standard deviation and the percent error.

**Theory:** For measurement in any scientific experiment there is a certain amount of precision that may be obtain using the instruments provided. These limitations to the accuracy of the instruments used may be caused by the instruments themselves or by the observer conducting the experiment. These uncertainties in the measurements must be regulated so that if two experimenters measure a quality, the results that are calculated may correlated. To maintain a correlation, significant figures are used. For a number such as $1117$ there are four significant figures, for $11$ there are two significant figures. However, for $20$ there is one significant figure and here we employ scientific notation, $2.0 * 10^1$. For multiplying or dividing measurements we use the use the number with least amount of significant figures which correlates to the less accurate number.

$$\frac{1028}{14} = 73.428571428571428571428571428571 \cong 73$$

When adding and subtracting, the number with the least amount of digits after the decimal place is used.

$$172.25 - 13.875 = 158.375 \approx 158.38$$

Standard deviation shows the amount a variation or dispersion from the expected value or average. The percent error from the standard value indicates the error in the experiment in relation to the values that have been set to be the standard of the value.

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i = \frac{x_1 + x_2 + x_3 + x_4 \dots \dots + x_N}{N} = average$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}} = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2 \dots + (x_N - \bar{x})^2}{N-1}}$$
$$= standard\ deviation\ for\ a\ small\ number\ of\ trials$$

$$\%\ error = \left|\frac{\bar{x} - x_s}{x_s}\right| * 100$$

Perform the indicated operation giving the answer to the correct amount of significant digits.

A. 15.3 x 7.9 = _____ D. 15.3 ÷ 7.9=_____

B. 16.47 - 4.2 = _____ E. 1.2 x $10^{-3}$ - 0.001=_____

C. 3.14 + 360 = _____

**Apparatus:** Electronic caliper, meter stick, balance

**Procedure:**

Dimensions of Object (Determining Volume):

1. Each group will be provided with an object. Using the electronic caliper two group members will measure the diameter, length, width, and height of the object.
2. Using the meter stick, two group members will measure the diameter, length, width and height of the object.
3. All group members will record each group member's values for the dimensions of the object in table 1 of each object.
4. Calculate the volume of the object using the formulas provided below.
5. Using your group's data determine the best value for the volume of the object (average or mean) and the standard deviation in this value.

Mass of Object (Determining Density):

1. Using the caliper, allow two group members to measure the diameter, length, width and height of the metal object and record these values in table 2 of each object.
2. Have two group members measure the diameter, length, width and height of the object also using the caliper.
3. Obtain the mass of the object.
4. Calculate the volume of the object. Using your measured value for the mass and the calculated value for the volume, determine the density of the object.
5. Using your data and data provided by group members, determine the best value for the density of the object (mean) and the average deviation of the mean.
6. Using the "standard value" for density provided by the instructor, determine the percentage error in your measurement.

$$\rho = \frac{m}{V}$$
$$V_{block} = L * W * H$$
$$V_{sphere} = \frac{4}{3} * \pi * r^3$$
$$V_{cylinder} = \pi * r^2 * h$$

**Object: Cube**

Table 1:

| Group Member | Length (L) | Width (W) | Height (H) | Volume (V) |
|---|---|---|---|---|
| **1 (Caliper)** | | | | |
| **2 (Caliper)** | | | | |
| **3 (Ruler)** | | | | |
| **4 (Ruler)** | | | | |
| **Average Volume:** | | | | |
| **Standard Deviation in Volume:** | | | | |

Volume of Object: _____ in units of _____

Table 2

| Group Member | Mass | Volume (V) | Density (ρ) |
|---|---|---|---|
| **1** | | | |
| **2** | | | |
| **3** | | | |
| **4** | | | |
| **Average Density:** | | | |
| **Standard Deviation in Density:** | | | |

Density of Object: _____ in units of _____

Percent Error: _____ %

What is the cube made of? _____

**Object: Cylinder**

Table 1

| Group Member | Diameter (D) | Height (H) | Volume (V) |
|---|---|---|---|
| **1 (Caliper)** | | | |
| **2 (Caliper)** | | | |
| **3 (Ruler)** | | | |
| **4 (Ruler)** | | | |
| **Average Volume:** | | | |
| **Standard Deviation in Volume:** | | | |

Volume of Object: _____ in units of _____

Table 2

| Group Member | Mass | Volume (V) | Density (ρ) |
|---|---|---|---|
| **1** | | | |
| **2** | | | |
| **3** | | | |
| **4** | | | |
| **Average Density:** | | | |
| **Standard Deviation in Density:** | | | |

Density of Object: _____ in units of _____

Percent Error: _____ %

What is the cylinder made of? _____

**Object: Sphere**

Table 1

| Group Member | Diameter (D) | Volume (V) |
|---|---|---|
| **1 (Caliper)** | | |
| **2 (Caliper)** | | |
| **3 (Ruler)** | | |
| **4 (Ruler)** | | |
| **Average Volume:** | | |
| **Standard Deviation in Volume:** | | |

Volume of Object: _____ in units of _____

Table 2

| Group Member | Mass | Volume (V) | Density (ρ) |
|---|---|---|---|
| **1** | | | |
| **2** | | | |
| **3** | | | |
| **4** | | | |
| **Average Density:** | | | |
| **Standard Deviation in Density:** | | | |

Density of Object: _____ in units of _____

Percent Error: _____ %

What is the sphere made of? _____