There are two kinds of quantities in physics: *measured* quantities and *calculated* quantities. Measured quantities are the numbers you read from measuring instruments. Calculated quantities are the numbers you get from calculations, using measurements. In this activity you will measure the dimensions of a cylinder and use these measurements to determine its volume and its density.

You can find the inherent error in a measurement by finding the *average deviation in the mean* (or the average deviation). Suppose that I measure the length of a line 5 times. My measurements are as follows:

\[ L_1 = 5.32 \text{ cm} \]
\[ L_2 = 5.28 \text{ cm} \]
\[ L_3 = 5.30 \text{ cm} \]
\[ L_4 = 5.34 \text{ cm} \]
\[ L_5 = 5.33 \text{ cm} \]

The average length is given by:

\[ \langle L \rangle = \frac{\sum_{i=1}^{N} L_i}{N} = \frac{L_1 + L_2 + L_3 + L_4 + L_5}{5} \]

\( N \) is the number of data points.

To calculate the average deviation, you will find the absolute value of the deviation of each point from the mean and average these values.

\[ \text{Average deviation} = \frac{\sum_{i=1}^{N} |\langle L \rangle - L_i|}{N} = \frac{|\langle L \rangle - L_1| + |\langle L \rangle - L_2| + |\langle L \rangle - L_3| + |\langle L \rangle - L_4| + |\langle L \rangle - L_5|}{5} \]
So, first, find the average of my measurements:

\[
\langle L \rangle = \frac{5.32 + 5.28 + 5.30 + 5.34 + 5.33}{5} = 5.314
\]

And then find the absolute value of the deviations of the measurements:

\[
\delta L = \frac{|5.314 - 5.32| + |5.314 - 5.28| + |5.314 - 5.30| + |5.314 - 5.34| + |5.314 - 5.33|}{5} = 0.0128
\]

Now, round off to one significant figure: \( \delta L = 0.01 \)

Write the measurement and uncertainty in proper form:

\[
(L \pm \delta L) \text{ cm} = (5.31 \pm 0.01) \text{ cm}
\]

I. Meter stick
   What is the least count of a meter stick?

Select a cylinder and measure its height and diameter. Make each measurement 5 times. Record them in this table:

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<tr>
<th>Height</th>
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Calculate the Mean Value and the Average Deviation From The Mean. Write them below, including one-half the least count of the meter stick.
Which is the larger of the two uncertainties, the Average Deviation or half of the least count? Use the larger one for the uncertainty.

\[ \delta h = \]
\[ \delta d = \]

Write the height and the diameter of the cylinder in proper form:

\[ h = ( \quad ) \text{ cm} \]
\[ d = ( \quad ) \text{ cm} \]

Calculate the volume of the cylinder:

\[ V = \pi r^2 h \]

Calculate the uncertainty in the volume calculation. (See the handout on Uncertainty and Error Propogation.)

\[ V + \delta V = \]

II. Mass Measurement:
What is the least count of the electronic balance?

Measure the mass of your cylinder once and record the measurement and the uncertainty:

\[ m \pm \delta m = \]

III. Density Calculation:
Density is a property of matter. All materials have a characteristic density; for example, the density of aluminum is 2.7 g/cm\(^3\). Density is calculated as follows:
\[ \rho = \frac{m}{V} \]

Use the mass and the volume that you calculated in part I and calculate the density of the cylinder, and its uncertainty. *Show your calculations.*

\[ \rho \pm \delta \rho = \]