Introduction:
Humans measure all the time. We measure the food we buy in the grocery store. We measure our weight. We measure our speed on the highway. We measure our academic performance; yes, grades are a kind of measurement too!

Physics is a science that is based on measurements. In every lab you do in this course, you will take measurements, and you will learn to use different measuring instruments.

Units:
If you are American, you probably measure your weight in pounds, and your height in feet and inches. You measure the mileage on your car, and you watch for police officers when you're driving at 80 miles per hour.

These units (pounds, feet, inches and miles) are part of a system of measurement known as the US Customary System, which is also known as the English System of units. (England switched over to the metric system a long time ago, so we don't call the old system the English System very much any more.) You may be used to these units, but we do not use them in physics.

We will use the metric system of units. This is more formally known as the SI system, after the French Systeme Internationale. The metric system really is international. The US is the only country in the world that still clings to the old units!

We will use meters to measure length. We will use seconds to measure time. We will use kilograms to measure mass. (At times, like in this lab, we will use centimeters for length, but not very often. Most of the time, it will be meters.)

Measurement:
You already know how to use a ruler to measure length. Or do you? How long is this line?
What is your answer?

The correct answer to this question is \textbf{4 cm}. Any other answer is incorrect. That includes 4.0, 4.2, 4.3 or any other answers. The only correct answer is 4 cm.

That seems kind of silly; isn't 4.0 exactly the same? Mathematically, yes; \(4 = 4.0\)! But in physics these numbers aren't the same when we are making measurements. That is because every measuring instrument is different.

Let's move that ruler and measure again.

We've simply moved the ruler so that the line is up against a different measuring scale. It's the same line. It's a different measuring instrument. What is the length of the line now?

The line's length is 4.2 cm.

So, what is the difference between these measurements?
The difference is in the **precision** of the instrument. The first scale that we used was in centimeters (cm). Each centimeter was marked, but only whole centimeters were shown. From zero to one, from one to two; only whole centimeters were shown. Therefore, we must measure in whole centimeters. We can clearly see that the line is longer than 4 cm and shorter than 5 cm, but the scale gives us no way to know how much longer than 4 cm. Out in the world, you might make a guess, and your guess might be pretty good. But in a physics lab, we don't guess. We record what we know. We see a 4, we see no decimal numbers, and we see that the end of the line is much closer to 4 than to 5. The measurement is 4 cm. This measurement is not very **precise**. It is **accurate**. **Accuracy** refers to how close to the real answer our measurement is.

However, when we use the other edge of the ruler, the precision of the instrument changes. Again, we see the large centimeters marked off, just as they were on the first edge. But we also see that the space between whole centimeters is divided into ten spaces. Each one of these is 0.1 cm, or $\frac{1}{10}$ cm. The end of the line is clearly just barely past the 4.2 cm line, so we will record 4.2 cm. Is it really 4.2 cm? No, not exactly; it's probably close to 4.22 cm. But we can't read that last **digit** on the scale; it's a guess. And we don't guess in a physics lab.

The number of digits in a measurement is determined by counting the **significant digits**, or **significant figures**.

**Purpose:** The purpose of this experiment is to practice measuring with two different measuring instruments, and to determine the correct number of significant figures to use in each measurement.

**Equipment:** A cm ruler, a vernier caliper, two 2-dimensional shapes.

**Procedure:** For each shape, measure the indicated sides. Use the centimeter ruler to measure. Repeat these measurements using the vernier caliper. Record all your measurements.
Before you start, answer these questions:

1. What is the smallest distance that you can measure with a meter stick?

     cm

So, how many decimal places will your ruler measurements have?
2. What is the smallest distance that you can measure with a vernier caliper?

__________ cm

So, how many decimal places will your vernier caliper measurements have?

<table>
<thead>
<tr>
<th></th>
<th>Ruler</th>
<th>Vernier Calipers</th>
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**Conclusions:**

Q1: True or false: Vernier caliper measurements are better than ruler measurements. Explain your answer clearly.

Q2: True or false: It is always better to have more precision (more decimal places) than less precision (fewer decimal places).

Q3: Four teams of students measured pi. (Pi is the ratio of the circumference of a circle to the diameter of a circle. Pi = 3.141592653587...) Their results were as follows:

Team 1: Pi = 3

Team 2: Pi = 2.15994015

Team 3: Pi = 1.2
Team 4: Pi = 3.142

Place these results on the following grid:

<table>
<thead>
<tr>
<th>Less Precise</th>
<th>More Precise</th>
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<tbody>
<tr>
<td>Less Accurate</td>
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<td></td>
<td>More Accurate</td>
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Q4: Look at your results. Is it possible to have very poor results that are very precise? Is it possible to have good results that are not at all precise?

Q5: Name a situation where you want an accurate measurement, but not a very precise one.

Q6: Name a situation where you want an accurate measurement that is very precise.