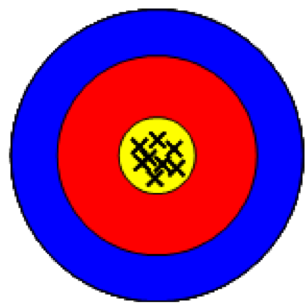
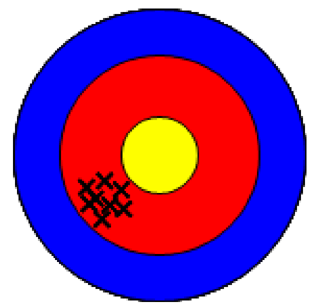
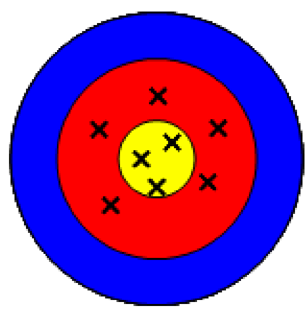
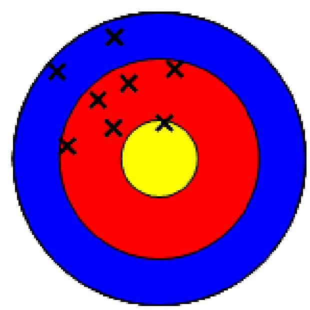
Measurement, Uncertainty, and Significant Digits (Figures)

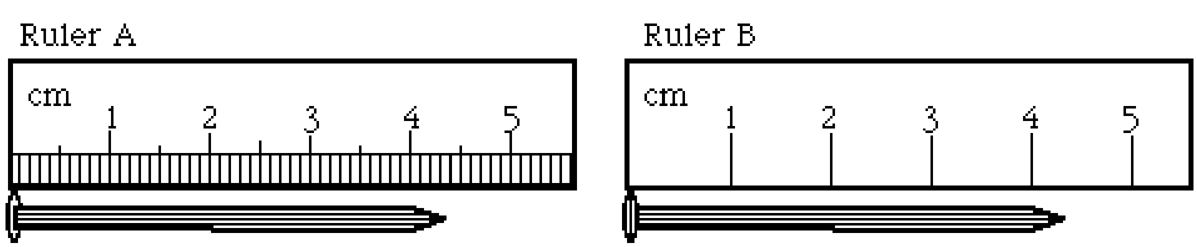
1. Precise and accurate measurements are important in any field of science.

2. Experimental errors can be classified into two basic types -systematic and random. Systematic errors result from an instrument that is in some way inaccurate (the first cm is cut off the ruler). Random errors usually result in the limitations of the measuring device.

3. Accuracy refers to how close the measurement is to the correct value while precision refers to the smallest measurable unit on your measuring device.

	Accurate	Inaccurate (systematic error)
Precise		
Imprecise (reproducibility error)		

4. Uncertainty comes from the limitation of the measuring device (the precision of the device).



5. Ruler A measures the length to be 4.35cm while ruler B measures the length to be 4.3cm. A typical ruler has an uncertainty (precision) of about +/- 0.5 mm.

6. If a measurement does not have a specified uncertainty it is then assumed to have an uncertainty of one unit of the last digit.

Example 10.23cm has an uncertainty of +/- 0.01cm

7. Uncertainty can be expressed as a percent, this is known as the percent uncertainty. The percent uncertainty is the ratio of the uncertainty to the measured value and multiplied by 100. This is used to indicate the precision of the measured value in terms of a percent.

Example: The percent uncertainty for the previous example is

$$\frac{0.01}{10.23} \times 100$$

0.09775%

0.1%

10.23 +/- 0.1%

8. If an experimenter wants to compare how close their value is with the accepted value then percentage error is used. The percent error is the ratio of the difference between the accepted and measured values and the accepted value.

$$\frac{(\text{Measured} - \text{Accepted}) \times 100}{\text{Accepted}} = \text{percent error}$$

Example: The accepted value for the speed of light is 3.0×10^8 m/s. You measure the speed of light to be 2.5×10^8 m/s. What is the percent error?

$$\frac{(\text{Measured} - \text{Accepted}) \times 100}{\text{Accepted}} = \text{percent error}$$

$$\frac{(2.5 \times 10^8 - 3.0 \times 10^8)}{3.0 \times 10^8} \times 100 = -17\%$$

9. Significant digits are all certain digits and one uncertain digit.

Rules for counting significant digits:

1. All nonzero digits are significant.
   Example: 536 3 sig figs
2. Zeros at the beginning are not significant.
   Example: 0.0056 2 sig figs
3. Imbedded zeros are significant.
   Example: 506 3 sig figs
4. Trailing zeros in a decimal number are significant.
   Example: 3.0 2 sig figs

5. Exact numbers have an infinite number of sig figs.

Example: 1 dozen is 12, the number 12 is exact.

10. Scientific notation helps avoid confusion since it reports only the significant figures.

Example: 2.35×10^6 has 3 sig figs

11. We will use two rules when calculating with significant digits (figures).

1. When adding or subtracting with sig figs you cannot report the answer more precisely than the least precise number used in the calculation.

Example: 2.35 + 2.5 = 4.9 (2.5 is the least precise number used, it is precise to one decimal place while 2.35 is precise to two decimal places)

2. When multiplying or dividing report the answer with the same number of sig figs as the smallest number of sig figs used in the calculation.

Example: 2.35 x 2.254 = 5.30 (2.35 has the least number of sig figs – 3).

12. When a combination of mathematical operations occur we will use the multiplication and division rule for significant figures.

Example:

$$\frac{(3.56 + 2.0)}{2} \times 5.3 = 147.34$$

One sig fig due to the number 2

147.34 => 100 (one sig fig)