PreLab 1 - Measurement and error

<u>Measurement</u> involves reading some sort of scale. The scale marking spacing is always limited and the width of the scale lines is always nonzero. The final reading must be estimated and is therefore uncertain. This kind of scale-reading error is **random** (or **statistical**) since one expects that half of the time the estimate will be too small, and the other half of the time the estimate will be too large. One thus expects that random errors should cancel on average, that is, many measurements of the same quantity should produce a more reliable estimate.

<u>Statistical errors</u> can be decreased by performing a large number of measurements. The error estimate on a single scale reading can be taken as the smallest step of the scale. For example, if you were measuring length with a scale marked in millimeters, you might quote the reading as 17.0 cm ± 0.1 cm. The quoted error assumes that one can visually distinguish measurements of the order of 1 mm (the marked spacing). If you measured the same length many times, you would expect the error on the measurement to decrease. The best estimate of the measured quantity is the **mean** or **average** of all the measurements. Simply add all the individual measurements **m** together and divide by the number **N** of measurements:

$$\text{Mean or average} = \frac{m_1 + m_2 + \cdots + m_N}{N}.$$

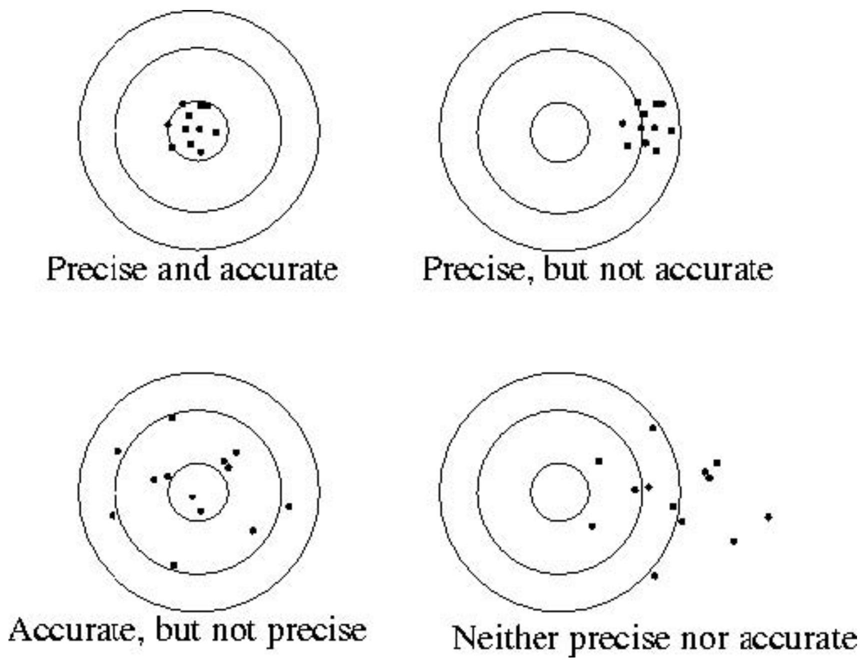
The best estimate of the error is given by the error on a single measurement divided by the square root of the number of measurements:

$$\text{Error estimate} = \frac{\text{error of a single measurement}}{\sqrt{N}}.$$

Obviously, this will decrease as the number of measurements increases. The final reading for a quantity should be quoted as: (mean) ± (error estimate).

<u>Systematic errors</u> are difficult to detect, and the sizes of systematic errors are difficult to estimate. Increasing the number of measurements has no effect on systematic errors because the error is always in the same direction (all measurements too high, or all measurements too low). Careful instrument calibration and understanding of the measurement being made are part of prevention. For example, suppose that you are using a stopwatch to time runners in the 100-meter dash. You are quite adept at making the measurement, but -- unknown to you -- the watch runs 5% fast. All times will be 5% too high. There will be no immediately obvious indication of a problem. If you happen to be familiar with the runners' normal times, you might notice that everyone seems to be having a slow day. To prevent such problems, one should calibrate the stopwatch with a known standard watch.

<u>Error rules:</u> 1) the error should have one significant figure; 2) the number of decimal places in the measurement should be the same as the number of decimal places in the error.



<u>Accuracy and precision</u> have different meanings. The figure gives a good account of their meanings.

LAB 1

PART 1 - Measure the length of the metal rods

Equipment: plastic ruler, metal ruler, metal rod

(a) Using **only** the plastic ruler, measure the length of the rod 6 times. When you are finished, average the values to get a better measure of the piece's true length.
(b) Next, use your metal ruler to measure the rod again. Measure 6 times as before and compute the average to refine your measured value.

PART 2 - Measure the height of a candle flame

Equipment: candle, metal ruler

Light your candle and let the flame burn steadily for a minute or so. Use the metal ruler to measure the height of the flame. Make 6 measurements and try not to melt the ruler. Hold the ruler a small distance away from the flame. Record your measurements. Estimate for each measurement its error. Identify the technique you used to find the uncertainty of your final answer. **Remember to write only a sensible number of significant figures**.

PART 3 - Measure your reaction time

Equipment: ruler

Your reaction time is the time that passes between some external stimulus and your first action.

a) Have your partner hold the regular ruler vertically, holding it by the top and having the zero point toward the bottom.

b) Place your thumb and forefinger at the ruler's bottom, surrounding the zero point. Be prepared to pinch the ruler as if it were to fall. Rest your forearm on the lab table to steady your hand.

c) Your partner will drop the ruler without warning.

d) Pinch and grab the falling ruler as fast as you can. Record the distance the ruler fell. This will tell you your reaction time.

e) Make 5 measurements and record the corresponding reaction times. Record your reaction times on your data sheet. Do not mix your times with your partners. This means you will make 5 measurements per person. Compute and record the individual 's for each measurement. The reaction time should be calculated from $t = \sqrt{2d/g}$. Identify the technique you used to find the uncertainty of your final answer. Be sure that both you and your lab partner have your reaction times measured.

PART 4 - Measure the mass of water

Equipment: balance, cup, water

You and your partner will be given a cup containing some water. Using the balance on the instructor's table, measure and record the mass of the cup 5 times. After each measurement, and before the next measurement, pour approximately (make a "visual" estimate) half of the water in the cup down the sink.

LAB 1 - Report

Name: ______________________ **Section**: ___________________

Rod length	Plastic	Error	Metal	Error
Measurement 1	__________	_______	__________	_______
Measurement 2	__________	_______	__________	_______
Measurement 3	__________	_______	__________	_______
Measurement 4	__________	_______	__________	_______
Measurement 5	__________	_______	__________	_______
Measurement 6	__________	_______	__________	_______
Average Value	__________		__________	
Uncertainty	__________		__________	

a) Explain the possible sources of error in this measurement?

Flame Height	Value	Error
Measurement 1	__________	_______
Measurement 2	__________	_______
Measurement 3	__________	_______
Measurement 4	__________	_______
Measurement 5	__________	_______
Measurement 6	__________	_______
Average Value	__________	
Uncertainty	__________	

a) Describe the possible sources of error in this measurement.

b) What might you do to get a better measurement of the flame's height?

Reaction time	Value	Error
Measurement 1	__________	_______
Measurement 2	__________	_______
Measurement 3	__________	_______
Measurement 4	__________	_______
Measurement 5	__________	_______
Average Value	__________	
Uncertainty	__________	

a) Describe the possible sources of error in this measurement and explain their relevance.

Mass of water	value ± error
Measurement 1	____________________
Measurement 2	____________________
Measurement 3	____________________
Measurement 4	____________________
Measurement 5	____________________

a) Describe the possible sources of error in this measurement and their relevance.

b) Do you see any pattern in the measured masses? What is it?

Which of your measurements (metal rods, flame height, reaction time, mass) was the most uncertain? Why?

Which of your measurements (metal rods, reaction time, flame height, etc.) was the least uncertain? Why?

Which measurements (metal rods, reaction time, flame height, water), if any, suffered from systematic error?

Explain.

Conclusions. Succinctly describe what you learned today.