Measurement Uncertainty

1. **Human Response Time Experiment**

   This is an exercise in understanding measurement and uncertainty. The basic idea is that nothing is ever measured exactly, and it is therefore a good idea to try to understand the uncertainty of anything you try to estimate experimentally.

   (a) Break up into pairs and have each pair grab a ruler (Note: you can have a group of three if you want).
   (b) Have one person hold the ruler vertically while the other person holds their thumb and forefinger on either side of the bottom of the ruler.
   (c) Have the first person drop the ruler at a random time while the second person pinches it as fast as they can.
   (d) The ruler will have dropped some distance before being grabbed. Repeat this a few times until you get a distance which you feel is representative. Record this distance and swap roles.
   (e) Once everyone has a distance, I will write down the measurements on the board. We will then use these measurements for an analysis to be done individually (I will help you if you are having trouble).

2. **Helpful Hints for Analysis**

   For the analysis, you will need to know how to compute the *mean* of a set of measurements as well as the *standard deviation*. The mean value is just the average of the measured values. The standard deviation is a measure of how uncertain the mean value you calculated is (remember, no measurement is ever exact...).

   Here are the definitions of the mean and standard deviation. For the mean, just add up the measured values x_i and divide by the number N of values you used in the sum:

   $$\langle x \rangle = \frac{1}{N} \sum_{i=1}^{N} x_i$$

   Now you can use the mean you calculated to derive σ_x, the standard deviation, using the following formula:

   $$\sigma_x = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (x_i - \langle x \rangle)^2}$$

In addition, you will need to convert the distance x that the ruler dropped into a reaction time t. This is accomplished using the formula for an object in free fall:

$$x = \frac{1}{2}gt^2$$

where g is the acceleration of gravity on Earth's surface (what is the value of this constant?).

3. **Analysis and Questions**

   Now you will derive a reaction time (with an uncertainty) that is characteristic of the class.

   (a) Convert each distance measurement x into a corresponding reaction time.

   (b) Compute the mean and standard deviation of the set of reaction times.

   (c) What is the fractional (or percentage) uncertainty in the estimated value for the reaction time? For instance, if you were writing an article describing your results, you might say "This value is uncertain to X%" to give the audience an idea of how precisely you can estimate such a thing.

   (d) Can you think of a way in which you might reduce the uncertainty? (Hint: let's assume that we must use the same people but we are allowed to change the experimental setup).

   (e) Hockey goalies are known for their fast reaction times. Suppose the class invited a hockey goalie to participate in the experiment and it was found that his reaction time was 20 ms faster than the fastest time we recorded in class (refer to your table). Is his reaction time *significantly* faster than the average person (assuming our class is representative of the average)? Why or why not?

   (f) What does this tell you about claims like:

   - "This medicine works faster than the leading brand."
   - "This mutual fund outperformed all others in the 4th quarter."
   - "I am the fastest person on the track team."