Uncertainty and Error Analysis

Introduction

In every measurement you make, there is always some uncertainty in your result. For example, when measuring the length of an object with a ruler, you must estimate the last digit because the reading falls in between the smallest divisions on the scale. And if the object being measured is not uniform, this introduces even more uncertainty. You should always observe and record the uncertainty in measurements you make. For example, you might record that the length of an object was 24.2 cm ± 0.3 cm. Note that your measurement must also include units! You should always round your final answers to an appropriate number of digits.

Figure 1: Four Different Diameter Disks

Equipment

Qty	Items	Part Number
1	Discover π Set	ME-6806
Required, but not included:		
1	PASCO Capstone software	

Setup

In this lab you will learn to observe and record the uncertainty in measuring the diameter and circumference of four different sized disks (shown in Figure 1) using the supplied clear flexible ruled tape.

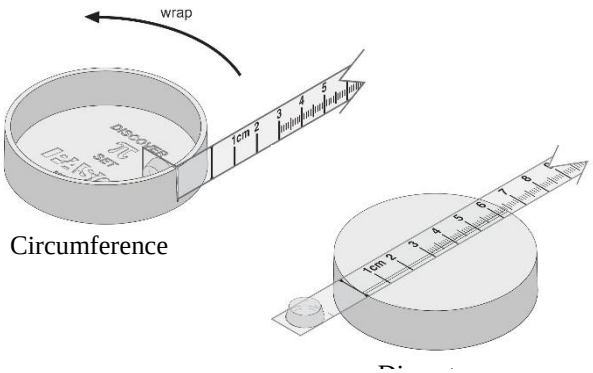

Figure 2: Measuring Diameter and Circumference

To measure circumference: As shown in Figure 2, slip the folded end into the slot on the side of the disk and wrap the tape once around the disk so that it overlaps the zero-line marker.

To measure diameter: As shown in Figure 2, place the tape along the line marked on the face of the disk.

Estimating Uncertainty

1. In PASCO Capstone, create a table called Table I: Largest Disk. In the first column, add a user-entered data set called “Circumference” with units of (cm). Delete the second column. Then turn on the statistics, with the mean and standard deviation both turned on.

2. Create a graph of Circumference vs. Index. Turn on the statistics, with the mean, max, min, and standard deviation all turned on.

3. One way to estimate uncertainty is to repeat a measurement several times. Try this method for measuring the circumference of the largest disk. The tape is marked to 0.1 cm, but you can measure an additional digit by estimating between the tick marks. Re-wrap the tape and repeat the measurement. Do you get a different answer depending on the tension you apply?

4. Record your two measurements into Table I. These measurements will be plotted on the graph. As you add in more values, observe how the max, min and mean (average) change. Have each person in your group take separate measurements without looking at each other's measurements. Record all the values for the circumference of the largest disk in Table I.

5. The Standard Deviation is often used as a good estimate of the uncertainty. Record your final value for the circumference in the form "Mean Value" ± "Standard Deviation". Do you need to do any rounding? Never include more digits than makes sense. Don't forget the units!

6. Create another table called Table II: Measurements for 4 Disks. In the first column, create a user-entered set called “Disk” without units. Enter the values Largest, Large, Medium, and Smallest. Create another user-entered data set in the second column called “Circ.” with units of (cm). Record your value for the circumference of the largest disk in the first row. Add another column and create a user-entered data set called “Diameter” with units of (cm).

7. Use the plastic ruler to measure the diameter of the largest disk as shown in Figure 2.
   What is the uncertainty in this measurement? You do not need to make the large variety of measurements that you did on the previous page, but at least make a few to allow you to estimate the uncertainty.
   Record the diameter of the largest disk in Table II.

8. Measure the circumference and diameter of the other 3 disks, and record in Table II.

Analysis

1. In Capstone, create a graph of Circ. vs. Diameter. This will display the data from Table II.

2. What is the relationship between the circumference and diameter of a circle? Select the Linear Curve Fit from the graph tool pallet. What is the slope of the line? What is it supposed to be?

3. Note the uncertainty in the value of the slope. This is based on the values you input, but remember that there is an uncertainty in those measurements.

   In Table II, take the ± uncertainty value you determined earlier for the circumference of the disk, and add this uncertainty to the circumference of the largest disk, and subtract it from the circumference of the smallest disk. By how much does this change the slope? This change is a good estimation of the uncertainty in your value for the slope.

4. Record your best value for the slope (including uncertainty).

5. Percent Error: Often in the lab you are measuring something that has a known or accepted value. To compare your measured result with the accepted value, it is useful to calculate the percent error in that measurement.

$$\% \text{ Error} = \left|\frac{\text{Measured} - \text{Accepted}}{\text{Accepted}}\right| \times 100$$

   Compare your answer to the accepted value by calculating the percent error.