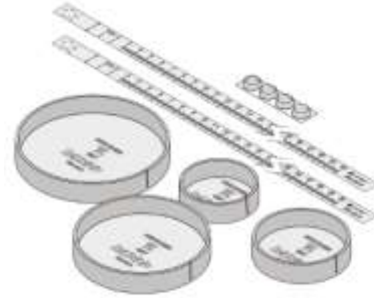

Manual to Lab 1: PHY2048C.

Florida State University – Republic of Panama

Measurements and dimensions

About labs in this class

The labs in this class will have general instructions, and many things need to be figured out by the students. People will be grouped (normally 4 groups in total), but groups can communicate with each other as well. I will be answering any specific questions the students may have without completely giving away the key to the puzzle. **Answer the questions and record all measurements in your lab notebook; submit a scan of all pages to canvas before next class.**

About this lab

When a pendulum swings back and forth, it is said to be vibrating in SHM. The time (in seconds) it takes for a pendulum to complete one complete vibration is known as its period. The inverse of this – the number of waves that pass by in one second – is known as frequency (measured in Hz). In today's lab, we will predict and test which factors affect the period and frequency of a pendulum. Using our results, we will compare it to the theoretical calculations for the period of a wave, and question why there are differences between what we should find and what we see.

The goal of this lab is to develop an intuition on how making multiple measurement reduces the error bar on a measurement. **The confidence of your measurements will be the minimal marking on the tape measure you use, called the precision (P) of the measurement apparatus.** So, if a measurement falls between 1 and 2 millimeters, then you report the measurement as $1.5\ \pm 0.5$ mm.

If we use this length (call it *L*) to compute any other quantity (like an area) then this error *propagates*. The propagation of error formula yields the error of the new computed quantity. It uses *differentials* to calculate how an error in *L* translates to an error in the Area. For a quantity F computed from measurement L, the error σ_F is given by:

$$\sigma_F = \left|\frac{dF}{dL}\right| \sigma_L$$

where σ_L is the error on L (in the above example is 0.5 mm) and we use the absolute value because errors are definite positive

Question 1: Let σ_R be the error on the measurement *R*, of the radius of a circle, what is the error of the area of this circle?

For multiple variables, one just extends the formula to the other variables. Consider a rectangle, for which one must measure side L_1 and side $L_2$to get the area. In this case:

$$\sigma_A^2 = \left(\frac{\partial A}{\partial L_1}\sigma_{L_1}\right)^2 + \left(\frac{\partial A}{\partial L_2}\sigma_{L_2}\right)^2$$

where instead of using absolute values to get a positive definite answer, we take the squares of the individual contributions to the error[1]

Activity 1: measure both sides of a rectangular object 10 times. Take an average value for each side. Compute the area using these averages and compute the error of the area. Record your measurements on a table like this:

L_1 [cm]	L_2 [cm]
50±0.05	12±0.05
12±0.05	15±0.05
…	…
Average = ? ± ?	Average = ? ± ?
Area = ? ± ?	

Activity 2: measure the radius of the provided circles. Each person in your group should record the radius of each circle once (so four measurements per radius). Then, take the average, compute the area of the circle, and the error of the area. Record your measurements on a table.

Activity 3: Similar to Activity 2, measure the circumference of the provided circles. Write an equation for π in terms of the circumference the radius. Using this formula, compute the value of π and its error.

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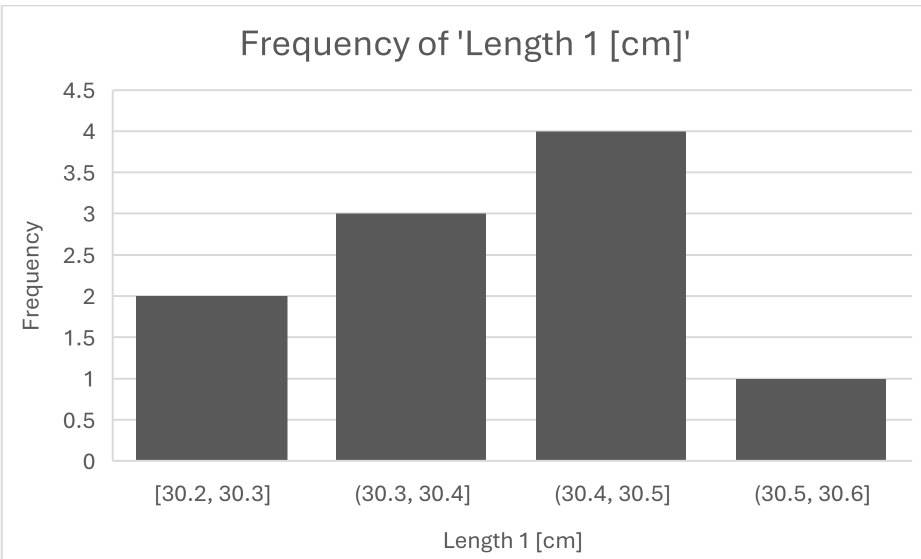
[1] For the derivative symbol we use ∂ instead of d because multiple variables are involved. These are called “partial” derivatives.

Question 2: Analyze: if π is a mathematical constant, how come our measurement of it has an error? Does our best-known value of π also has error bars (albeit very small ones)?

Histograms

From your table in **Activity 1** you can construct a histogram. A histogram records how many times things happen. If for one side you measured 30.5 cm four times, 30.3 cm two times, and 30.4 cm three times, and 30.6 cm one time, then your histogram would look like this:



(Excel likes to present the data as intervals instead of single digits).

You can make a histogram with Excel by writing the numbers on a column (and writing a name for the column in the first row). Then click “analyze data” in the top-right corner of the window and write “histogram” in the bar that appears on the right. You can also make the histogram by hand on your notebook

Activity 4: make a histogram of your 10 length measurements. Sketch the result in your lab notebook.

While I wrote earlier that the error of a measurement is the lowest marking separations on the measuring tape, in practice, the error bars are calculated by computing the spread, or standard deviation, of a series of measurements.

Hence, we have defined two factors (natural variation, measurement error/systematic error) which can produce changes in measurements.

Measurement and systematic errors are caused by the fact that we can't measure with infinitely small precision.

Natural variation, on the other hand, refers to the intrinsic spread in a quantity (for example, differences in age or height of a population), or to the inevitable variation in manufactured items (even the United States Mint cannot produce truly identical pennies). Strictly speaking, natural variation is an intrinsic characteristic and not a source of error, but in reality, scientists use the spread in the data as error bars in many branches of physics. This is why the symbol for error in mathematics is the symbol σ, which is also used for the standard deviation of a set.

Consider your previous measurements of the length of the rectangular object. Compute the spread σ. If you used the link above to plot the histogram, the spread is automatically reported. If you used Excel, you have to write in an empty cell:

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=DEVSQ(
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select your data with the pointer, and the number will appear in the chosen cell.

Activity 5: Compute the spread (σ) for your 10-point data set. You can use Excel or this website: http://astronomy.nmsu.edu/geas/labs/html/plotter.shtml

Now, compare the value of σ, and the precision P (the smallest difference that you could measure between two values):

Q. 3: Which of these two values represents your natural variation? (σ / P)

Q. 4: Which of these values represents your measurement error? (σ / P)

Q. 5: How does your precision compare to your value for σ? Take the ratio.

Activity 5: Now perform 10 more measurements of one side of the rectangular object and see the spread.

Q. 7 Has the spread decreased or increased?

Q. 8 Does the measurement error (P) decrease, increase, or stay the same with repeated measurements? Why do you think that is?