

Name: \_\_\_\_\_

Partner(s): \_\_\_\_\_

1118 section: \_\_\_\_\_

Desk # \_\_\_\_\_

Date: \_\_\_\_\_

## Introduction to 1118 Labs

Introductory materials are at: <http://langraphysics.com>. You may find following three links useful for this lab: “Measurements: Basic”, “Lab Report Requirements” and “Sample Lab Report” under “Introductory Materials For 1114/1118 Labs”. (All these documents are also available on Brightspace.)

**Purpose** To learn the basic elements of 1118 labs and to practice writing a lab report.

### Part 1 How to record data

The rules for recording data are:

- Provide a description of your data.
- Record all certain digits plus one estimated digit. These are all significant digits.
- Determine the uncertainty. See the examples below on how to decide the uncertainty.
- Give the units. Use the units of the measuring tool.

In other words, all data must have meaning, value, uncertainty and units.

You must assign an uncertainty to every piece of data while making measurements. If the only factor that affects the reading accuracy is the measuring device, you can take half of the smallest division to be the uncertainty. This is based on you can estimate between the division lines (see Example 1 below). However, quite often, there are other factors that affect the reading confidence, and you should assign an uncertainty that is big enough so that the actual value lies within the plus-minus range. It is common to get different uncertainty with the same measuring device (Example 2 and 3).

The uncertainty, when estimated by you, should have only one non-zero digit. However, if you calculate the uncertainty based on the manual or read it from a digital device, then it sometimes can have two non-zero digits (Example 4).

In all cases, the value and the uncertainty must have the same decimal place and same units<sup>1</sup>.

Let's see how the rules work in the following examples.

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<sup>1</sup> The power of 10 in scientific notation is part of the units. Therefore, the value and the uncertainty must also use the same power of 10. However, in most cases, you should not need to use scientific notation when recording data.

**Example 1:** A student uses a 2-pan balance to measure the mass of a metal cylinder. When the balance is reached, the pointer is just above the 23.7 g line. She thinks the mass is 23.71 g, where “1” is an estimated digit. Half of the smallest division is 0.05 g. So she records:

The mass of the metal cylinder  $m = (23.71 \pm 0.05)$  g.

**Example 2:** A student tries to drop a rubber ball from a 90 cm height. He lines up the upper edge of the ball to the 90 cm mark on the metre stick. Because the ball is round, he figures he could line it up within 0.2 cm at best. In other words, the “0” after the decimal point in 90.0 cm is already an estimate, and there is no way to estimate another digit. So he records:

The drop height  $y_d$  is  $(90.0 \pm 0.2)$  cm.

**Example 3:** The student above measures how high the ball bounces by judging the highest point of the upper edge with his eyes. It was close to 81 cm, but could be anywhere between 80 and 82 cm. With a 2 cm range, he records:

The bounce height  $y_b$  is  $(81 \pm 1)$  cm.

**Example 4:** A student reads from the 2-pan balance that the mass of a metal block is 473.45 g, because the pointer was between 0.4 and 0.5 g. She used two counter masses. The instructor told her that each counter mass has an uncertainty of  $\pm 0.05$  g, and the 2-pan balance itself also has  $\pm 0.05$  g. The overall uncertainty, including the uncertainty from the counter masses and the scale itself, is  $\pm 0.15$  g. So she records:

The mass of the metal block  $m = (473.45 \pm 0.15)$  g.

Now, try it for yourself.

**Activity 1-1:** Record the data for the following measurements. See <http://langraphysics.com/1118/pictures.html> for photos showing the measurements.

1. The mass of metal cylinder  $m$  is \_\_\_\_\_ g.
2. The length of the metal cylinder  $l$  is \_\_\_\_\_ cm.
3. The position of the end of the spring’s hook is at \_\_\_\_\_ cm.
4. The length of the thin Nichrome wire is \_\_\_\_\_ cm.
5. The voltage across the light bulb is \_\_\_\_\_ V.

**Activity 1-2:** Determining the number of significant figures in the data.

After taking measurements and deciding on the uncertainty, you should know how many digits in your measurement are significant figures (sig. figs). This will eventually decide how many sig. figs. you will report in your final conclusions.

Let's look at the following data. One thing we need to remember is that the value and uncertainty must have the same decimal places and the same unit, otherwise they do not match.

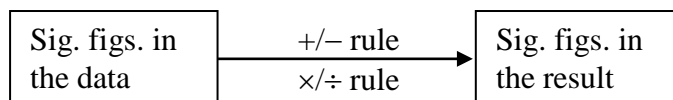
	Is the format correct?	How many sig. figs are there? (for correct formats only)
(a) $(90.00 \pm 0.05)$ g		
(b) $(90 \pm 0.05)$ g		
(c) $(90 \pm 2)$ cm		
(d) $(9 \pm 2)$ cm		
(e) $(9.0 \pm 2)$ cm		
(f) $(9.0 \pm 0.2)$ cm		
(g) $(0.49 \pm 0.05)$ g		
(h) $(0.49 \pm 0.05) \times 10^{-3}$ kg		
(i) $0.00049$ kg $\pm 0.05$ g		
(j) $(233.18 \pm 0.20)$ g		
(k) $(2.12 \pm 0.22)$ s		

**Explanation/hints:** (a) has the correct format because both the uncertainty and the last sig. fig are at the second decimal place. All digits—one “9” and three “0”s are significant: the number of sig. figs. is 4. Note that the trailing “0”s count towards sig. figs. In (b) the value “90” does not match the uncertainty “0.05” in decimal places so the format is wrong. (c) has the right format and there are 2 sig. figs. (d) has a value that is much shorter than (c), and there is only 1 sig. fig. It shows that for the same uncertainty, larger quantities tend to have more sig. figs. and higher precisions. It is wrong trying to force to 2 sig. figs. in (e) by adding another 0 to the value, because then the value does not match the uncertainty. In order to have more sig. figs. you need to reduce the uncertainty like (f). (g) and (h) are actually the same data so they should have the same sig. figs. This tells us that the unit conversion does not change the number of sig. figs. Note that leading zeroes do not count towards sig figs. (i) has a wrong format because the value uses a different unit than the uncertainty. (j) and (k) are the special cases where the uncertainty has two non-zero digits. To find the number of sig. figs., you need to first underline the last sig. fig., which is at where the uncertainty kicks in: for both, it is the digit “1”.

## Part 2 Calculating the results

In the “Calculations” section of your report, you use your measured data to calculate a final result. For example, to find the volume of a room, you would measure the length, width and height of the room and then calculate the volume. While there are rules to explicitly calculate the uncertainty in the results, you are not required to do so in this lab course. However, you need to understand that there are uncertainties in the results; therefore, the results have a finite number of significant figures. In the “Conclusion” section of the lab report, you must report the result to the proper number of sig. figs.

There are two rules to determine the number of sig. figs. in a calculated result as introduced in the “Measurements: Basic” section from the online lab manual.



To avoid “round-off error”, you should keep plenty of digits (5 non-zero digits recommended) in the calculations. To keep track of the sig. figs., you should underline the last significant digit for intermediate numbers. In the conclusion, the final result must be rounded to the correct number of significant figures with no underlining.

Example:

Calculations:

$$\text{Length } l = 1056 \text{ cm} = 10.56 \text{ m (4 sig. figs.)}$$

$$\text{Width } w = 722 \text{ cm} = 7.22 \text{ m (3 sig. figs.)}$$

$$\text{Height } h = 254.5 \text{ cm} = 2.545 \text{ m (4 sig. figs.)}$$

$$\text{Volume } V = lwh = 10.\underline{56} \text{ m} \times 7.\underline{22} \text{ m} \times 2.54\underline{5} \text{ m} = 194.\underline{04} \text{ m}^3 \text{ (3 sig. figs. according to } \times/\div \text{ rule)}$$

Conclusion:

The volume of the room is 194. m<sup>3</sup>.

(The decimal point after 194 indicates that it is a rounded result rather than an exact integer.)

**Activity 2-1:** Practice the sig. figs. rules with the following calculations.

	# of sig. figs. in the result
Example: $\frac{45.3 \times (9.81 - 8.92)}{0.7666} = \frac{45.3 \times 0.89}{0.7666} = 52.592 = 53.$	2
$4.56 \times 17.23 =$	
$\frac{0.0002}{7.54 \times 88.8} =$	
$17.1 + 11.234 =$	
$98.5 - 27.5 =$	
$27.5 - 20.5 =$	
$(8.7 + 6.5) \times 7.325 =$	
$(1.3 \times 10^9) + 76,550 =$	
$\frac{\pi(2.22)^2 \times (3.7 - 3.1)}{1.5442} =$	

**Activity 2-2:** This is a complete practice on calculations. You are required to take measurements of your desktop and then calculate the approximate volume  $V$  of the desktop.

**Data:** Measure the dimensions of your desktop and record the results below. Decide the uncertainties while making the measurements.

Dimensions of the desktop of Desk numbers # \_\_\_\_ / \_\_\_\_ (cm)

	Length $l$	Width $w$	Thickness $t$
Reading			
Uncertainty			

**Calculations:**

First convert all data readings (but not the uncertainty) from cm to m:

Next calculate the volume in 3 steps: “equation – numbers – result”. Do not include uncertainties in the calculation. Keep all units. For the result, keep 5 non-zero digits, then use the uncertainties and the sig. figs. rules to decide how many sig. figs. are in the result, and underline the last sig. fig.

$$V = lwt =$$

**Conclusions:** (give sig. figs. and units.)

The volume of the desktop of Desk # \_\_\_\_ / \_\_\_\_ is \_\_\_\_\_.

### Part 3 How to write lab reports

**Activity 3:** Measure of the density of a metal cylinder.

Follow the guidelines given in the “Lab Report Requirements” and the “Sample Lab Report” documents. Both links can be found at <http://langaraphysics.com> under “Introductory Materials For 1114/1118 Labs”. Below are some key points of these two documents as applied to this lab:

- Write everything in ink.
- Purpose: State the goal of the experiment.
- Apparatus: List all instruments you will use: a ruler, a Vernier caliper, a 2-pan balance and a metal cylinder. Be sure to quote the identifying number on the cylinder and on the tools if there is any.
- Data: Take one reading of each quantity: the length, the diameter and the mass of the cylinder. Use the units on the equipment (cm and g). Follow the format on Page 2 of this lab.
- Calculations: You are only dealing with the values of the data, not their uncertainties. First convert units to meters and kilograms. Then calculate the density using  $\rho = \frac{4m}{\pi d^2 l}$ . Keep 5 non-zero digits for the result, but underline the last significant digit based on the sig. figs. rules. You should write your result in scientific notation because it is a large number. Another reason to use scientific notation is that you will soon see that is the format of the reference value.

Next find the reference value of the density for your cylinder, and calculate the percentage discrepancy between your result and the reference value, using:

$$\text{Percentage discrepancy} = \frac{|\text{your value} - \text{reference value}|}{\text{reference value}} \times 100\%$$

- Conclusions: Report your result with the correct significant digits and state the comparison with the reference value.

*Note: Your future lab reports must follow the same format as in this activity.*

Name:

Partner:

1118 Section \_\_

Desk # \_\_

Date \_\_\_\_\_

## Density of a Metal Cylinder

Purpose

Apparatus

Data

Calculations

According to \_\_\_\_\_, the reference value is \_\_\_\_\_.

Percentage discrepancy =

Conclusions

The density of \_\_\_\_\_ was found to be \_\_\_\_\_,  
which is \_\_\_\_\_ than the reference value of \_\_\_\_\_.