Lab 1 Objectives

The objectives of this lab are to be acquainted with the basics of measurements, percent error, percent difference, and to become familiar with the PASCO Capstone software interface. In addition, you will

- ♦ Learn to calculate percent error and percent difference
- ♦ Determine when percent error or percent difference is not appropriate
- ♦ Learn significant numbers
- ♦ Learn to use a caliper gauge, ruler, meter stick, level, and balance

Materials and Equipment

- Ruler
- Meter stick
- Caliper gauge
- 1.586 cm (diameter) metal ball
- Wooden block
- Dynamics cart
- Dynamics track
- End stop for dynamics track
- Level
- Spring
- Mass hanger (50 g)
- 20 gram mass
- Large base with metal rod
- Right angle clamp
- Small metal rod
- Motion Sensor
- Force Sensor with hook attachment
- PASCO Capstone software
- PASCO GLX Data Collection device
- USB connector (for GLX to laptop interface)
- Balance (one per lab session)
- (Optional) USB Drive to download data as CSV file

Safety

The caliper gauge has sharp parts and caution is needed when using it.

The metal ball, large base, mass hanger, and metal rods can cause injury if they fall off the table. Take care not to let any equipment shift on the lab bench until required to do so.

The spring can cause serious injuries if it is pulled too hard or allowed to fly from the hook. Do not pull the spring any farther or with more force than necessary.

Take care not to push the dynamics cart with too much initial velocity; it should either gently bounce off the end stop or come to rest before it reaches it. If it is pushed too hard or too fast, it will break through the end stop and potentially injure a peer.

Procedure

Set Up

The equipment has largely been set up for you today. You should see all the components (except the balance) on your lab bench. Prior to your arrival. Check to see that each of the following is complete or visible:

- ☐ a metal ball is placed in a plastic container (to prevent the ball from rolling off the table); near the ball should be a caliper gauge, still in its protective leather case;
- ☐ a wooden block is place on the table; near the wooden block, there should be a ruler with a millimeter scale;
- ☐ the dynamics track is set up horizontally on the table with the track end stop at one end and the motion sensor on the other; the dynamics cart will be sitting on or near the dynamics track;
- ☐ a large base with vertical metal rod should be positioned near one edge of the lab bench; a right angle clamp and short metal rod are attached at the top of the vertical rod so that the short rod is horizontally oriented and protrudes outward from the table; a force sensor with a hook attachment is secured to the horizontal rod with a thumb screw;
- ☐ a metal spring is positioned near the large base apparatus, along with a 50 mg mass hanger and 5 mg slotted mass.
- ☐ a GLX data collection device should be positioned between the dynamics track and the large base apparatus; the force sensor and the motion sensor should be plugged into the GLX, and the GLX should be plugged into a wall socket;
- ☐ a laptop loaded with the PASCO Capstone software should be connected to the GLX with a USB cable and the Capstone software should be running on the laptop;
- ☐ the Capstone file "PHYS210_Lab1" should be opened in the software.

This lab has multiple parts. There is no formal lab report for this experiment, but you are expected to type answers to each of the questions posed in each part of the lab in a Google Doc and submit to your instructor according to her instructions.

Before beginning, make sure the GLX is plugged into a wall socket. Check the battery charge on the laptop and plug it into a wall socket if the battery is below or falls below 50%.

Part I: A Metal Ball

You have been provided with a metal ball whose reported (expected) diameter is 1.586 cm.

Table 1: The accepted values of the metal ball

Diameter (cm)	Volume (cm^3), $V = \frac{4}{3}\pi r^3$
1.586	2.089

Part I: Collect Data

I.1. Make sure that the "Metal Ball and Ruler" tab is active in Capstone.

I.2. Measure the diameter of the solid metal ball with a *millimeter scale of a ruler*. Repeat the measurement two more times and enter the values in the table. Note that the table is set up to automatically perform some calculations, including the volume of the ball, the error, and percent error, as well as the mean for measurements.

Table 2: The experimental measurement of a solid metal ball with the millimeter scale of a ruler and its percent error in the volume.

Diameter (cm)	**Mean Diameter (cm)**	**Mean Volume (cm^3)**	**Error in the average volume (cm^3)**	**Percent Error of the average volume**

I.3. Switch to the "Metal Ball with Caliper" tab in Capstone.

I.4. Measure the diameter of the solid metal ball with *the caliper gauge*. Repeat the measurement two more times and fill out Table 3

Table 3: The experimental measurement of a solid metal ball with the caliper and the percent error in the volume. (Expected volume is 2.089 cubic centimeters)

Diameter (cm)	Mean Diameter (cm)	Mean Volume (cm^3)	Error in Volume (cm^3)	Percent Error

I.5. Find the difference of the volumes measured with the two methods.

Table 4: The difference in volume in cubic centimeters and the percent difference

Mean Volume (cm^3) from Table 2	Average Volume(cm^3) from Table 3	Difference (cm^3)	Percent Difference

I.6. Switch to the "Metal Ball Density" tab in Capstone.

I.7. Measure the mass of the metal ball using the balance.

First, measure the mass of the empty plastic container and record it in the proper location in Capstone.

Next, measure the mass of the plastic container with the metal ball inside and record this value in the proper location.

The lab file is set up to compute the difference between the two, as an estimate for the mass of the ball.

I.8. The **density** of an object is its mass divided by its volume. Enter the *assumed* volume (Table 1) of the metal ball to compute the density ρ (rho) in units of $\frac{gm}{cm^3}$.

Part I: Analysis

I.9. How many significant numbers are there in the diameter of the metal ball measured by the ruler? How about the significant number of the diameter of the ball measured by a caliper gauge? Why?

I.10. When measuring the length of a small object, which one of the tools listed below would you choose to obtain a high accuracy? Is there another tool you could use?

A. Regular ruler with millimeter scale

B. Caliper gauge

I.11. When estimating the density of the metal ball, why do you think I asked you to use the *reported* volume rather than any of the volumes you estimated from measuring the diameter?

I.12. What types of errors did you encounter when measuring the diameter of the ball with either tool? (Review the Types of Errors section before responding.)

I.13. What techniques did you learn from this experiment and subsequent calculations?

Part II: A Wooden Block

You have been provided with a wooden block of unknown dimensions and unknown mass.

Part II: Collect Data

II.1. Make sure that the “Wooden Block” tab is active in Capstone.

II.2. Measure the length, width, and height of the wooden block with the ruler and record the values in Capstone.

II.3. Notice that capstone will automatically compute the volume for this set of measurements.

II.4. Repeat the measurements two more times and notice the mean of your measurements is displayed at the bottom of the page in Capstone.

Table 5: Wooden Block Measurements

[redacted]	**Length (cm)**	**Width (cm)**	**Height (cm)**	**Volume (cm^3)**
Mean:				

II.5. Compute the product of the mean length, mean width, and mean height using a calculator. Find the *difference* and percent *difference* between this estimate of the volume and the mean volume provided by Capstone:

Difference: ______________________________ cm^3

Percent Difference: _______________________%

II.6. Switch to the "Wooden Block Density" tab in Capstone.

II.7. Measure the mass of the wooden block with the balance. Record the value in the appropriate location.

II.8. Enter the *mean* of the estimated volumes in the appropriate location (you may have to switch tabs if you did not write down the mean). The density will be computed (estimated) automatically.

II.9. Capstone has been set up to automatically compute the density of the wooden block, based upon the values you entered.

Table 6: Wooden Block Density

Wooden Block Volume (cm^3)	Wooden Block Mass (g)	Wooden Block Density (g/cm^3)

Part II: Analysis

II.10. What source of errors did you encounter in this part of the experiment?

II.11. What could you have done to mitigate any errors encountered?

II.12. Why did I ask you to compare the volume computed from the mean dimensions to the mean of the computed volumes?

II.13. Compare the densities of the metal ball and the wooden block. Is one greater than the other? What do you think are the sources of the difference (if any)?

Part III: A Metal Spring

You have been provided with a metal spring. We are going to use the force sensor to measure the force exerted by a mass attached to the spring which the spring is oscillating, and use Capstone to estimate the motion of the attached mass with a trigonometric model.

Part III: Collect Data

III.1. Switch to the "Metal Spring" tab in Capstone.

III.2. Loop one end of the metal spring over the hook attachment on the force sensor.

III.3. Use the meter stick to measure the length of the spring (from top coil to bottom coil) as it hangs from the force sensor. Try to keep the metal spring from moving while you measure. Record the value here: ______________________________ cm

III.4. Attach the mass hanger to the free end of the metal spring by looping its hook over the bottom loop of the metal spring.

III.5. Slide the 20 g slotted mass onto the mass hanger.

III.6. Use the meter stick again to measure the length of the distressed spring (top coil to bottom coil). Record the measurement here: ________________________ cm

III.7. What is the difference between the at rest length and the distressed length of the spring? __________ cm

III.8. The lab file is set up to compute the *displacement* of the spring, which is the change in length from the *at rest* position to the length in the *distressed* or *burdened* position.

III.9. Tare the force sensor by pressing the [Zero] button on it. (The label may be upside down.)

III.10. While one member of your group prepares to click the record button on Capstone (making sure that the Force Sensor is the selected device on screen), another member of your group should gently pull the mass hanger downward approximately 5 cm. Simultaneously, release the mass hanger and begin recording. (The lab file is set to stop recording after 3 seconds.)

III.11. Observe the force exerted on the spring as it oscillates, as represented on the Force versus Time graph.

III.12. A model for the force exerted on the spring versus elapsed time has been provided for you in the lab file. Copy the model below:

F(t) = __________________________________ Newtons

Part III: Analysis

III.13. Why do you think that the exerted force oscillates between positive and negative values?

III.14. What does the first point on the graph represent?

III.15. What do you think it means when the force is 0 Newtons?

Part IV: A Moving Cart

You have been provided with a dynamics cart that you will cause to move along the dynamics track horizontally, away from the motion sensor and towards the end stop.

IV.1. Switch to the "Moving Cart" tab on Capstone.

IV.2. Use the level to determine if the dynamics track is horizontal. Do this by positioning the level across the track and noting whether the bubble is centered. Repeat by positioning the level along the track. Adjust the foot pegs on the track to level the track, as necessary.

IV.3. Make sure that the "Motion Sensor" is the active device on the "Moving Cart" page.

IV.4. Check to see that the slider bar on top of the motion sensor is set to monitor the cart (not a person).

IV.5. While one member of your group prepares to click the record button, another should position the cart on the track, approximately 10 cm from the motion sensor.

IV.6. Simultaneously, give the cart a gentle push, providing initial velocity, and begin recording. Avoid allowing any part of your body or clothing to be between the motion sensor and the cart.

IV.7. Stop recording just before the cart hits the end stop.

Part IV: Analysis

IV.8. Observe that the position (horizontal displacement) of the cart is being plotted on the Position vs. Time graph in Capstone. A model has already been added to the plot. Copy the model below:

x(t) = ______________________________ m/s