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LAB #1: MEASUREMENT AND DATA ANALYSIS

OBJECTIVES:

To learn to use a variety of measuring instruments and to practice gathering and manipulating data.

EQUIPMENT:

Equipment Needed	Qty	Equipment Needed	Qty
Measurement Equipment Tray	1	Measurement Lab Container	1
Balance	1	Table Clamp with rod	1
Pendulum Clamp	1	Meter Stick	1
Linear Graph Paper on Front Desk	2	String on the Front Desk	

SAFETY REMINDER • Follow all safety instructions. • Keep the area clear where you will be walking.	**THINK SAFETY** **ACT SAFELY** **BE SAFE!**

INTRODUCTION:

In this lab you will be introduced to several different measuring devices. You will use these to take a number of measurements of several different kinds of quantities. You will then graph some of your results.

PROCEDURES:

Answer all of the questions on this handout.

PART 1: Finding the Density of Aluminum

To determine the density of an object, we must measure it mass and volume, and then divide the two. That is

$$\textbf{density} = \rho = \textbf{mass / volume} = M / V$$

In your Measurement Lab Container you will find three cylinders. Remove the aluminum cylinder. (If you are not sure which one is aluminum, ask your instructor.)

To measure the cylinder's mass, we will use the triple-beam balance.

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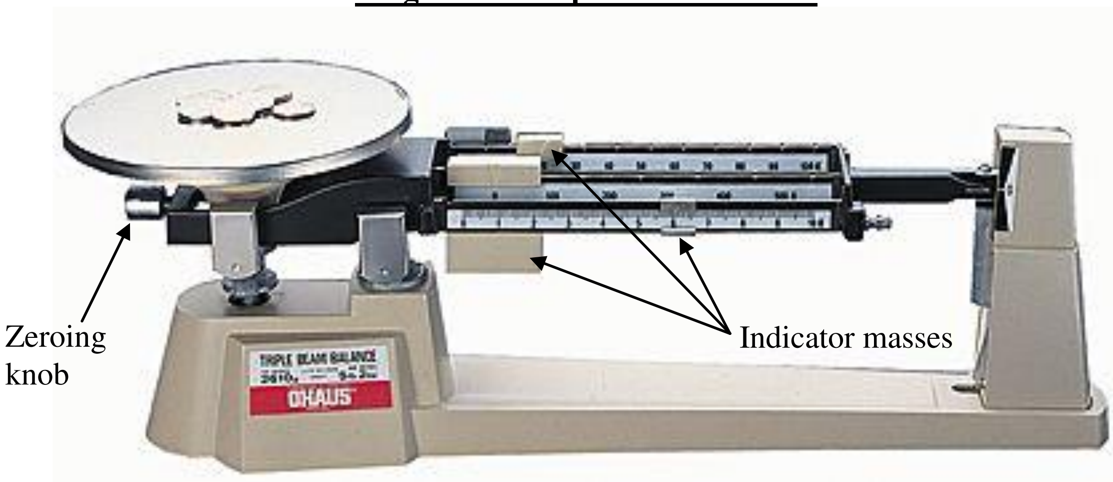
Diagram 1: Triple-Beam Balance



Before placing the cylinder on the balance pan. Slide all of the balance's indicator masses to the left and align them with their zeroes. Turn the knob under the pan on the left side in order to "zero" the balance. The balance is correctly zeroed when the two white lines at the right end of the balance are aligned. Do this very carefully as all of your mass measurements will depend on how accurately this is done.

Place the cylinder on the balance pan. This will cause the pan to drop down, and the pointer at the right side of the balance to rise up above zero. Move the largest indicator mass over to the first notch (i.e. 100 grams). If the pointer has not dropped below zero, move the mass over another notch (i.e. 200 grams). Keep moving the mass slowly, notch by notch, until the pointer drops below zero. Then, move the mass back one notch. Continue in this way with the middle-sized indicator mass. Then move the smallest indicator mass until the pointer is aligned as closely as possible with zero. The mass of the cylinder is then the sum of the numbers indicated by the three indicator masses. Estimate the mass of the cylinder to the nearest <u>one-tenth</u> of a gram.

1. What is the mass of your aluminum cylinder in grams?

2. What is the mass of your aluminum cylinder in kilograms?

To determine the cylinder's volume, we need to measure its length and diameter. To measure its length we will use a metric ruler. Place the cylinder along the ruler, but <u>not</u> at one end. This may seem silly, but it will allow us to get some slight variations in our measurements.

Determine the location of the left end of the cylinder to the nearest one-hundredth of a centimeter. Subtract your measurements to get the length of the cylinder. Let another student move the cylinder to another part of the ruler and repeat. Do this for a total of four length measurements. Add the four lengths together and divide by four to find the average. Enter your average value, to the nearest one-hundredth of a centimeter, in the table.

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Diagram 2: Measuring the length of the cylinder

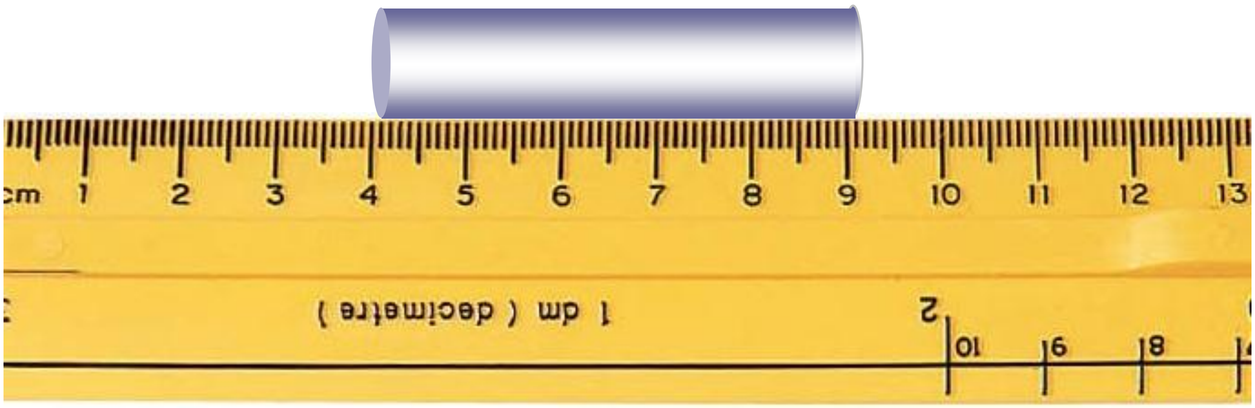


Table 1: Cylinder Length

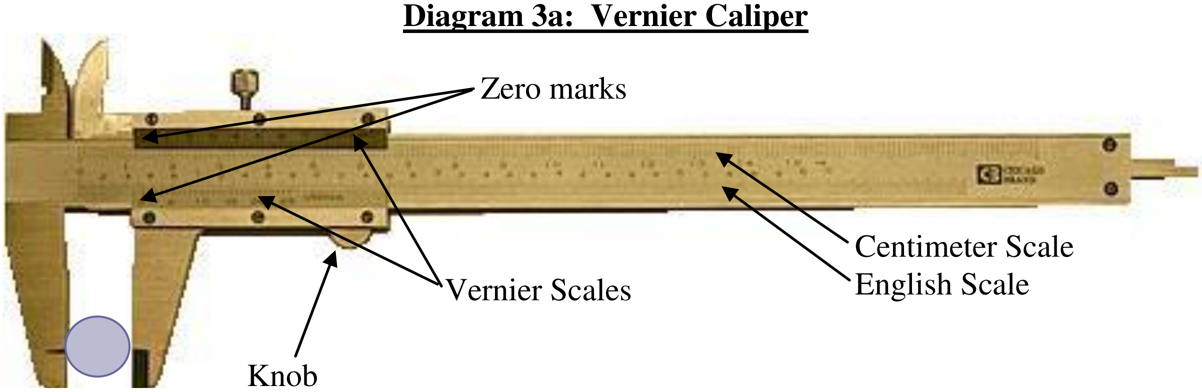
Right End (cm) -	Left End (cm) =	Length (cm)
	Average =	

3. What are your four length measurements?

4. What is the average value for the length of the cylinder in centimeters?

5. What is the average value for the length in meters?

Diagram 3a: Vernier Caliper



To measure the diameter of the cylinder we will use a vernier caliper. To open or close the jaws, push on the knob. Please see Diagram 4 for an enlarged version of the vernier scale.

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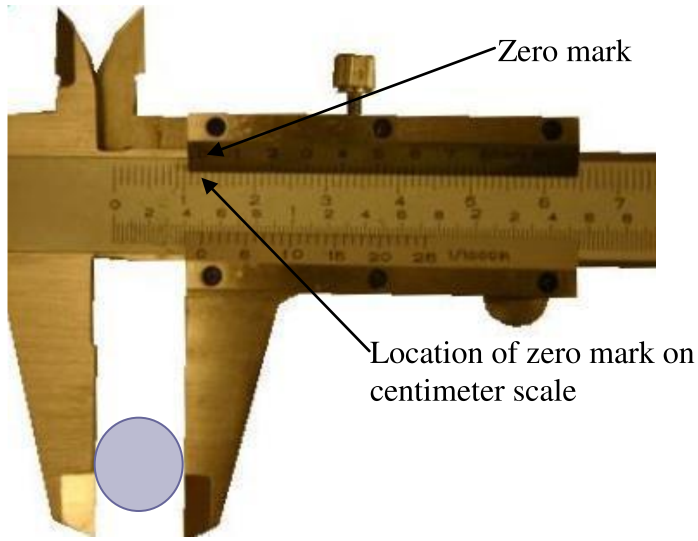
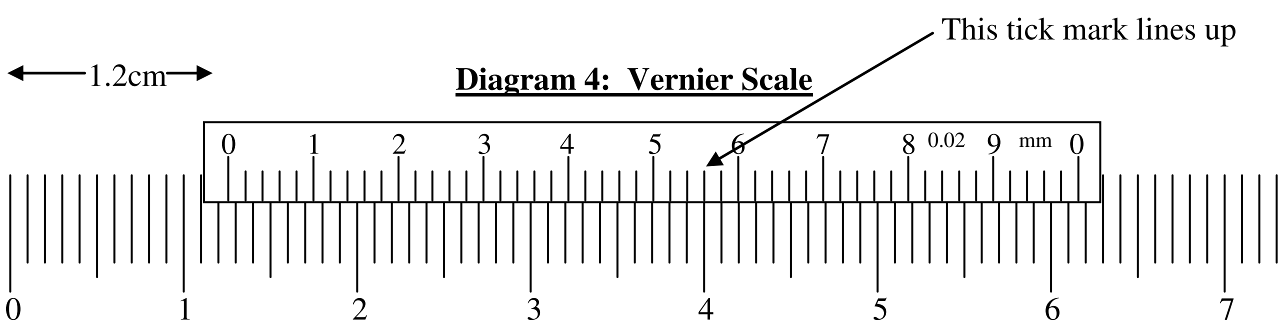
Diagram 3b: Vernier Caliper



To read the caliper in centimeters, the first two digits (units and tenths) are determined by the position of the "zero mark" in relation to the centimeter scale. (On the caliper in Diagram 3, as on yours, the centimeter scale is above the English (inches) scale.) In Diagram 4 you should see that the zero mark indicates the measurement to be between 1.2 and 1.3 cm . The next two digits, hundredths and thousandths of a centimeter, are determined from the centimeter vernier scale. You will notice that most of the vernier-scale tick marks do not align with the centimeter-scale tick marks below them. Choose the vernier-scale tick mark that is most closely aligned with a centimeter-scale tick mark below it. This vernier-scale tick mark will give the next two digits in the measurement. In Diagram 4, this would be the third tick mark after the "5" , that is, "5 and 3/5", or "5.6" . Notice that the vernier scale is calibrated in fiftieths of a millimeter, or to an accuracy of 0.002 cm .

Diagram 4: Vernier Scale



For example, if the centimeter scale and vernier scale aligned as above, the measurement would be 1.256 cm . If you think that two tick marks are equally aligned, you can choose the measurement between the two. If you don't understand this reading, ask your instructor to explain.

Measure the diameter of your cylinder four times. Let different students make measurements for a total of four. Enter your numbers in the left column of Table 2.

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Table 2: Cylinder Diameter

Measurement (cm) -	Zero Value (cm) =	Diameter (cm)
	Average =	

Unfortunately, calipers are not always zeroed correctly. Close your caliper completely and see if it reads 0.000 cm . If the caliper reads a number other than 0.000 cm , enter that number in the "Zero Value" column in Table 2, if not, enter 0.000 . Subtract the Zero Value from the Measurement to find the Diameter and average these values.

6. What are your four diameter measurements?

7. What is the average value for the diameter of the cylinder in centimeters?

8. What is the average value for the diameter in meters?

The volume of a cylinder is given by

$$\textbf{Volume} = \pi R^2 L = \pi (D/2)^2 L\ .$$

Using your average value in meters, calculate your cylinder's volume.

9. What is your cylinder's volume in m^3 ?

Remember that the density is given by

$$\textbf{density} = \rho = \textbf{mass / volume} = M / V\ .$$

Using the cylinder's mass in kilograms and the volume in m^3, determine its density.

10. What is your cylinder's density in kg/m^3 ?

11. What is the accepted value for the density of aluminum?

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12. What reference book did you use for the accepted value? (Give name, author, and page.)

When comparing an experimental value with an accepted value, the percent error is given by

% error = [(experimental value – accepted value) / (accepted value)] x 100% .

13. What is the percent error of your value?

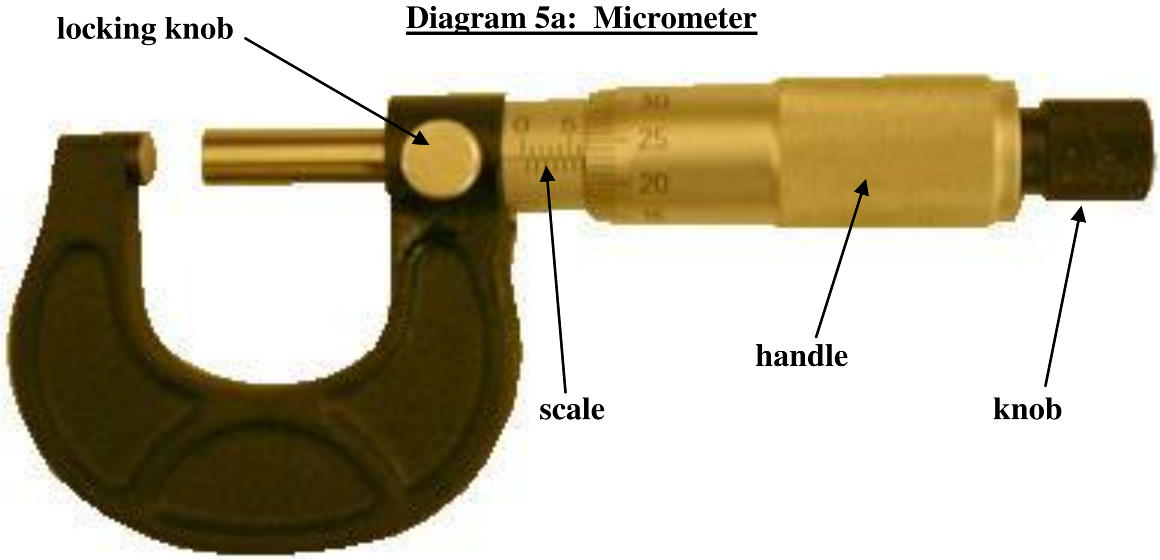
14. What do you think contributed to this error?

If your value has an error of 5% or more, you need to determine what went wrong and do the incorrect measurements over again.

PART 2: Analyzing a Simple Pendulum

In your Measurement Lab Container you will find a ball with a hole in it. If it does not have a string tied to it, get a piece of string about 1.5 m in length and tie the ball to one end. Using the Micrometer, you will measure the diameter of the ball.

Diagram 5a: Micrometer



To close or open the jaws of the micrometer, rotate the handle (on the right in the picture) clockwise or counterclockwise. When closing the jaws onto an object, turn the handle gently by holding the small knob at the end of the handle. Turn the knob slowly until it starts to slip. The jaws are then at the correct tightness for making the measurement. **DO NOT tighten the jaws by turning the handle, this can overstress the micrometer and damage it.** If the handle will not turn, loosen the locking knob by turning it counterclockwise. The locking knob can be tightened if you want to bring the micrometer to your instructor without changing the measurement.

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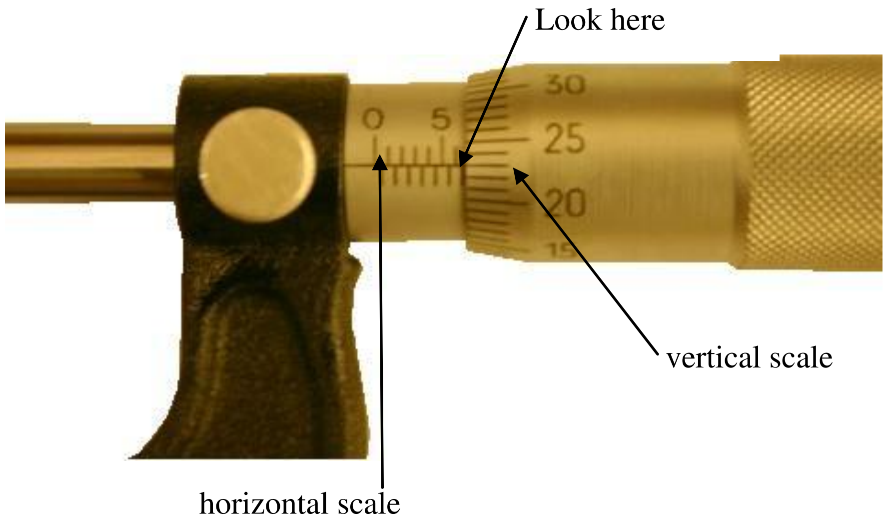
The micrometer measurement is then determined by reading the scale.

Diagram 5b: Micrometer



The micrometer scale has two parts, the horizontal scale and the vertical scale. The first significant figures of the measurement are determined by where the vertical edge of the handle crosses the horizontal scale. The numbers along the upper part of the horizontal scale give the number of millimeters. There are tic marks on the lower part of the horizontal scale every other half-millimeter, 0.5mm . If the vertical edge of the handle has passed a tic mark on the lower part, you need to add in an extra 0.5mm to your measurement. The final significant figures of the measurement are found from the vertical scale. The tic marks on the vertical scale represent hundredths of a millimeter. In Diagram 5b we can see that the handle crosses the horizontal scale between "6.5" and "7.0" . The vertical scale reads ".23" , so the measurement shown above would then be "6.5mm" plus "0.23mm" or "6.73mm" .

Use the micrometer to measure the diameter of the pendulum ball.

15. What is the diameter of the ball in millimeters and in meters?

16. What is the radius of the ball in meters?

Attach the table clamp to the end of your lab bench, put one end of the metal rod in the table clamp so that most of the rod is above the bench, attach the pendulum clamp to the top of the rod. Attach the free end of the string to one of the pendulum clamp string holders. You should be able to adjust the length of the pendulum easily by loosening the string-holder knob and sliding the string up or down. Adjust the length of the pendulum string to approximately 10 cm. Measure this length with a meter stick to the nearest millimeter and enter the length in meters in Table 3. Insert the ball radius in meters in the table and add the string length to the ball radius to get the pendulum length.

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Table 3: Pendulum Data

String length (m) +	Ball radius (m) =	Pend. Length (m)	20 Periods (s)	Period (s)

Pull the pendulum ball a few centimeters to the side and release it, allowing it to swing freely. The period of the pendulum is the time it takes for the ball to make one complete oscillation. That is, for example, starting as the ball passes through the lowest point of the swing moving to the right, one oscillation will end as the ball passes through the lowest point again moving to the right, not when it passes the lowest point moving to the left, which completes only one-half of an oscillation. For accuracy we will determine the period by measuring the time for twenty complete swings. Start your stopwatch as the pendulum passes through the lowest point. Count off twenty complete oscillations and stop the watch at the completion of the twentieth. Enter the time in Table 3. Divide the time by twenty to find the period and enter it into the table.

Readjust the length of the pendulum string to approximately 20 cm, and make all of the above measurements. Enter the data in Table 3. Continue increasing the string length by approximately 10 cm and taking the measurements until you have completed with a pendulum approximately 100 cm long.
Notice that as the pendulum length increases, so does the period. We would like to determine, if possible, the relationship between these two quantities.

On a sheet of graph paper, plot the period as the dependent variable (ordinate or vertical axis) vs. the length as the independent variable (abscissa or horizontal axis). Be sure to label your axes including the units, and include a graph title. Choose your axes to maximize the size of your graph on your graph paper.

17. What type of function does your graph resemble? (Does it look like a line, parabola, exponential, etc?)

Let's continue under the assumption that it looks like a sideways parabola, so we might guess that L is proportional to P^2. Re-enter your data into Table 4, but rather that the period, P, enter the period squared, P^2.

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Table 4: New Pendulum Data

Pendulum Length (m)	$Period^2$ (s^2)

On another sheet of graph paper, plot the period squared as the dependent variable (vertical axis) vs. the length as the independent variable (horizontal axis). Be sure to label your axes including the units, and include a graph title.

This graph should look like a straight line. Using a ruler, draw the best fit straight through your data points. Choose two points, one at each end of your line and mark them with an X. Determine the slope of the line using these two points. Show your calculation on your graph.

18. What is the slope of your graph?

19. What is the equation for your line in "y = mx + b" form? (Use P^2 and L instead of y and x, and include the correct units.)

PART 3: Environmental Measurements

At the back of the room there is a weather station with three dials hanging on the wall. The top dial indicates the temperature in Fahrenheit and Celcius. The middle dial indicates the barometric pressure in inches of Mercury (in-Hg) and millibars. The bottom dial indicates the percent humidity.

20. What is the temperature in Fahrenheit and Celcius?

21. What is the barometric pressure in in-Hg and millibars?

22. What is the percent humidity?

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CONCLUSIONS:

23. What is the accuracy of the ruler, that is, what is the smallest difference between two measurements that you can determine with your ruler?

24. What is the accuracy of the meter stick?

25. What is the accuracy of the vernier caliper?

26. What is the accuracy of the micrometer?

27. What is the accuracy of the balance?

Clean-Up

Replace the pendulum ball and aluminum cylinder into the Measurement Lab Container. Replace the vernier caliper into its cover, the micrometer into its box, and return them and the rulers into the Measurement Equipment Tray.