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Partners _____

Measurement of Length, Mass, Volume and Density

Experimental Objective

The objective of this experiment is to acquaint you with basic scientific conventions for measuring physical quantities. You will measure the dimensions of various objects using a metric ruler, english ruler, vernier caliper and micrometer caliper. You will obtain the mass of each object using a triple-beam balance, determine its density and calculate their volumes from the measurements of their dimensions.

Theory

In the study of physical objects is very important to be able to systematically measure the quantities of length, mass and time. Every measurement that you make is a comparison. The characteristic you wish to quantify must be measured in comparison to a standard. The standard unit for length is the meter. Historically, the meter was intended to be a convenient fraction, (1/10,000,000) of the distance between the North Pole and the equator traveling along a line through Paris. There are different ways to measure length. The method chosen to make a linear measurement depends upon the accuracy desired and the distance involved. It is important to recognize that any measurement you make is subject to error. The best value of the quantity measured is given by the average of the values obtained or the arithmetic mean.

The standard unit for mass is the kilogram. Mass is the property of material bodies that makes them hard to accelerate. Weight is the force of gravity with which earth attracts a body. Mass and weight are not the same and should not be confused. The mass of an object is constant and its weight varies according on the location of the object.

The density of the material of which each is made is defined as the material's mass per unit volume,

$$D = \frac{M}{V} \qquad (1)$$

where M is the mass in grams, V is the volume in cubic centimeters and D is the density with units grams per cubic centimeter. For the metal cylinders and the wire the volume is given by

$$V = \pi r^2 L = \frac{\pi d^2 L}{4} \qquad (2)$$

where r is the cylinder's radius, d is the diameter (2r), and L is the length of the cylinder. For the irregular body the volume will be determined by measuring the volume of the liquid that it displaces.

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Equipment Needed

Aluminum Cylinder	Brass Cylinder
Iron Cylinder	Vernier Caliper
Micrometer Caliper	Balance
Length of Copper Wire	Irregular Solid
English Ruler	250 mL Graduated Cylinder

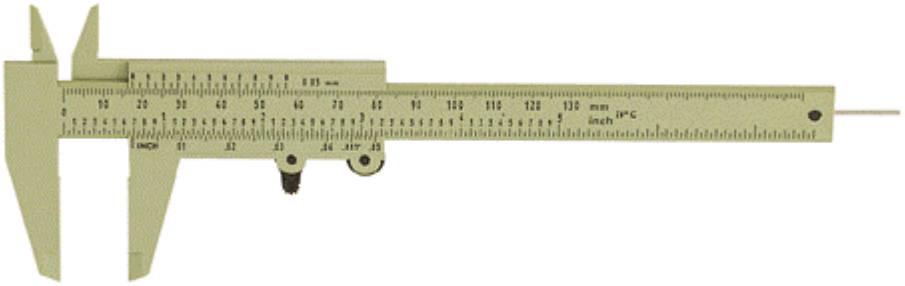
PART 1: Measurement of Wire Length

Use the metric ruler and the english ruler to measure the length of the copper wire.

1. Measure the length of the piece of copper wire with the metric ruler. Read the position of both ends of the wire. Have each lab partner take readings at different locations on the ruler. Record both readings to 0.01 cm in Data Table #C1.
2. Repeat step #1 to measure the length of the wire using the english ruler. Record both readings to 1/32" in Data Table #C2.

PART 2: Length and Diameter of Metal Cylinders

Use the vernier caliper to measure the length and diameter of aluminum, brass and iron cylinders.



The vernier caliper is a device used to make measurements with a precision of one tenth of a millimeter. It consists of a fixed part that contains the main scale and a movable jaw that has the vernier scale. The main scale is divided in centimeters and millimeters. The vernier scale slides along the main scale, it is nine millimeters long and is divided into ten parts each 0.9 mm long. To obtain a measurement place an object between the two jaws of the caliper, first get the reading of the main scale, then read the position where the zero line of the vernier falls on the main scale. Then obtain the fractional part of the main scale division by noting which line on the vernier coincides with a line on the main scale.

1. Obtain the reading when the jaws of the vernier caliper are closed and in contact with each other. This is the zero reading of the vernier caliper and it can be either positive or negative. Have each lab partner take readings, make sure to open and close the jaws before each reading. Record the zero reading to 0.01 cm in Data Table #C4.

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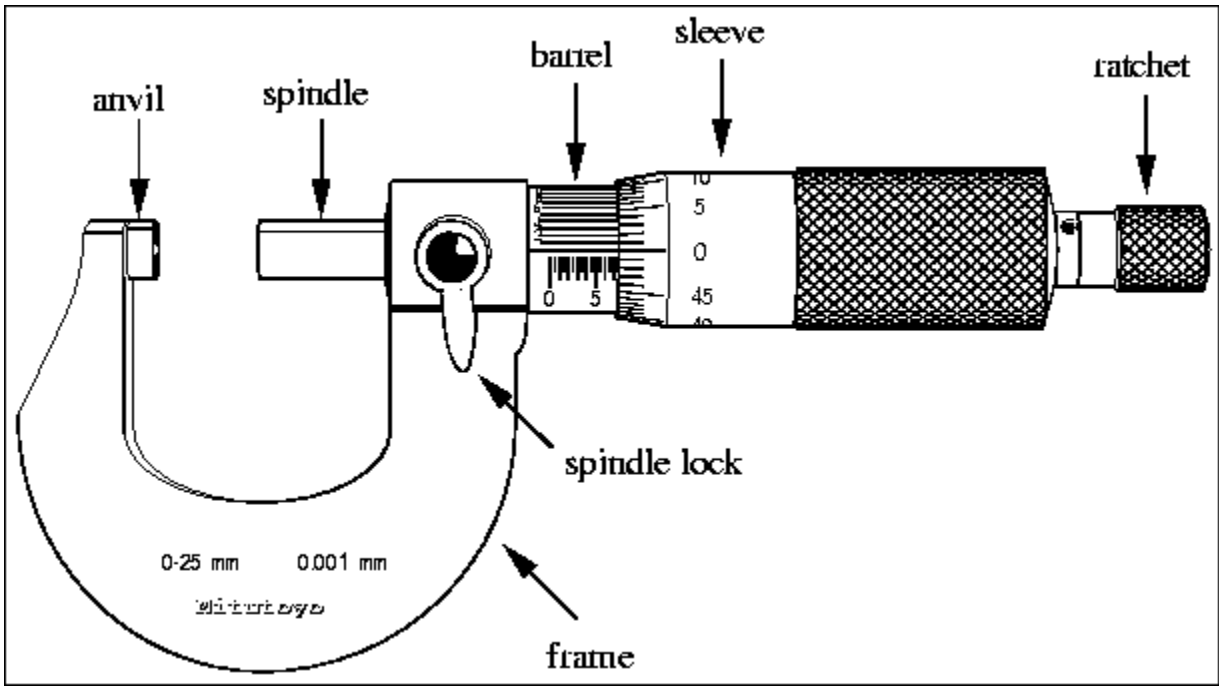
2. Measure the length and diameter of each cylinder with the vernier caliper. Each lab partner should take a length and diameter reading for each cylinder. Record the reading to 0.002 cm in Data Table #C4.

PART 3: Diameter of Copper Wire

Use the micrometer caliper to measure the diameter of the copper wire.



The micrometer caliper is used to measure distances with more precision than a vernier caliper. It has a 0.5 mm pitch screw, this means that you read millimeters and half millimeters along the barrel. Every revolution of the ratchet knob will open the jaws a half millimeter. The sleeve is divided into 50 divisions corresponding to one hundredth of a millimeter (0.01 mm) each. To take a measurement place the object between the anvil and the spindle, grip the ratchet and turn until the object is lightly gripped, do not overtighten. The first part of the measurement is taken from the barrel, each division is 0.5 mm, note that the millimeters and half-millimeters are on opposite sides of the line. Next obtain the reading of the sleeve and add this value to the reading you obtained from the barrel.

1. Obtain the reading when the surfaces of the anvil and the spindle are in contact. This is the zero reading of the micrometer caliper, it can be either positive or negative. Record the zero reading to 0.0001 cm. Have each lab partner take readings and record in Data Table #C5.

2. Measure the diameter of the copper wire. Place the wire between the anvil and the spindle, grip the ratchet and twist until the wire is lightly gripped. Do not overtighten. Have each lab partner take measurements at different points along the length of the copper wire. Record the reading to 0.0001 cm in Data Table #C5.

PART 4: Volume and Density

1. Determine the volume of the irregular solid using the displacement method. Partly fill the graduated cylinder with water, read and record the water level in Data Table #C6.
2. Hold the irregular solid by its thread and lower it into the graduated cylinder until it is completely submerged. Read and record the water level in Data Table #C6.
3. Determine the mass of each cylinder, the irregular solid and the copper wire using the triple-beam balance. Record in Data Table #C7 .

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Calculations:

Part 1: Measurement of Wire Length

1. For each set of measurements obtained using the metric ruler calculate the length of the copper wire.
2. Obtain the average value of the length by finding the arithmetic mean of the lengths. Remember to use the proper number of significant figures.
3. Calculate the deviations of the lengths obtained from the average value of the length.
4. Calculate the average deviation from the mean. The average deviation should be entered in your table as the average of your deviations.

Data Table #C1: Measurement of Wire Length Using a Metric Ruler

Ruler Readings (cm)		Length	Deviation	(Deviation)^2
Left End	Right End			
Average Values				

5. Compute the standard deviation, σ , these is obtained by taking the square root of the averages of the squares of the individual deviations.

$$\sigma = \sqrt{\frac{\left(x_1 - \bar{x}\right)^2 + \cdots + \left(x_N - \bar{x}\right)^2}{N}}$$

where σ is the standard deviation, x_1, x_2,…x_N are the N individual measurements and $\bar{x}$ is their average.

Value of σ _____

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6. Repeat Calculations #1 – #5 for the measurements obtained with the english ruler.

Data Table #C2: Measurement of Wire Length Using an English Ruler

Ruler Readings (in)		Length	Deviation	(Deviation)^2
Left End	Right End			
Average Values				

Value of σ _____

7. Calculate the number of centimeters in one inch using the data you obtained with the metric ruler and the english ruler. Use the calculated average values of the length of the copper wire for the metric ruler and the english ruler.
8. Find the difference between your calculated value and the accepted value.
9. Find the percent error.

Data Table #C3: Number of Centimeters in One Inch

Calculated Value	
Accepted Value	
Difference Between Calculated Value and Accepted Value	
Percent Error	

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Partners _____

Part 2: Length and Diameter of Metal Cylinders

10. Calculate the average value of the zero reading of the vernier caliper.
11. Calculate the average value for the length and diameter of each cylinder.
12. Calculate the measured length and diameter of each cylinder taking into account the zero reading of the vernier caliper.

Data Table #C4: Length and Diameter of Metal Cylinders

	Vernier Caliper Readings				Average Value	Measured Value
	1	2	3	4		
Zero Reading						----------
Length, Aluminum						
Length, Brass						
Length, Iron						
Diameter, Aluminum						
Diameter, Brass						
Diameter, Iron						

Part 3: Diameter of Copper Wire

13. Calculate the average value of the zero reading of the micrometer caliper.
14. Calculate the average value for the diameter of the copper wire.
15. Calculate the diameter of the copper wire by taking into account the zero reading of the micrometer caliper = _____ cm.

Data Table #C5: Diameter of Copper Wire

	Micrometer Caliper Readings				Average Value
	1	2	3	4	
Zero Reading					
Diameter Along Length					

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Part 4: Volume and Density

16. Calculate the volume of the irregular solid by substracting the reading of the initial water level from the reading of the water level with the irregular solid.

Data Table #C6: Volume of Irregular Solid

Initial Water Level	
Water Level with Irregular Solid	
Volume of Irregular Solid	

15. Calculate the volume and density of each object. For the length and diameter of the metal cylinders use the measured values obtained in Part 2 of the calculations (Data Table #C4). For the length of the copper wire use the average length value obtained in Part 1 of the calculations (Data Table #C1).
16. Find the percent error between the values of the calculated density and the accepted density.

Data Table #C7: Volume and Density

	Mass (g)	**Length (cm)**	**Diameter (cm)**	**Volume (cc)**	**Calculated Density**	**Accepted Density**	**% Error**
Aluminum Cylinder							
Brass Cylinder							
Iron Cylinder							
Copper Wire							
Irregular Solid		----------	----------				

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Partners _____

Questions:

1. Why are several readings taken for each measurement?

2. a.) What is the smallest part of a centimeter that can be read or estimated with a meter stick?

   b.) What is the smallest part of a centimeter that can be read or estimated with your vernier caliper?

   c.) What is the smallest part of a centimeter that can be read or estimated with a micrometer caliper?

3. Why was the micrometer used instead of the vernier caliper to determine the diameter of the copper wire?

4. In measuring the length and diameter of a cylinder, which dimension should be measured more carefully? Why? (Keep in mind that you measured the length and diameter to determine the volume).

