

E-02-OL- Measurements of Mass, Volume and Density

Rev 05/20/2020

ONLINE VERSION OF THE MANUAL.

READ THROUGH THIS MANUAL TO UNDERSTAND HOW TO PERFORM THE EXPERIMENT AND HOW TO USE THE MEASURING DEVICES. THEN SEE THE VIDEO OF EXPERMENTS BEING PERFORMED, AND NOTE AND RECORD THE DATA FROM THE VIDEO. THEN USE THAT DATA TO CALCULATE THE DENSITIES AND WRITE YOUR REPORT.

Link to video: <https://youtu.be/kJ0zoHsomeY>

THE MEASUREMENTS FOR THE COPPER WIRE ARE MISSING DUE TO EQUIPMENT MALFUNCTION. IGNORE THAT PART OF THIS LAB.

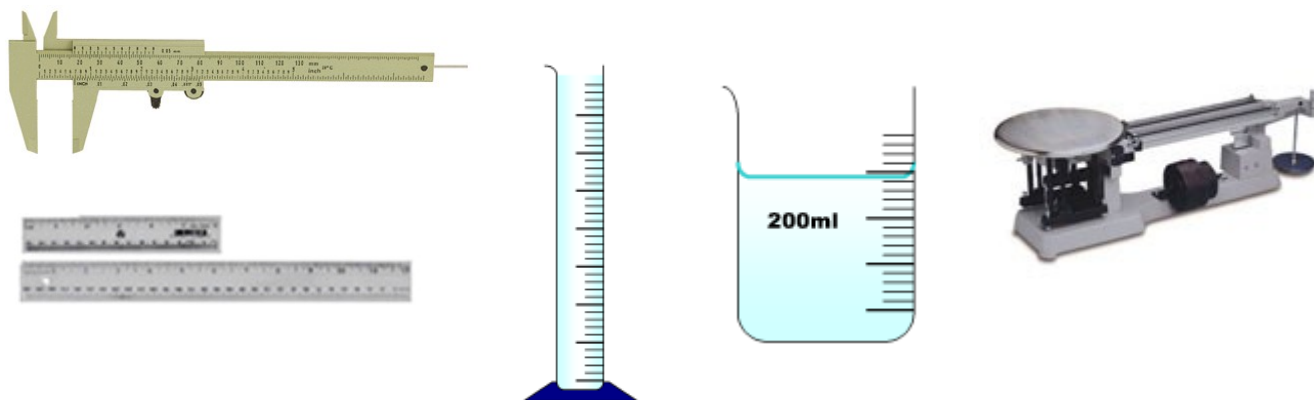
OBJECTIVES

In this laboratory experiment, the following objectives will be achieved:

- (i) Determination of densities of three metal cylinders, a rectangular solid, an irregular shaped solid, and a copper wire, by finding their volumes and masses.
- (ii) Identifying the materials by comparison of densities with the accepted values.

EQUIPMENT

1. Triple- beam balance
2. Vernier Caliper
3. Micrometer
4. Electronic Balance
5. A ruler (inches and centimeters)
6. Graduated Cylinder
7. A roll of copper wire.
8. Wire Cutter
9. Irregular object (lead, zinc, etc.)
10. Three cylindrical metals (brass, iron, aluminum, steel, tin, zinc, etc.) and copper wire.



INTRODUCTION:

Physics is a science of measurement that involves measurements of various parameters. Therefore, we need to learn how to take accurate measurements and how to use these numbers for calculations. In any measurement the uncertainty associated with it and the number of significant figures should be of particular interest to the experimenter. It should be underlined that the number of significant figures to be kept in a reading depends on the measuring device used.

In this experiment the dimensions of various objects will be determined by means of a meter ruler, a Vernier caliper, and a micrometer caliper and the probable error in these measurements will be determined. The mass of each object will be measured with a triple beam balance (or electronic balance if available) and the density of each object as well as the material from which it is made will be determined.

Density is the measurement of the compactness of matter in a substance. This might be done experimentally by measuring the mass and obtaining the volume of the substance. The volume may be obtained depending on the shape of the substance. For example, if the substance is cylindrical in shape then its volume can be computed from the equation $V = \pi r^2 h$, where h is the height or length of the substance. If the material is shaped like a sphere, the density is calculated from the equation volume $V = \frac{4}{3} \pi r^3$ (where r is the radius of the sphere). For a rectangle, the volume is $L \times W \times H$ (Length x Width x Height).

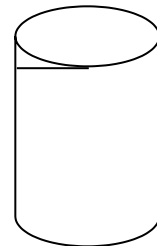
In the case of an irregularly shaped object, its density may be determined by submerging object in water contained in a graduated cylinder. Usually, an object displaces its own volume of water hence the difference in the cylinder reading before and after the immersion gives the volume of the object. Density denoted by a Greek alphabet, ρ , is usually expressed in g/cm^3 or kg/m^3 , and sometimes in lb/ft^3 . Density is one of the useful quantities scientists use to identify different materials with.

THEORY:

$$\text{Density: } \rho = \frac{\text{Mass}}{\text{Volume}}$$

The volume of a cylinder is: $V = \pi r^2 h$ or $V = \frac{\pi d^2 h}{4}$

In order to make precise measurements one needs to use accurate devices that will minimize the errors in our measurements:



a) Triple-Beam Balance

We use it to find the mass of each object. It consists of three beams along each one slides a weight. One beam has a notch every 100 g, the next one every 10 g and the last one every 1 g. Since this beam consists of 100 divisions equaling a mass of 10 g then this balance can read to 0.1 g and estimate to 0.05 g.

b) Vernier Caliper

A Vernier caliper is a common tool used to measure the length of an object, the outer diameter (OD) of a round or cylindrical object, the inner diameter (ID) of a pipe, and the depth of a hole. The Vernier caliper is more precise than a metric ruler because it gives an accurate measurement to within 0.01cm. and can be used to estimate to 0.001 cm.

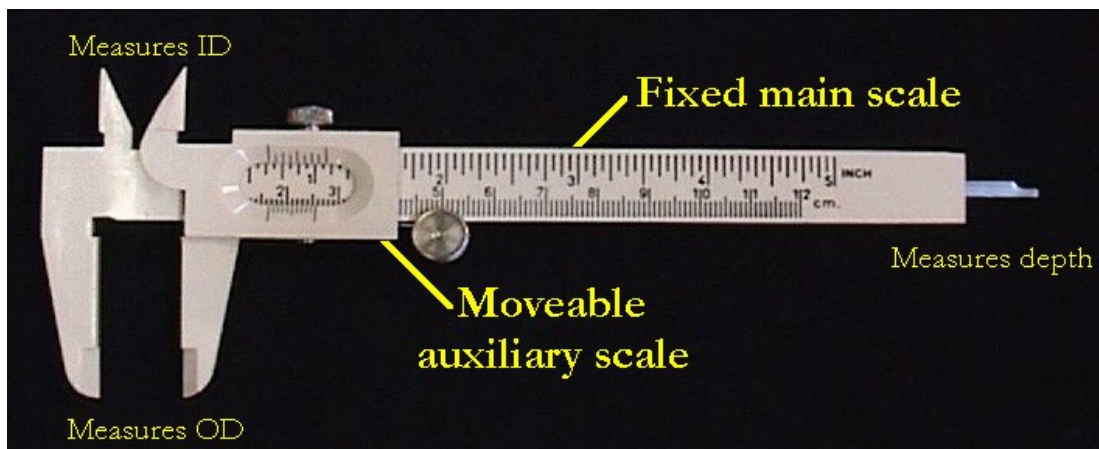


Figure 1

The Vernier consists of a main scale engraved on a fixed ruler and an auxiliary Vernier scale engraved on a movable jaw. The movable auxiliary scale is free to slide along the length of the fixed ruler. The Least count is the smallest measurement that can be taken by a measuring instrument. The least count is obtained by: $\text{Smallest division on main scale} / \text{No. of divisions on Vernier scale}$.

In this picture, the Vernier's main scale is calibrated in centimeters with the smallest division in millimeters. The auxiliary (Vernier) scale has 10 divisions that cover the same distance as 9 divisions on the main scale. Therefore, the length of the auxiliary scale is 9.0 mm. The Least Count of a measuring instrument is the smallest change in the measured quantity that can be resolved on the instrument's scale.

$\text{Least Count} = \text{smallest division on the main Scale} / \text{Number of divisions in the Vernier Scale}$.

For our Vernier Calipers, this comes to $0.1 \text{ cm} / 10 = 0.01 \text{ cm} = 0.1 \text{ mm}$. Once the Vernier is positioned to make a reading, the jaws are closed on the object and we make a note of where the first mark on the auxiliary scale falls on the main scale. In Figure 2, we see that the object's length is between 1.2 cm and 1.3 cm because the first auxiliary mark is between these two values on the main scale. The last digit (tenths of a millimeter) is found by noting which line on the auxiliary scale coincides with a mark on the main scale.

In our example, the last digit is 3 because the third auxiliary mark lines up with a mark on the main scale. Therefore, the length of the object is 1.23 cm.

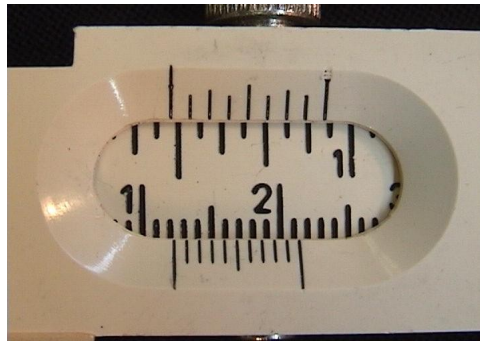


Figure 2

c) Micrometer

It is used to measure very small thicknesses and diameters of wires and spheres. It consists of a horizontal scale along a barrel divided into millimeters and a circular scale that has 50 divisions. The thimble has a scale of 50 equal divisions, each division is 0.01mm. (Figure 3). The Least count = $0.5 \text{ mm} / 50 = 0.01 \text{ mm} = 0.001 \text{ cm}$.

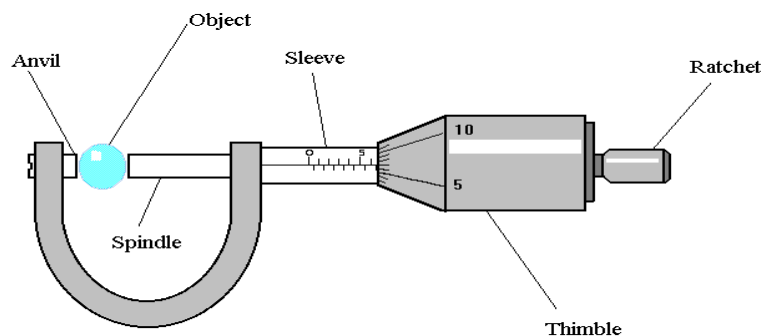


Figure 3

To take a measurement using the micrometer, place the object to be measured between the anvil and 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 sleeve. Each division is 0.5 mm (note that the millimeters and half millimeters are on opposite sides of the line). Care is needed as the thimble may partially obscure this reading, particularly when the thimble reading is close to zero. In the diagram the reading on the sleeve is 6.5mm. Note that the '0.5' mark is just showing.

The thimble reading must now be added to this. In the diagram the line on the sleeve is in line with the seventh division on the thimble, showing 0.07 mm (each division being equal to the least count). The total reading is therefore $6.5 + 0.07 = 6.57$ mm.

EXPERIMENTAL PROCEDURE

- 1) Determine the mass of each cylinder, the copper wire and the irregular solid.
- 2) Determine the zero reading of the Vernier caliper. This is when the jaws are in contact with each other. In this condition, the reading should be 0.00 cm. A non-zero reading is the zero error of the instrument. If the value is less than zero, the zero error is negative. Record the values in centimeters. Make sure to open and close the jaws before each measurement.
- 3) Measure the length and diameter of each cylinder with the Vernier caliper. Record them in centimeters to two decimal places. The actual value will be: Reading - Zero error.
- 4) Measure the length of the copper wire with the metric ruler
- 5) Determine the zero reading of the micrometer by allowing the anvil and the screw to approach each other very slowly. Record the values in centimeters. Make sure to open and close the micrometer before each measurement.
- 6) Measure the diameter of the wire with the micrometer by gripping the wire between the anvil and the screw. Try to change the location of the measurement on the wire in order to get different diameters.
- 7) Determine the volume of the irregular solid by submerging it in a graduated cylinder and measuring the volume of the liquid that is displaced.
- 8) Calculate the densities.
- 9) Look up the description of different materials to determine which solids you had. Then find their densities and calculate the percent errors in your measurement of densities. Use the following information to determine the materials:

Copper: Element. Reddish-orange color, denser than iron.

Brass: Alloy of copper and zinc; bright gold-like appearance. Denser than iron

Aluminum: Element. Silvery white, soft. Low density.

Steel: Alloy of iron and carbon. Hard.

Lead: Element. Soft and malleable, Dull grayish color. Denser than iron.

Zinc: Element. Commercial grades have a dull finish. Density less than iron, more than aluminum.

CALCULATIONS

- 1) Calculate the volume and density of each object.
- 2) Find the percent error for the density of each object:
$$\text{Percent error} = [(computed\ value - accepted\ value) / (accepted\ value)] \times 100\%$$

E-02: Measurements of Mass, Volume, and Density

REPORT FORM

Date: _____

Part I. Dimensions of the Solids with Vernier Caliper

	1	2	3	4	Average	Reading - Zero Error
Zero Error						X
Length of cylinder-1						
Length of cylinder-2						
Length of cylinder-3						
Diameter of cylinder-1						
Diameter of cylinder-2						
Diameter of cylinder-3						
Length of Rectangular Solid						
Width of Rectangular Solid						
Height of Rectangular Solid						

Part II. Dimensions of Copper Wire with the Micrometer and Meter Stick

	1	2	3	4	Average
Zero reading of Micrometer					X
Diameter Reading with micrometer					X
Diameter of wire (=reading - zero error)					
Length of copper wire with metric ruler					

Part III. Determination of Mass with Electronic Balance

	1	2	3	4	Average	Reading - Zero Error
Zero error of triple beam / electronic balance						X
Mass of cylinder-1						
Mass of cylinder-2						
Mass of cylinder-3						
Mass of rectangular solid						
Mass of irregular object						
Mass of copper wire with Electronic balance						

Part IV. Determination of Volume of Irregular Solid using Overflow Can

	1	2	3	4	
Level before immersion					
Level after immersion					Average Volume
Volume of solid					

Part IV. Calculation of Density

Object	Mass g	Length cm	Radius cm	Volume cm ³	Computed Density g/cm ³	Material of object	Accepted Density g/cm ³	Percent error in density
Cylinder-1								
Cylinder-2								
Cylinder-3								
Rect. Solid		x	x					
Copper Wire								
Irregular Solid		x	x					

RESULTS

Object	Computed Density g/cm ³	Material of object	Accepted Density g/cm ³	Percent error in density
Cylinder-1				
Cylinder-2				
Cylinder-3				
Rectangular Solid				
Copper wire				
Irregular Solid				

ADDITIONAL INFORMATION:

How to use a Vernier caliper:

2.42 min <https://www.youtube.com/watch?v=FNdkYIVJ3Vc>

5.04 min <https://www.youtube.com/watch?v=4hINi0jdoeQ>

How to use a micrometer

4.50 min <https://www.youtube.com/watch?v=oHqaLMEHlnE>

5.11 min https://www.youtube.com/watch?v=i_jygJkJujE

Inside a Micrometer

3.57 min https://www.youtube.com/watch?v=cXU__cf1Xlk

POINTS TO THINK ABOUT

1. Why is each measurement taken more than once?
2. Why was micrometer used instead of Vernier caliper for measuring the diameter of the wire?
3. What is the “least count” of the measuring devices used?
4. How can you get the density of an irregular shaped object?
5. Was the cross-section of the wire circular?
6. What is the effect of kinks in the wire?
7. Why is electronic balance used for the wire, but not for the cylinders?
8. Can you identify the material by knowing the density and appearance?
9. How tight should the micrometer and Vernier be made while making measurements?
10. What are the equations for volume of a cylinder, cube and sphere?
11. How would you calculate the mass of an object if its density is known?
12. To how many decimal places in cm can the Vernier and micrometer read?
13. To what place of decimal can the triple beam balance read?
14. What range of errors are “acceptable”?
15. What are the most likely sources of error?