

Lab Manual
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PURPOSE

In this experiment, experience is gained in performing measurements and in making calculations using these units. Learn how to assess the uncertainty in a measurement. Learn how to decrease the uncertainty in the measurement (that is, increase the accuracy) of something that repeats in a regular way.

INTRODUCTION

Read the theory for Lab #1:

- **University Physics Volume 1** Chapter #1: | [UNITS AND MEASUREMENT](#)
- [Statistic.pdf](#)

MATERIALS

- a 12-inch ruler with metric rulings on the back (e.g., centimeters and millimeters)
- a yardstick with metric rulings on the back, or a meter stick
- a book
- a room with a flat ceiling

PART ONE: CALCULATING THE VOLUME OF A BOOK IN CUBIC METERS

- 1.) Measure the length L of your book to the nearest millimeter at three different locations on the book (see Figure 1), and record these values on your data table.
- 2.) Measure the width W of your book to the nearest millimeter at three different locations on the book (see Figure 1), and record these values on your data table.
- 3.) Measure the thickness T of your book to the nearest millimeter at three different locations on the book (see Figure 1), and record these values on your data table.

Figure 1

A Pictorial Representation of the Top of Your Book

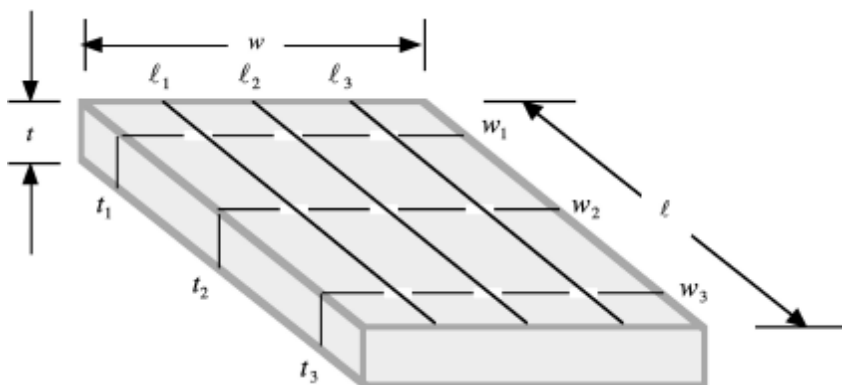


Figure 1: A Pictorial Representation of the Top of Your Book

Data

Measure and record the length of each side of a textbook or other book, to the nearest millimeter.

Calculations

1. Using your measurement data, calculate the arithmetic mean $\vec{L}$ for the length of your table top, and record this value on your data table.
2. Using your measurement data, calculate the arithmetic mean $\vec{W}$ for the width of your table top, and record this value on your data table.
3. Using your measurement data, calculate the arithmetic mean $\vec{T}$ for the thickness of your table top, and record this value on your data table.
4. Using your measurement data, calculate the standard deviation of the length of your book top σ_l and record this value on the data table.
5. Using your measurement data, calculate the standard deviation of the width of your book top σ_w and record this value on the data table.
6. Using your measurement data, calculate the standard deviation of the thickness of your book top σ_T and record this value on the data table.
7. Calculate the relative error of your measurement of the length of your book top ε_l and record this value on the data table.
8. Calculate the relative error of your measurement of the width of your book top ε_w and record this value on the data table.
9. Calculate the relative error of your measurement of the thickness of your book top ε_T and record this value on the data table.
10. Using your data, calculate the best estimate of the area of your book top A and determine the best estimate of the error of this measurement a, σ_{top} and record these values on the data table.
11. Using your data, calculate the best estimate of the volume of your book V and determine the best estimate of the error of this measurement a, σ_{vol} and record these values on the data table.

12. Using the data you measured for each side of the book, calculate the volume of the book in cubic meters.

Length Data

i	L_i	$d_{i,l}$	$ d_{i,l} ^2$
1			
2			
3			
4			
5			
6			
7			

$$\bar{L} = \frac{1}{N} \sum_i^N L_i$$

$$\sigma_{i,L} = \sqrt{\frac{1}{N} \sum_i^N |d_{i,l}|^2}$$

Where,

$$d_{i,l} = L_i - \bar{L}$$

$$\varepsilon_L = \frac{\sigma_{i,L}}{\bar{L}}$$

Width Data

i	L_i	$d_{i,w}$	$ d_{i,w} ^2$
1			
2			
3			
4			
5			
6			
7			

$$\bar{W} = \frac{1}{N} \sum_i^N W_i$$

$$\sigma_{i,W} = \sqrt{\frac{1}{N} \sum_i^N |d_{i,W}|^2}$$

Where,

$$d_{i,W} = W_i - \bar{W}$$

$$\varepsilon_W = \frac{\sigma_{i,W}}{\bar{W}}$$

Thickness Data

i	L_i	$d_{i,T}$	$ d_{i,T} ^2$
1			
2			
3			
4			
5			
6			
7			

$$\bar{T} = \frac{1}{N} \sum_i^N T_i$$

$$\sigma_{i,T} = \sqrt{\frac{1}{N} \sum_i^N |d_{i,T}|^2}$$

Where,

$$d_{i,T} = T_i - \bar{T}$$

$$\varepsilon_L = \frac{\sigma_{i,T}}{\bar{T}}$$

PART TWO: CALCULATING THE VOLUME AND WEIGHT OF THE AIR IN A ROOM

Data

1. Measure and record the length and width of a room that has a flat ceiling at three different locations. Estimate the ceiling height of the room without actually measuring it.
2. Make a guess of the weight of the air in the room and record your guess.

3. Find, using your textbook or an internet search, the density of air in units of kilograms per cubic meter.
4. Create the data table and enter your measurements.

Calculations

1. Calculate the volume of the room in cubic meters.
2. Determine the best estimate of the error of this measurement.
3. Convert the density of the air you found in kilograms per cubic meter to Newtons per cubic meter by multiplying by “g”, the acceleration due to gravity, i.e., 9.8 m/s^2 . The density of air in kilograms per cubic meter is called a mass density because it is mass divided by volume. The density of air in Newtons per cubic meter is called a weight density because it is weight divided by volume.
4. Calculate the weight of air in the room in Newtons by multiplying the weight density of air you calculated in #3 (in Newtons per cubic meter) by the volume of air (in cubic meters) you calculated in #1.
5. Determine the best estimate of the error of this measurement *and* record the value on the data table.
6. Convert the weight of air in the room that you calculated in #4 from Newtons to pounds and record your result. Does the weight of the air in the room (in pounds) surprise you?