Lab #1
Measurement of length, Mass, Volume and Density

Readings
Before you begin this laboratory read chapter 1 of the textbook.

Objectives
After completing this lab, you will be able to:
1. Make measurements to the nearest 1/10 of a millimeter using a meter stick.
2. Use a vernier caliper to make measurements to the nearest 1/10 of a millimeter.
3. Use a micrometer to make measurements nearest 10^{-6} meters using a micrometer.
4. Use an electric scale to measure mass to the nearest 1/100 of a gram.
5. Use a pendulum to measure the acceleration due to gravity.

Introduction
Physics is a quantitative experimental science and as such is largely a science of measurement. Over time, instruments of great accuracy have been devolved to help scientist make better measurements. One of the most basic measurements in physics is the measurement of length, which is where we will start this lab.

Another important physical quantity that is often measured is mass, which you will also be measuring in this lab. With the mass and the dimensions of an object known then the density can be calculated. Density depends on the mass and volume of an object. Density is a property of a material that is unique to that object. It can be used to calculate the mass of things that cannot be measured like bridges, and crowns.

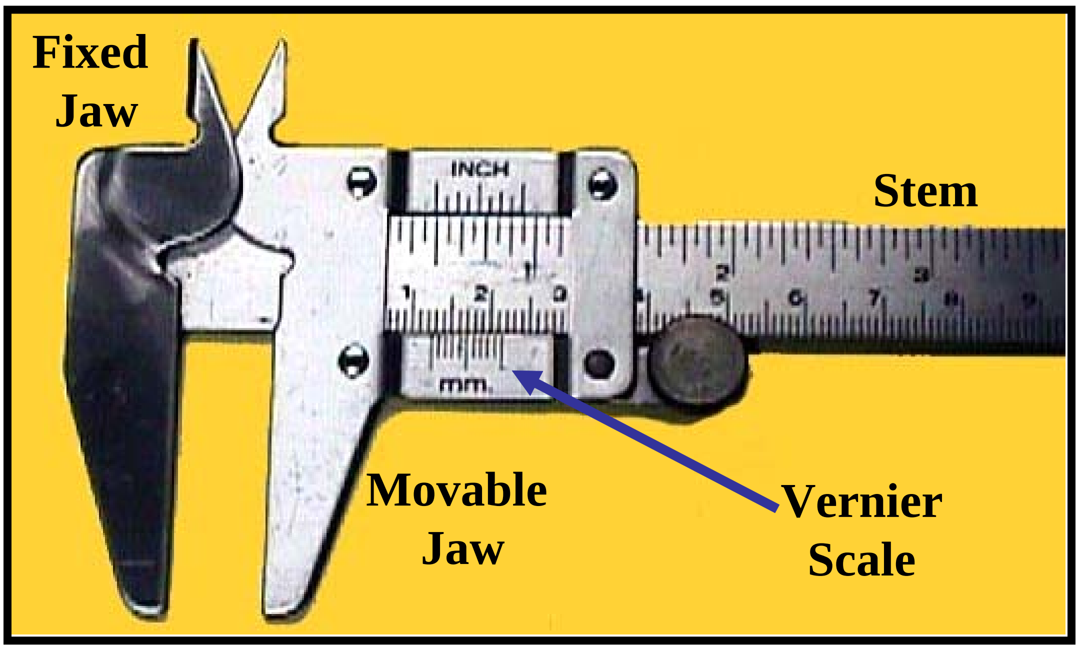
The last physical property to be measured in this lab is the acceleration due to gravity. This acceleration is rate that an object will fall at when drop near the surface of the Earth. The acceleration due to gravity is an important physical quantity, which is for the most part constant near the surface of the Earth, but really depends on how far away from the center of the Earth you are.

In this lab, the dimensions of various objects will be measured using a meter stick, vernier caliper, and micrometer. You will also get a chance to compare the British and metric system of units. With the use of an electric scale, the mass of some objects will be measured and from this, the density will be calculated.

Theory
Using the proper instrument is extremely important for making accurate measurements of physical properties. The easiest way to measure length is to use a meter (or English yard) stick. For normal everyday measurements, a visible comparison between the object of interest and the scale is all that is needed. To make precise measurements, the scale must be very accurately made and must be read to a fraction of its smallest scale division.

When an instrument is used to the limit of its precision, certain errors occur that cannot be eliminated. These errors are called random errors. When you make a series of measurements of a physical quantity, the individual results usually differ among themselves because of the random errors involved. The best value of the quantity measured is then the average of the values obtained.

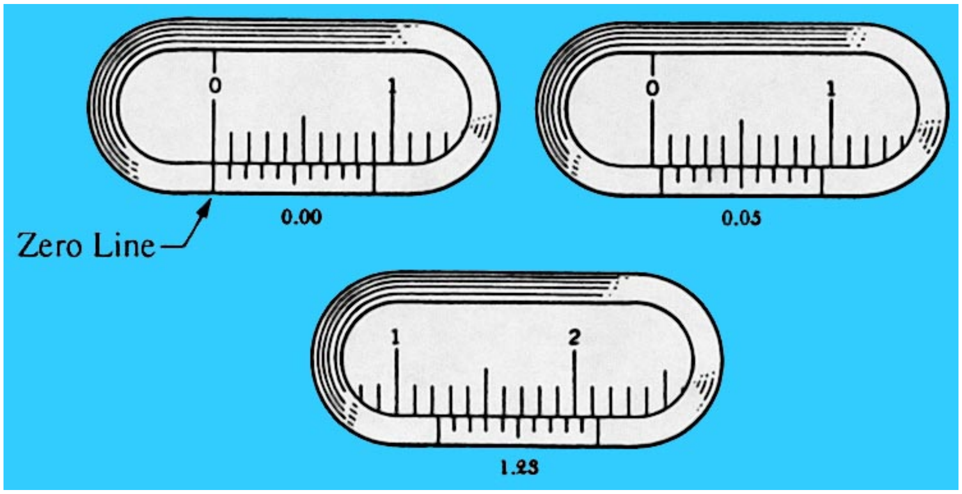
The precision of measurements can usually be increased by using more accurate and complex equipment and by being careful to eliminate errors as much as possible. No matter what type of instrument you are using, you should always try to make measurements with the greatest accuracy attainable.



The Vernier Caliper

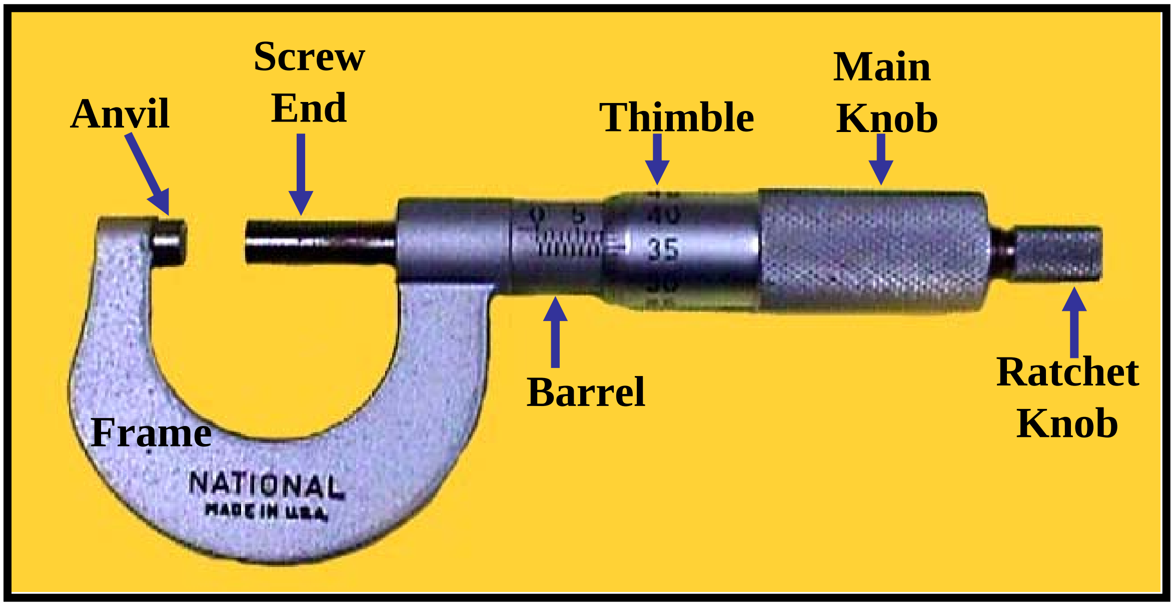
When you make a measurement using a meter stick you have to estimate the tenths of a millimeter (the millimeter being the smallest division on the meter stick). A vernier is a device that helps you to read the fractional part of a scale division. It is a small auxiliary scale that slides along the main scale. The scale of the vernier is different from those of the main scale, but they are simply related.

The vernier caliper (see figure above) consists of a fixed part and a movable jaw. The fixed part includes a stem, on which is the main scale (in centimeters and millimeters) and a fixed jaw attached to the stem. The movable jaw is free to slide on the fixed scale and has a vernier scale engraved on it. The vernier is divided so that ten divisions on it cover the same interval as nine divisions on the main scale. Hence, the length of each vernier division is $\frac{9}{10}$ the length of a main-scale division. When the jaws are closed, the first line at the left end of the vernier called the zero line coincides with the zero line on the main scale. However, the first vernier division is 0.1 mm away from the first main scale division, the second vernier division is 0.2 millimeters away from the second main scale division, and so on. If the jaws are slightly opened, it is easy to tell what fraction of the main-scale division the vernier index has moved by noting which vernier division coincides with a main-scale division.



A measurement is made with the vernier caliper by closing the jaws on the object to be measured and then reading the position where the zero line of the vernier falls on the main scale. To obtain the fractional part of the main-scale division make a note of which line on the vernier coincides with a line on the main scale. See above for three examples.

Sometimes a vernier will not read zero when the jaws are closed. In such a case, a zero correction may be applied to very reading. This correction can be either added or subtracted. If the errors are in the direction of increasing main scale readings they are considered positive, then zero corrections are made by subtracting the zero reading from all measurements.

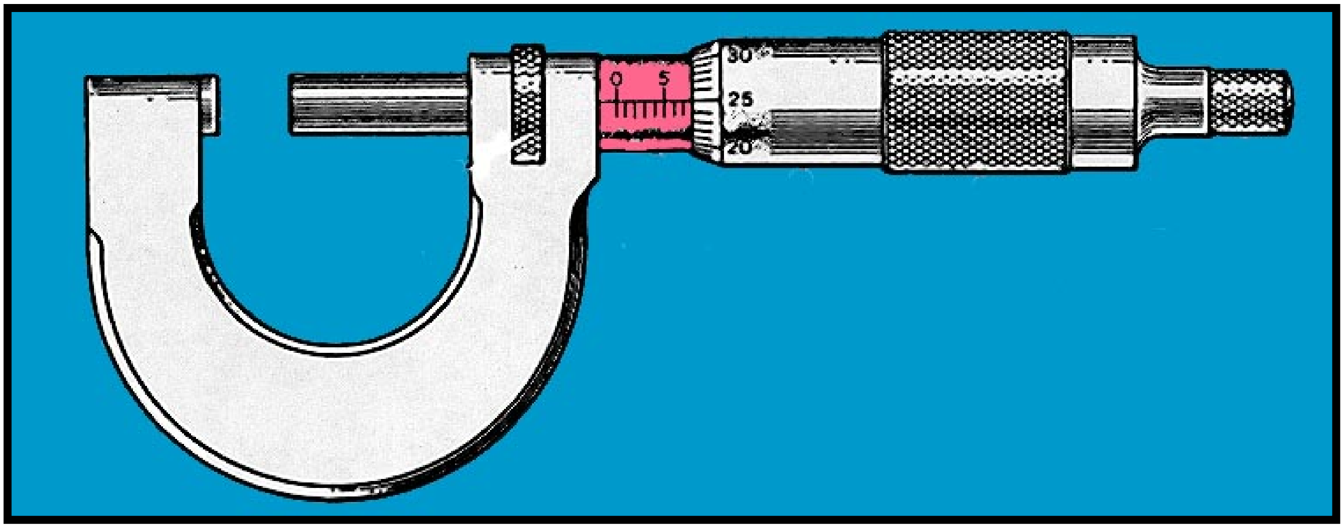


The Micrometer

The micrometer is an instrument used for accurate measurements of short lengths. Essentially, it consists of a carefully machined screw mounted in a strong frame. The object to be measured is placed between the end of the screw and the anvil. The screw is then advanced until the object is gripped gently between the two jaws of the instrument. Then the ratchet knob is used to finish tighten the screw. By using the ratchet, it is possible to tighten up the screw by the same amount of force each time and avoid using too much force.

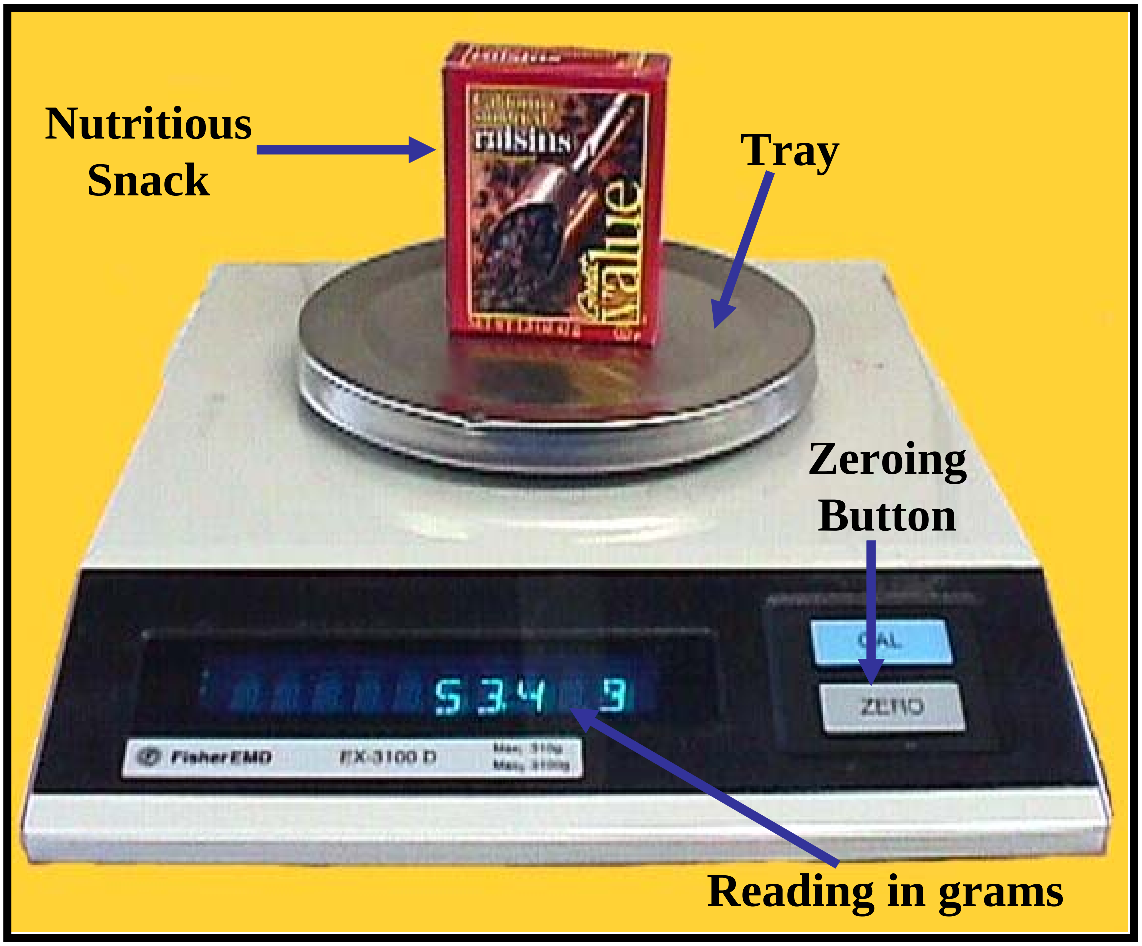
The micrometer we will be using in lab consists of a screw with a pitch of 0.5 mm, a longitudinal scale engraved along a barrel containing the screw, and a circular scale engraved around a thimble that rotates with the screw and moves along the scale on the barrel. The longitudinal scale is divided into millimeters. The circular scale has 50 divisions. Since the pitch of the screw is 0.5 mm, which is the distance, advanced by the screw in turning through one revolution; it is clear that rotating the thimble through one scale division will cause the screw to move a distance of $\frac{1}{50}$ of 0.5 mm, or 0.01 mm. Hence, readings may be taken directly to hundredth of a millimeter, and by estimating tenths of a thimble-scale division; they may be taken to one thousandth of a millimeter or one micrometer.

The micrometer is read by noting the position of the edge of the thimble on the longitudinal scale and the position of the axial line of the barrel on the circular scale, and adding the two readings. The reading of the main scale gives the measurement to the nearest half-main scale division; the fractional part of the main-scale division is read on the circular scale.



The reading above is 7.75 mm.

The micrometer should be checked for a zero error, for it may not read zero when the jaws are completely closed. In such cases, a zero correction has to be applied to every reading and may be either positive or negative. The value of the zero reading is obtained by rotating the screw until it meets the anvil and then noting the reading on the circular scale. Great care should be taken when doing this to ensure that both the screw and anvil surfaces are completely clean.



The Electric Scale

The electric scale is the easiest piece of equipment you will be using in this lab. The electric scale can measure the mass of objects to the nearest tenth of a gram. To measure an objects mass first make sure the scale reads zero. If the scale does not read zero press the zeroing button. After the scale reads zero, place the object of interest on the tray, wait a couple seconds and then record the reading. The electric scale does not allow the estimating of the nearest $\frac{1}{100}$ of a gram.

In this and all further work in physics, be very careful to distinguish between mass and weight, which are not the same despite the very common confusion between the two. Mass is the property of material bodies that makes them hard to accelerate. Even if a body is taken out into deep space far from the Earth, the Sun and other planets, it will not become massless---it will still have inertia; that is, a force will still be required to change its velocity. Weight, on the other hand, is simply the force of gravity with which the Earth attracts a body. Since this force depends on the distance between the Earth and the body, the body will indeed become weightless if taken far away (meaning many thousands of miles).

In this lab the masses of several objects will be determined and their volumes calculated from the measurements of their dimensions. The density of the material of which each is made, defined as the material's mass per unit volume, is then calculated from

$$\rho = \frac{m}{V}$$

where m is the in kilograms, V is the volume in cubic meters, and ρ (the Greek letter rho) is the density in units of kilogram per cubic meters $\left(\frac{kg}{m^3}\right)$.

For a cube the volume is

$$V = LWH$$

where L is the length, W is the width and H is the height.

Useful formulas:

$$\%\text{Difference} = \frac{\lvert \text{Actual} - \text{Experimental} \rvert}{\text{Actual}}$$
x_i = Data Value N = Number of Data Values $\overline{x}$ = Average Dev = Deviation σ = Standard Deviation
$$\overline{x} = \frac{1}{N}\sum_{i=1}^{N} x_i$$
$$\text{Dev}_i = \left(x_i - \overline{x}\right)$$
$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(\text{Dev}_i\right)^2}$$

Apparatus:

1. Electric balance	2. Micrometer
3. English ruler	4. Two metal cubes
5. Metric ruler (meter stick)	6. Vernier caliper
7. Length of copper wire	

Procedure:

1. Measure the length of the piece of copper wire with the metric ruler. Read the position of both ends of the wire, estimating to the nearest tenth of a millimeter. Record both readings in centimeters and read to 0.01 cm. Make four independent measurements—that is, use a different part of the ruler for each measurement—and record all the readings.
2. Measure the length of the wire with the English ruler. Read the position of both ends of the wire, estimating to the nearest tenth of the smallest scale division. Record both readings, expressed in inches, to the nearest 0.01 in. Make four independent measurements—that is, use a different part of the ruler for each measurement—and record all the readings.
3. Determine the zero reading of the vernier caliper. This is the reading when the jaws of the instrument are in contact with each other. Be sure that the jaws are clean so no grit or other foreign matter gets between them and prevents true contact. Record the zero reading to 0.001 cm make four independent determinations of the reading—that is, open and close the jaws before each setting—and record your results.
4. You should also measure the length, width and height of the two cubes. These measurements are made by closing the jaws of the caliper on the length or diameter of the object being measured and reading the position where the zero line of the vernier falls on the main scale. The fractional part of a main-scale division is obtained by noting which line on the vernier coincides with a line of the main scale. Record the reading in centimeters and read to 0.01 cm. Make four independent measurements—that is, open and close the jaws before each setting. This is most conveniently done by making all measurements for an object and then starting over again. Record all the readings.
5. Determine the zero reading of the micrometer caliper, that is, the reading when the surfaces of the anvil and the screw end are in contact. Be sure these surfaces are very clean, since even a small speck of dust can give a false reading. The screw end may be brought almost into contact with the anvil by turning the thimble directly, but actual contact must always be made by turning the ratchet slowly until it clicks several times. Record the value of this reading in centimeters and read to 0.0001 cm, estimating to one tenth of the smallest scale division. Make four independent determinations of the zero reading—that is, open and close the instrument before each

setting—and record the readings. Average the four readings and use them to make your corrections in the next part.

6. Measure the diameter of the copper wire with the micrometer caliper. The measurement is made by placing the wire between the screw end and the anvil and advancing the screw until the wire is gripped between the anvil and screw-end surfaces. Again, the ratchet should be taken not to force the screw. Record the reading in millimeters and read to 0.001 mm, estimating to one tenth of the smallest scale division. Make six independent measurements of the diameter of the wire—that is open and close the caliper before each setting, and make the measurement at different points along the wire's length. Also, spin the wire between measurements so that different diameters are measured each time. Record the six readings so obtained. To get the diameter of the wire add or subtract your average zero reading from the six measurements you took.
7. Determine the mass of each cube, cylinder, and copper wire using the electric balance.

Data:

Measurement of Wire Using Metric Ruler				
Ruler Readings		Lengths	Deviations	Deviations Squared
Left End	Right End			
Average Values				
			Value of σ=	

Measurement of Wire Using English Ruler				
Ruler Readings		Lengths	Deviations	Deviations Squared
Left End	Right End			
Average Values				
			Value of σ =	

Number of centimeters in 1 inch	
Calculated Value	Difference between calculated and accepted values
Accepted Value	Percent Error

Length and Diameter of Metal Cylinders and Cubes using a Vernier Caliper					
	Vernier Caliper Readings				Average
	1	2	3	4	
Zero Reading					
Length, Cube 1					
Height, Cube 1					
Width, Cube 1					
Length, Cube 2					
Height, Cube 2					
Width, Cube 2					

Diameter of Copper Wire Using a Micrometer Caliper							
	Micrometer Readings						Average
	1	2	3	4	5	6	
Zero Reading							
Reading with wire							
Diameter of wire							

Determination of Density								
Object	Mass in (*kg*)	Length (*m*)	Height (*m*)	Width (*m*)	Volume (m^3)	Density Computed (kg/m^3)	Density Actual (kg/m^3)	Percent Error
Cube 1								
Cube 2								
			Diameter (*m*)					
Copper Wire								