KINGSBOROUGH COMMUNITY COLLEGE
CITY UNIVERSITY OF NEW YORK

# EXPERIMENT 1
# The Metric System, Density and Temperature

Physics is a quantitative science, relying on accurate measurements of fundamental properties such as time, length, mass and temperature. To ensure measurements of these properties are accurate and precise, instruments such as a meter sticks, a tape measure, cent-o-gram balance, analytical balance, and laboratory thermometers are often used. It is important to understand how to properly use these devices. With any measurement tool, the student should always try to achieve the greatest accuracy the apparatus will allow.

**Meter stick.** The simplest way to measure length is to use an ordinary meter stick. In the laboratory, our meter sticks are carefully calibrated in centimeters with a millimeter least count. That is, the millimeter is the smallest subdivision on the meter stick, which can be seen in Figure 1. This means the millimeter is the unit of the smallest reading that can be made without estimating.

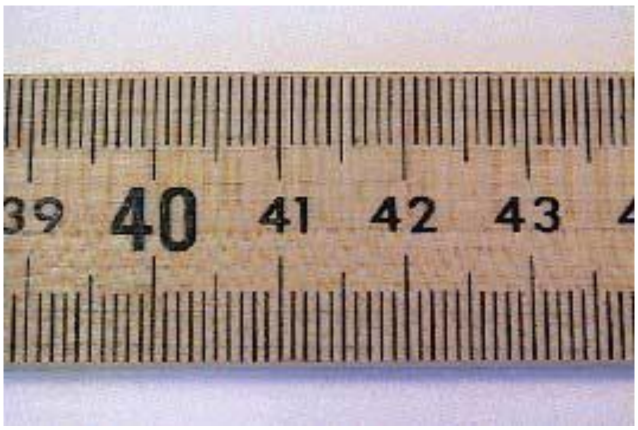



**Figure 1.** This meter stick is calibrated in centimeters (shown as the numbered major divisions) with a smallest number of millimeters.

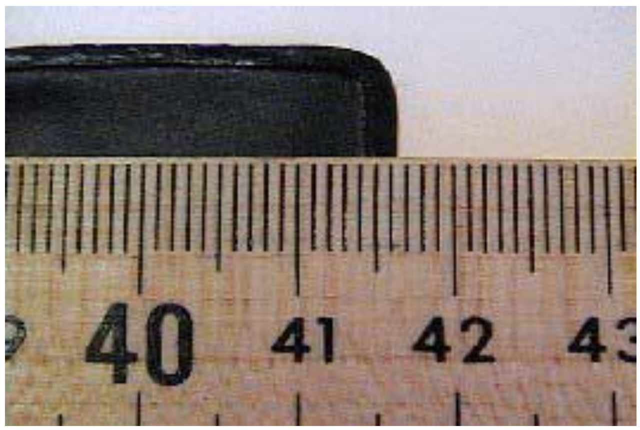
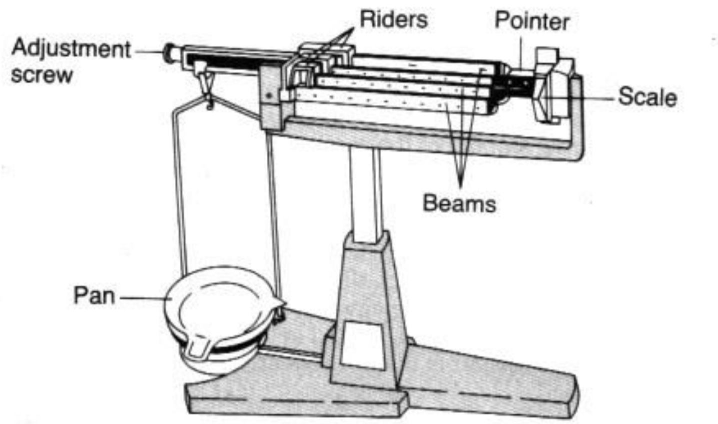



**Figure 2.** An example of a meter sticks reading. The object's length is measured to be 41.64 cm. (See text for description.)

A measurement reading usually has one more significant figure than the least count reading of the scale. The least count of our laboratory meter sticks is 0.1cm and therefore a reading can be made to 0.01cm. Figure 2 above shows a meter stick being used to measure the length of a plastic strip. The meter stick is calibrated in centimeters, so we know that the strip is between 41 and 42 cm. The least count of this meter stick is one millimeter, so we know with absolute certainty that the object is between 41.6 cm and 41.7 cm. We then estimate the object's length to the fractional part (doubtful figure) of the least count subdivision. In Figure 2, it we may estimate that the strip is closer to 41.6 cm than it is to 41.7 cm and report the length to be 41.64 cm or 0.4164 m.

**Cent-o-gram balance.** The cent-o-gram balance, or laboratory balance, measures the mass of an object by balancing the unknown mass with sliding masses of known values. The cent-o-gram balance is usually calibrated in grams with a least count of 0.1g. A measurement, then, can be made to 0.01g. It is important to note that laboratory balances are used to make measurements of an object's mass, not weight. (The weight of an object, as you will learn, is the product of the object's mass, m, and the acceleration due to gravity, g, or W = mg.)

Before the cent-o-gram balance is used to make a measurement, verify that the balance is properly zeroed. Fine adjustments may be made by turning the knob under the balance pan.




**<u>Objective:</u>** To become familiar with the metric system and the Celsius (centigrade) scale of temperature, as well as to learn how to use a meter stick, a tape measure, an analytical balance, a graduated cylinder and two thermometers (a "Tempa-Dot" and a modern electronic digital thermometer). Students will work in pairs, as well as individually, in order to learn both cooperation and independent observation. A review is included of the concepts of calculations and conversions from the British system of units to the metric system and vice versa.

**<u>Procedure:</u>**

1. Measure and record your height (in inches) using a meter stick. Convert it to centimeters, and meters.

Vertical: ___________ (*in.*) ___________ (*cm*) ___________ (*m*)

*Height:*

Horizontal: ___________ (*in.*) ___________ (*cm*) ___________ (*m*)

2. Measure a cubit (Remember Noah's Ark?) Measure the distance from your elbow to the tip of your middle finger. (Use the tape measure.)

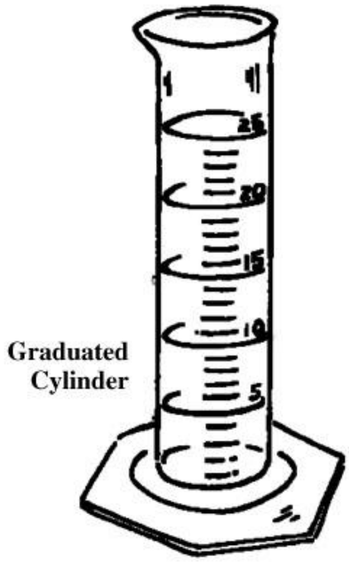
*Cubit:* ____________ *(cm.)*

3. The distance from the end of the nose to the tip of the right thumb ("definition" of one yard.)( Keep your head facing forward.)

______________ (*in.)*

4. Weight _______________

*Volume determination*




The instructor will explain how to read a graduated cylinder, especially what is meant by the "meniscus" and how to avoid the error of *parallax* in reading the level.

In determining the density, you must determine the mass and the volume. You will perform the steps in a certain order, but record the data in a way that is most convenient for calculations**.** The density of the copper cylinder is given and you will perform the experiment below to obtain the volume of the copper cylinder in order to determine the mass of the copper cylinder***. NOTE: Density of the copper cylinder is 8.96(g/mL).***

1. Pour 10 to 15 mL of distilled water into the graduated cylinder, dry the outside of the cylinder, if necessary. Record the volume below of the graduated cylinder and the water.

2. Place the copper cylinder in the graduated cylinder and the water. ***Please tilt the graduated cylinder before placing the copper cylinder.*** Record the new volume.
You are now ready to perform the calculations.

| | *Try#1* |
|---|---|
| a. Volume, graduated cylinder plus water | ____________ (*mL*) |
| b. Volume, graduated cylinder plus water plus copper cylinder | ____________ *(mL)* |
| c. Volume of copper cylinder (Line b – Line a) | ____________ *(mL)* |

*The determination of a mass from a known density and the experimentally determined volume displacement*

$$Density = \frac{Mass\ (g)}{Volume\ (mL)}$$ for example: 12 = X / 6 , solve for X , X = 72.

Therefore, the mass of the copper cylinder is found by solving the above expression for mass.

*Mass (g) = Density (g/mL) x Volume (mL) =* ____________________ *(g) :* $\boldsymbol{M_{exp}}$ ***#1***

*The determination of the mass of a copper cylinder using different balances.*
*NOTE: Dry the copper cylinder* ***before*** *determining its mass. Why?*

1. Using the cent-o-gram balance measure and record the mass of the copper cylinder. (to the nearest 0.01 g.)

Mass of copper cylinder ______________ *(g) :* $\boldsymbol{M_{exp}}$***#2***

2. Using the analytical balance measure and record the mass of the copper cylinder. (to the nearest 0.0001 g)

Mass of copper cylinder ______________ *(g)* **:** $\mathbf{M_{accepted}}$

*Note: the mass obtained from the analytical balance will be your accepted mass value for the copper cylinder* $M_{accepted}$.

**<u>Analyzing data:</u>**

Mass of copper cylinder (graduated cylinder):

$$\textbf{\% difference Mexp \#1} = \left| \frac{M_{accepted} - M_{exp}}{|M_{accepted}|} \right| \times 100 = \underline{\hspace{3cm}}.$$

Mass of copper cylinder (cent-o-gram balance):

$$\textbf{\% difference Mexp\#2} = \left| \frac{M_{accepted} - M_{exp}}{|M_{accepted}|} \right| \times 100 = \underline{\hspace{3cm}}.$$

*Step 4.*

A thermometer is an instrument that measures temperature, and it is thought to have been invented by Galileo in 1592. The type which contains a liquid in a glass operates on the principle that the liquid expands and contracts uniformly and proportionately with changes in temperature. The liquid is usually mercury, or colored alcohol for very low temperatures where mercury could solidify. The container is a tube, with a fine uniform bore, that is calibrated for degrees, and even for fractions of degrees, usually on the Fahrenheit or the Centigrade (also called Celsius) scale.

Precision thermometers operate on the principle that the electrical resistance of a wire changes with the temperature. The so-called Tempa-Dot thermometer is made up of a special mixture of two organic compounds (one that is called **o-chloronitrobenzene** and the other **o-bromonitrobenzene**), mixed in the proper proportion, in order to give the color change at various temperature readings. When these solids compounds melt, a liquid is formed and a blue dye is formed, indicated by a blue color on the "dot". If the melting point has not been reached, the dot changes to blue but later changes back to orange.

Andres Celsius (1701-1744) was a Swedish astronomer who constructed the Celsius or Centigrade thermometer in 1742. Gabriel Daniel Fahrenheit (1686-1736) was a German physicist. He improved the mercury thermometer to the point of practical use, devising the so-called Fahrenheit scale of temperatures which was later modified. He also discovered that the boiling point of a liquid varies with the atmospheric pressure.

1. Using a Tempa-Dot strip record your temperature after 5 minute period.

Temperature: _______________ (°C)

2. Convert the temperature from °C to °F using the following equation:

$$°C = \frac{5}{9}(°F - 32) \quad \text{or} \quad \frac{(°F - 32)}{1.8}$$

$$°F = \frac{9}{5}(°C) + 32 \quad \text{or} \quad 1.8\,(°C) + 32$$

*Note: Show all work.*

List four areas on your body where your temperature can be determined. Which is / are the most accurate?

ANSWER ALL OF THE FOLLOWING QUESTIONS BASED ON TODAY'S LAB FOR THE QUIZ IN THE NEXT LAB.

1) Archimedes (287-212 BC), a Green inventor and mathematician, made several discoveries important to science today. According to a legend, Hiero, the king of Syracuse, commanded Archimedes to find out if the royal crown was made of gold, only. The king suspected that the crown consisted of a mixture of gold, tin, and copper.

Archimedes measured the mass of the crown and the total amount of water displaced by the crown when it was completely submerged. He repeated the procedure using individual samples, one of gold, one of tin, and one of copper. Archimedes was able to determine that the crown was not made entirely of gold without damaging it.

Based on the reading passage, identify *one* physical property that Archimedes used in his comparison of the metal samples.

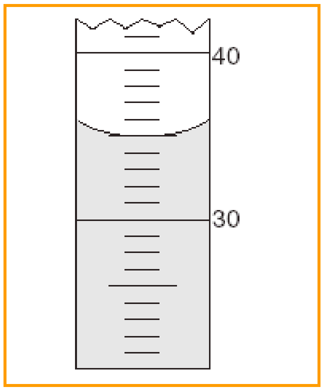
2) A student calculates the density of an unknown solid. The mass is 10.04 grams, and the volume is 8.21 cubic centimeters. How many significant figures should appear in the final answer?

A) 1　　B) 2　　C) 3　　D) 4

3) During a laboratory experiment, a sample of aluminum is found to have a mass of 12.50 grams and a volume of 4.6 milliliters. What is the density of this sample, expressed to the correct number of significant figures?

A) 2.717 g/mL　　B) 3 g/mL　　C) 2.7 g/mL　　D) 2.72 g/mL

4) The diagram below represents a portion of a 100-milliliter graduated cylinder.




What is the reading of the meniscus?

A) 45.0 mL　　B) 44.0 mL　　C) 35mL　　D) 36 mL

5) A student used a balance and a graduated cylinder to collect the following data:

| | |
|---|---|
| Sample mass | 10.23g |
| Volume of water | 20.0.mL |
| Volume of water and sample | 21.5mL |

(a) Calculate the density of the element. Include the appropriate number of significant figures and proper units. *[Show your work.]*

(b) If the accepted value is 6.93 grams per milliliter, calculate the percent error.

(c) What error is introduced if the volume of the sample is determined first?

6) A plan is being developed for an experiment to test the effect of concentrated strong acids on a metal surface protected by various coatings. Some safety precautions would be the wearing of chemical safety goggles, an apron, and gloves.

State *one* additional safety precaution that should be included in the plan.

7) Human body temperature is $37^{0}$C. What temperature does this correspond to on the Kelvin scale? *[Write the correct formula. Show all work.]*