Supplement – Density

The density of an object is defined as its mass per unit of volume. The formula below may be used to calculate the density of an object:

Density = mass/volume

Volume may be measured in several ways.

- Geometric formulas for volume include:

  Volume of a cylinder = $\pi r^2 h$

  Where **r** is the radius of the cylinder and **h** is the height.

  Volume of a rectangular prism = LxWxH

  Where **L** is length, **W** is width, and **H** is height

- Another method is fluid displacement. If you place water in a graduated cylinder or measuring cup, then add the coin, the water level will rise. This increase is the volume of the coin, measured in milliliters. Remember that 1 milliliter is equal to 1 cm^3.

Your table of material properties lists the density of several metals commonly used in coins.

Some coins are made from a blend of two or more metals called an "alloy". Brass, for instance, is an alloy of copper and zinc. The density of an alloy will be somewhere between the density of its constituent metals.

Supplement – Hardness

Hardness is a property which describes a material's ability to resist surface scratches and indentations. Diamond is a famous example of an extremely hard substance. A diamond will easily scratch any metal without being damaged in return.

Engineers have many methods of measuring hardness. Some are very sophisticated and use computer-driven tools which push an ultra-hard probe into the test material.

Today, you will use a very simple way to measure the relative hardness of your coin. There are nails made from various metals available. If the coin can scratch the nail, it must have the greater hardness. Any nail which can scratch the coin is harder than the coin.

The relative hardness of many metals is listed in your table of material properties.

The hardness of steel depends on how it was heated and cooled during the process by which it was manufactured. This explains the range of hardness values for steel in the reference table.

Some coins are made from alloys of several metals blended together. It is difficult to determine the metals in an alloy from its hardness. The hardness of an alloy is not the average of its constituent metals. Some alloys, such as bronze (copper and tin) are harder than either of their constituent metals.

Be careful not to cause more scratches on your coin than necessary. Scratches can reduce the archeological and monetary value. Try scratching the nail with the coin first. Only do the reverse when necessary to get a clear result.

Supplement – Specific Heat Capacity

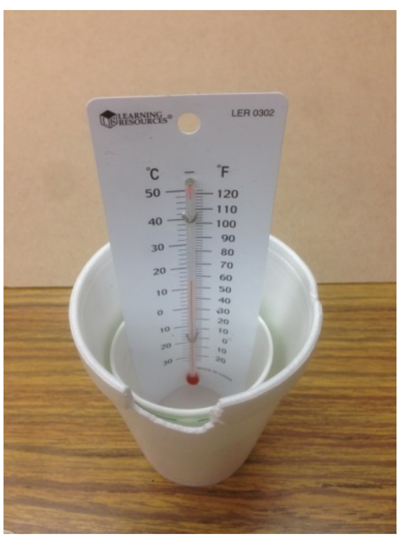
Specific heat capacity is the amount of heat energy required per unit of mass to raise the temperature of a substance by one degree. Metals have little freedom of motion due to the constraints of their crystalline structure. Thermal inputs primarily produce an increase in molecular vibration. The associated increase in kinetic energy is measurable as a temperature increase. For this reason, metals have relatively low specific heat capacities, compared with water or alcohol which can store internal energy in other modes. What distinguishes the specific heat capacity of one metal from another is primarily the difference in atomic mass.

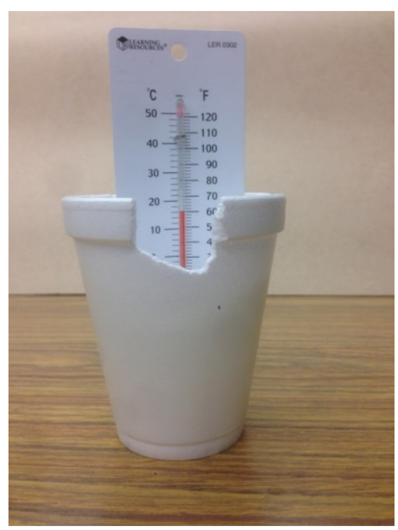
You will measure the specific heat of your coin by heating it in boiling water, then immersing it in isopropyl alcohol. Heat will flow from the coin into the alcohol until both are at the same temperature. This state is called **thermal equilibrium**. By measuring the tiny increase in the alcohol's temperature, you can calculate the coin's specific heat capacity.

1. Place the thermometer into the small Dixie cup. Push the thermometer down to the bottom.

2. Place the small Dixie cup into a larger Styrofoam cup.

3. Can you see the thermometer well enough to read the temperature accurately? It may be necessary to cut some of the Styrofoam cup away to allow you to see the thermometer clearly. You want to be able to read the temperature by looking in straight from the side. See the pictures on the next below.





4. You are going to add isopropyl alcohol to the small Dixie cup. You want just enough alcohol to completely cover the bulb of the thermometer. You will need to know the exact mass of the alcohol you added. Think about how this could be done. Now add the alcohol and record its mass below:

   The device you have just constructed is called a **calorimeter**. It is used to measure the transfer of heat from one object to another. You will be measuring the transfer of heat from the coin to the alcohol.

5. Measure the mass of your coin and record it below:

6. Cut a piece of string to about 30 cm in length and tie one end to your coin.

7. Attach a sticker label to the other end of your string and write your name on it.

8. Place the coin in boiling hot water, leaving the other end of the string out and dry.

9. After three minutes your coin will have become as hot as the boiling water (100 degrees C).

10. Measure and record the starting temperature of the alcohol in your calorimeter to the nearest half of a degree C.

11. Bring your calorimeter over to the boiling water. After being in the boiling water for at least three minutes, remove the coin by its string. Touching only the string, immediately lower your coin into the alcohol of your calorimeter. Be sure the coin is fully submerged, but <u>not</u> touching the glass bulb of the thermometer.

12. Within seconds, the temperature of the calorimeter water should rise. Watch the thermometer closely. When the temperature stops rising, record the final temperature to the nearest half of a degree C. This should take no more than two minutes.

13. The increase in alcohol temperature comes from the thermal energy that was stored in the coin. Calculate the temperature change of the alcohol in the calorimeter using your data from steps 10 and 12.

14. Using this temperature change we can calculate the heat capacity of the metal in your coin. Use the formula below to do your calculation. Show all of your work and your final answer in the box provided below.

$$C_c = m_a \, \Delta T_a \, C_a \; / \; m_c \, \Delta T_c$$

$$C_c = \frac{\text{(mass of alcohol)(temperature change of alcohol)(specific heat of alcohol)}}{\text{(mass of coin)(temperature change of coin)}}$$

- Mass of alcohol (measured in grams) was recorded in step 4
- Temperature change of alcohol (degrees C) was recorded in step 13
- The specific heat capacity of alcohol is **2.68 J/(g C)**
- The mass of the coin (measured in grams) was recorded in step 5
- Temperature change of the coin is the difference between its initial temperature (step 9) and its final temperature (step 12).
- C_c is the specific heat capacity of your coin. You can compare this value with the metals in your reference table. If your coin is an alloy of two or more metals, its specific heat capacity will be close to a weighted average of its constituent metals.

15. Your answer assumes that all of the heat held by the coin ends up in the alcohol of your calorimeter. Is it possible that the coin actually cooled while being moved from the boiler to the calorimeter? Is it possible that some of the heat went into the air and the cup, rather than the alcohol? Explain how that would affect your calculated heat capacity for the coin: