LABORATORY I:
CONSERVATION OF ENERGY AND HEAT

In 1101 labs, you used conservation of energy to determine whether or not the internal energy of a system changed during an interaction. In these labs, you will investigate more closely the behavior of a system's internal energy. In particular, you will use the relationship between an object's change in temperature and its change in internal energy to solve problems.

OBJECTIVES:

After successfully completing this laboratory, you should be able to:

- Use the principle of conservation of energy as a means of describing the behavior of a system when the internal energy of the system changes.
- Calculate the transfer of thermal energy from one object to another based on each object's properties such as its specific heat capacity, latent heat and mass, as well as their change in temperature.

PREPARATION:

Before coming to lab you should be able to:

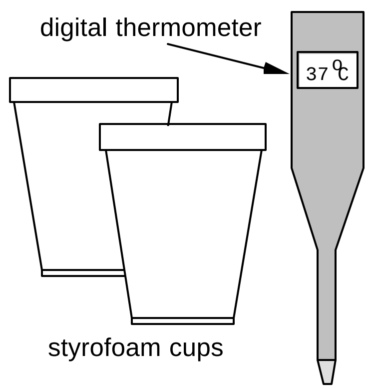
- Distinguish among these concepts:
  - Heat capacity, specific heat, and latent heat of fusion
- Use heat capacities to determine the internal energy change of a system based on its temperature change
- Recognize when two objects are in thermal equilibrium
- Use the latent heat to determine the internal energy change of a system during a phase change

PROBLEM #1:
TEMPERATURE AND ENERGY TRANSFER

You are working with a volunteer group that is renovating old homes. While cleaning up one house your team often discover pieces of old metal that can't be identified. Recalling your physics experience, you decide to set up a system to identify the metals by their *specific heat capacity*. Your plan is to immerse the object in a water bath at a different initial temperature than the metal and to measure the equilibrium temperature. Applying conservation of energy, you can then determine the metal's specific heat. However, you know that some energy will be transferred between the water bath and the environment during the time that the water and metal are coming to equilibrium. Since you cannot measure this energy "loss", you decide to choose an initial water temperature that minimizes it. To test the usefulness of your idea, you try to measure the specific heat capacity of a copper object and compare it to the known value for the specific heat capacity of copper.

EQUIPMENT

For this problem, you have a piece of copper and an insulating container (Styrofoam cup). Tap water, ice, glass beakers, and a hot plate are available so you can start with different initial temperatures of copper and water. Thermometers and a balance are provided.



PREDICTION

Based on your previous experience, make an educated guess about how the amount of energy transferred between the environment and the water-copper system depends on the initial temperature of the **water**. Remember that heat transfer occurs over the time it takes for the copper and water to reach equilibrium.

Sketch a graph that describes your idea of how the energy transfer depends on the initial temperature of the water. Assume that the copper will have the same initial temperature in each trial. Explain your reasoning.

The specific heat of copper is given in a table at the end of this lab.

WARM-UP

Read Serway & Vuille, Chapter 11, Sections 11.2 and 11.3 (or Cutnell & Johnson 12.6 and 12.7)

1. Draw two pictures of the situation, one just before the copper is placed in the water, and the other after the copper has been placed in the water and they have come to equilibrium. Label the temperatures and masses of both the water and the copper in each situation. Define your system as the copper and the water. If energy leaves the system, where does it go?

2. Using conservation of energy, answer these questions about the situation:

What is the change in internal energy of the *copper* from before it is put into the water to after the water and the copper come to equilibrium?

What is the change in internal energy of the *water* from before the copper is put into it to after the copper and water come to equilibrium?

How does the change in internal energy of the system relate to the change in internal energy of the copper and the water?

How does the change in internal energy of the system relate to the amount of energy transferred between the environment and itself?

EXPLORATION

Decide on an initial temperature for the copper that is the same for each trial. What is the reason for your choice? How will you determine the copper's initial temperature?

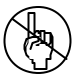
Will you use the same amount of water each time? You can get different water temperatures by using the ice bath and the hot plates. Each time you use a different water temperature, feel the Styrofoam cup. Is it hot or cold? What does this tell you about the energy transfer? (Is the water-copper system losing or gaining energy?) Try putting two cups together, one inside the other. Do you feel less energy transfer? Try putting a cover on the cup. Do you feel less energy transfer? Arrange your system so that there is minimal energy transfer to the environment. How many different temperatures will you use to establish how the transfer of energy depends on the water's initial temperature?

Will the time it takes for the copper and water to come to equilibrium affect the amount of energy transferred to the environment? During the time that you are taking your measurements of the copper-water system, set aside a cup (configured to minimize energy transfer to the environment) of water at the same initial temperature and observe its temperature change. Use several different initial temperatures for the water. Is there a difference in the two systems' temperature change over time?

How would the following actions affect the amount of energy transferred into the environment?
- shaking or stirring the water
- spilling water out of the Styrofoam cup
- slowly transferring the copper from the hot or cold-water bath to the Styrofoam's water

Do you need to take into account the heat capacity of the thermometer? Will you avoid the added complication of the thermometer transferring energy to the water by pre-warming or pre-cooling the thermometer to the water's temperature?

WARNING: The hot plate and the heated water can both burn you!



How can you tell when the copper and the water reach equilibrium? Does the location of the thermometer in the water bath have any effect on the equilibrium temperature?

Plan the procedure that you are going to use. You will use the same procedure when you do the actual analysis of your unknown metals.

MEASUREMENT

Using your experience from the exploration section and your answers to the method questions, take the necessary measurements to determine how the initial temperature of the water affects the energy transferred to the environment while the water and copper come to equilibrium. Do not forget uncertainties.

Be careful when using the hot water!

In addition, determine how the amount of energy transferred to the environment depends on time by observing the temperature of a cup of water set apart from the copper-water system.

ANALYSIS

Use your answers to the method questions to calculate the amount of energy transferred between the system and the environment for each of the different initial temperatures that you used. Is the amount of energy transferred reasonable? Compare it to the change of the internal energy of the water. If the numbers don't seem reasonable, explain why.

Is the amount of energy transferred positive or negative? What is happening between the system and the environment if the energy transfer is positive? Negative?

CONCLUSION

How does the amount of energy transferred depend on the initial temperature of the water? What initial temperature of water minimizes the energy transfer? How precise and reliable is your measurement scheme?

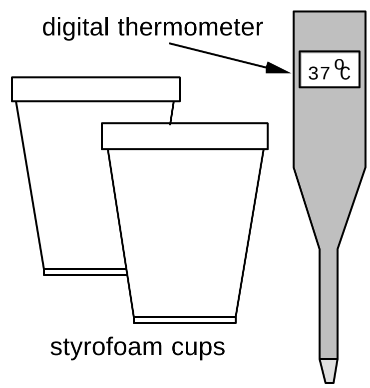
Energy transfer may depend on many variables, are there some you do not take into account?

PROBLEM #2:
TEMPERATURE AND ENERGY TRANSFER II

While working at an antique shop you come across several old door hinges in a back room. Your boss wants to know what type of metal they are, as that will affect how much he can sell them for. Recalling your physics experience, you decide to identify the metal by its *specific heat capacity*. Your plan is to immerse the object in a water bath at a different initial temperature than the metal and to measure the equilibrium temperature. Applying conservation of energy, you can then determine the metal's specific heat. However, you know that some energy will be transferred between the water bath and the environment during the time that the water and metal are coming to equilibrium. Since you cannot measure this energy "loss", you decide to choose an initial water temperature that minimizes it. In the shops work room, you have proper equipment to alter the temperature of the metal, but not the temperature of the water. Thus you decide you will have to use water of a constant temperature and vary the temperature of the metal. To test the efficiency of your idea, you try to measure the specific heat capacity of a copper object and compare it to the known value for the specific heat capacity of copper.

EQUIPMENT

For this problem, you have a piece of copper and an insulating container (Styrofoam cup). Tap water, ice, glass beakers, and a hot plate are available so you can start with different initial temperatures of copper and water. Thermometers and a balance are available.



PREDICTION

Based on your experience, make an educated guess about how the amount of energy transferred between the environment and the water-copper system depends on the initial temperature of the **copper**. Remember that energy transfer occurs over the time the water and copper take to reach equilibrium. Sketch a graph showing the relationship between energy transferred and the initial temperature of the copper. Assume that you will keep the water's initial temperature constant for each trial. Explain your reasoning.

The specific heat of copper is given in a table at the end of this lab.

WARM-UP

Read Serway & Vuille, Chapter 11, Sections 11.2 and 11.3 (or Cutnell & Johnson 12.6 and 12.7)

1. Draw two pictures of the situation, one just before the copper is placed in the water, and the other after the copper has been placed in the water and they have come to equilibrium. Label the temperatures and masses of both the water and the copper in each situation. Define your system as the copper and the water. If energy leaves the system, where does it go?

2. Using conservation of energy, answer these questions about the situation:

What is the change in internal energy of the *copper* from before it is put into the water to after the water and the copper come to equilibrium?

What is the change in internal energy of the *water* from before the copper is put into it to after the copper and water come to equilibrium?

How does the change in internal energy of the system relate to the change in internal energy of the copper and the water?

How does the change in internal energy of the system relate to the amount of energy transferred between the environment and itself?

EXPLORATION

Decide on an initial temperature for the water that will be kept constant for each measurement. Will you use the same amount of water each time?

How will you determine the copper's initial temperature?
You can obtain different copper temperatures by putting it in hot or cold water. Each time you use a different copper temperature, feel the Styrofoam cup. Is it hot or cold? *What does this tell you about the energy transfer?* Is the water-copper system losing or gaining energy? Put two cups together, one inside the other. Do you feel less energy transfer? Try putting a cover on the cup. Do you feel less energy transfer?

How many different temperatures will you use to establish how the amount of energy transferred depends on the copper's initial temperature?

Will the time it takes for the copper and water to come to equilibrium affect the amount of energy transferred? During the time that you are taking your measurements, set aside a cup of water, and observe its temperature. Use several different initial temperatures for the water. Does the temperature of the isolated water change with time?

How would the following actions affect the amount of energy transfer?
- shaking or stirring the water
- spilling some of the water from the Styrofoam cup
- slowly transferring the copper from the hot or cold-water bath to the Styrofoam's water

Do you need to take into account the heat capacity of the thermometer? Will you avoid the added complication of the thermometer transferring energy to the water by pre-warming or pre-cooling the thermometer to the water's temperature?

WARNING: The hot plate and the heated water can both burn you.

How can you tell when the copper and the water reach equilibrium? Does the location of the thermometer in the water bath have an effect on your ability to determine the equilibrium temperature?

Plan the procedure that you are going to use. You will use the same procedure when you analyze your unknown metal.

MEASUREMENT

Using your experience from the exploration section and your answers to the method questions, make the necessary measurements to determine how the initial temperature of the copper affects the energy transferred to the environment while the water and copper come to equilibrium. Do not forget to determine the uncertainties in your measurements.

Be especially careful if you use hot water!

ANALYSIS

Use your answers to the method questions to calculate the amount of energy transferred between the system and the environment for each of the different initial temperatures that you used. Is the amount of energy transferred reasonable? Compare it to the change of the internal energy of the water. If the numbers don't seem reasonable, can you explain why?

Is the amount of energy transferred positive or negative? What is happening between the system and the environment if the energy transfer is positive? Negative?

CONCLUSION

How does the amount of energy transferred depend on the initial temperature of the metal? What initial temperature gave the smallest energy transfer?

Upon what other variables does the energy transfer depend?

What initial temperatures for the water and the metal will you use to test unknown metals? Are your methods precise enough to conclude what type of metal was found at the archeological site?

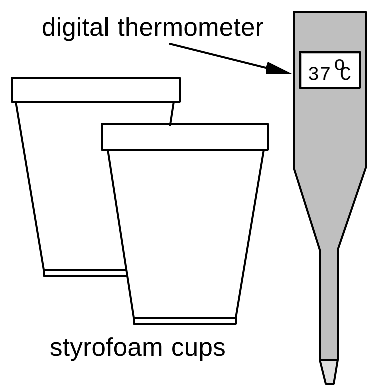
PROBLEM #3:
IDENTIFYING UNKNOWN METALS

You are working with an archeological team that is excavating a lost city. Your team has found metal fragments among the ruins. The types of metals used by a civilization can help determine its level of technology. Unfortunately, the metal fragments are unidentifiable by visual inspection! Recalling your physics experience, you decide to identify the metal by its *specific heat capacity*. Your plan is to immerse the object in a water bath at a different initial temperature than the metal and to measure the equilibrium temperature. Applying conservation of energy, you can then determine the metal's specific heat. Using methods that will minimize the amount of energy lost you can estimate how much error energy "loss" will introduce into your measurement. Thus, you are ready to identify the two unknown metals that your team found by measuring their specific heat capacities!

EQUIPMENT

For this problem, you will have two metal objects and an insulating container (Styrofoam cup Tap water, ice, gals beakers, and a hot plate are available so you can start with different initial temperatures of metal and water. Thermometers are provided and a balance is available to measure the relevant masses.

Note: The two different metals are difficult to differentiate visually. Use their differing densities to distinguish them.



PREDICTION

Calculate the specific heat capacity of a metal object in terms of quantities that are known or can be measured.

WARM-UP

Read Serway & Vuille, Chapter 11, Sections 11.2 and 11.3 (or Cutnell & Johnson 12.6 and 12.7)

1. Make two pictures of the situation, one just before the metal object is placed in the water, and one after the metal object has been placed in the water and they have come to equilibrium. Label the quantities that you will be able to look up (see table on page 25) or measure. Label quantities that designate the energy of each object in the system. Draw and label arrows to represent energy transfers.

2. Using conservation of energy, answer these questions about the situation:

What is the change in internal energy of the *metal object* from (a) just before it is put into the water to (b) after it and the water have reached equilibrium?

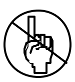
What is the change in internal energy of the *water* from just (a) before the metal object is put into it to (b) after the metal and the water have reached equilibrium?

Assuming there **is** energy transfer into or out of the system, as you measured in Problems 1 and 2, what is the relationship between the metal's internal energy change and the water's internal energy change?

You should now be able to solve for the specific heat capacity of the unknown metal as a function of variables that you can either measure or look up.

EXPLORATION

Review your exploration notes from Problem #1 or #2 of this Lab. Plan the procedure that you will use to determine the specific heat capacity of the unknown metals.



WARNING: The hot plate and the heated water can both burn you.

MEASUREMENT

Choose your technique so that you minimize the energy transfer between your system and the environment.

Using your measurement plan, make the necessary measurements to determine the specific heat capacities of the unknown metals. Make sure that you have a good plan before you start -- you could waste a lot of time with a poor procedure. Do not forget to discuss uncertainties.

Be careful when using the hot water!

ANALYSIS

Use your Prediction equation to calculate the specific heat capacity of each unknown metal taking into account the value of the energy transfer you measured in problem #1 or #2. Include an estimate of the uncertainty of each value.

Use the table on page 25 to identify the unknown metals. What other metals fall within your uncertainty range?

CONCLUSION

What are the two unknown metals? What will you tell your team leader?

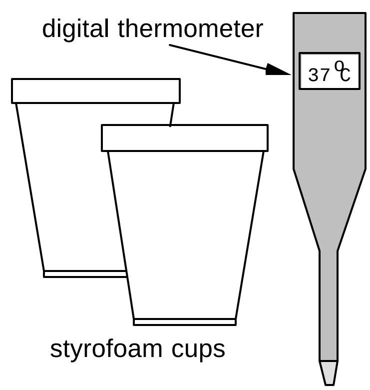
How could you use the table of densities on page 25 to verify that you have identified the metals correctly? Calculate the densities of the unknown metals. Do the densities of the metals agree with the corresponding specific heat capacities?

PROBLEM #4:
THE COMPOSITION OF A COMPOUND OBJECT

You have a summer job working for a metal parts company. You are working on devising an inexpensive quality control measurement for a product that is a mixture of aluminum and copper. Your assignment is to devise a procedure to determine if the product has the correct fraction of aluminum *without* destroying it. You decide to do this by measuring its specific heat.

EQUIPMENT

You will have a compound metal object and an insulating container (Styrofoam cup). Tap water, ice, glass beakers, and a hot plate are available so you can start with different initial temperatures of copper and water. Thermometers are provided and a balance is available to measure masses.



PREDICTION

Use the specific heat of an object to calculate the fraction of its total mass that is aluminum in terms of quantities that are known or can be measured.

WARM-UP

Read Serway & Vuille, Chapter 11, Sections 11.2 and 11.3 (or Cutnell & Johnson 12.6 and 12.7)

1. Draw two pictures of the situation at different times, one just before the metal object is placed in the water, and one after the metal object has been placed in the water and they come to equilibrium. Label the quantities that you will be able to measure or look up (see the table on page 25). Label quantities that designate the energy of each object in the system. Draw and label arrows to represent energy transfers.

2. Using conservation of energy, answer these questions about the situation:

What is the change of internal energy of the metal object? Consider the metal object as being two individual objects, one made of copper and the other of aluminum.

What is the change in internal energy of the water?

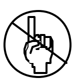
Assuming there is no energy transfer into or out of the metal-water system, what is the relationship between the metal's internal energy change and the water's internal energy change? Is this a valid assumption? How would you change your relationship to account for this energy transfer?

How many unknowns are there in your conservation of energy equation? Are there any other relationships between the mass of the aluminum and the copper that can be used to reduce the number of unknowns?

3. Solve your equations for the fraction of the mass of the metal object that is aluminum in terms of quantities that can be determined in this problem.

EXPLORATION

Review your exploration notes from previous problems of this Lab to plan your measurement procedure.



WARNING: The hot plate and the heated water can both burn you.

MEASUREMENT

Make the necessary measurements consistent with your plan to determine the fraction of aluminum in the metal object. Make sure that your procedure minimizes the energy transfer from your system.

ANALYSIS

Use your prediction to calculate the fraction of the object's mass that is aluminum. Estimate the uncertainty in this measurement.

CONCLUSION

What fraction of the metal object's mass is aluminum? How precise is your measurement?

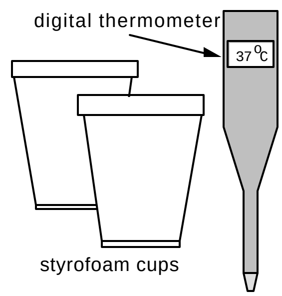
Use the densities found in the Table on page 25 as the basis of another method of determining the fraction of the object's mass that is aluminum.

PROBLEM #5:
LATENT HEAT AND THE MASS OF ICE

One of your friends has an idea for a better coffee brewing-machine, but needs your help. Coffee usually comes out too hot to drink because the ideal brewing temperature is higher than the ideal drinking temperature. This machine would brew the coffee at the high temperature, and then add a little ice so that it is cool enough to drink. Since no one wants the coffee to taste watered-down, the machine would initially brew the coffee with less water to compensate for the melted ice. Your contribution is to determine the amount of ice needed to bring the coffee from brewing temperature to drinking temperature. Before investing the money in building the machine, you decide to test your calculation with some ice and an insulated cup of water.

EQUIPMENT

You will have Styrofoam cups, water and ice. A thermometer is available and a balance is provided.



PREDICTION

Calculate the mass of the ice that completely melts in the water in terms of quantities that can found in a "thermal properties table" at the end of this lab, or that can be measured.

WARM-UP

Read Serway & Vuille, Chapter 11, Section 11.4 (or Cutnell & Johnson 12.8)

1. Draw three pictures of the situation: (a) just before the ice is placed in the water, (b) while the ice is melting, and (c) when the water from the melted ice and the original amount of water in the cup have come to equilibrium. Label the quantities that you will be able to measure. Label quantities that designate the energy of each object in the system. Draw and label arrows to represent energy transfers. Write down the quantities you can find either from the table on page 25 or from your previous measurements.

2. Using conservation of energy, answer these questions about the situation:

What is the change in internal energy of the ***ice*** from (a) just before it is put into the Styrofoam cup to (b) after it is put in the Styrofoam cup but before it begins to melt (even though this happens at different times for different parts of the ice)?

What is the change in internal energy of the ***ice*** from (a) just before it melts to (b) just after it melts?

What is the change in internal energy of the ***water from the melted ice*** from (a) just after the ice has melted to (b) the time the melted-ice water comes to equilibrium with the water originally in the Styrofoam cup?

What is the change in internal energy of the ***water*** from (a) just before the ice is put in the Styrofoam cup to (b) after the ice is put into the cup and the melted-ice water comes to equilibrium with the original water in the Styrofoam cup?

If there was **no** transfer of energy into or out of the Styrofoam cup, what would the relationship be between the ice's total internal energy change and the original water's internal energy change? Is this a valid assumption, that no energy is transferred? What corrections need to be applied for energy transfer out of the system?

3. Solve your equations for the mass of the ice in terms of quantities that you can look up or can measure.

EXPLORATION

This exploration is similar to the other problems of this lab. First decide on the amount of water that you will use in the Styrofoam cup and then choose an initial temperature of the water that will result in the least amount of energy transferred to the environment. Then determine how much ice should be placed in the water so that it doesn't take too long to melt, but it is large enough so that the experiment produces useful results.

Some procedures speed up the melting process, such as gently stirring or shaking the water, but do they transfer a measurable amount of energy to your system? Use a cup of water and a thermometer to check this out.

What do you think is the temperature of the ice? Check it out.

Measuring the mass of the ice before you put it into the water is difficult because some of it can melt during the weighing process. Decide how you can measure the mass of the ice after you have put it into the water. Outline the measurement procedure you plan to use.

MEASUREMENT

Using your experience from the exploration, plan your measurement carefully. Make the necessary measurements consistent with your prediction to calculate the mass of the ice placed in the cup.

Use your plan from your exploration to directly measure the mass of the ice that you added to the water.

ANALYSIS

Use your Prediction equation to calculate the mass of the ice that was put into the water. Be sure to include the uncertainty.

Compare that calculation to the directly measured mass of the ice.

CONCLUSION

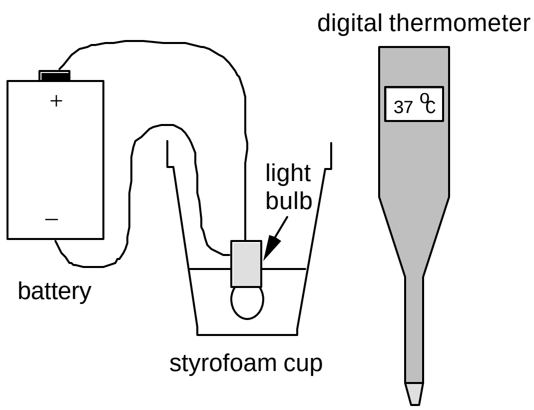
How close was the calculated mass of ice based on the temperature change of the water to your measurement of its mass? Explain any differences. Based on your results, will this machine work? What were some of the uncertainties that your analysis could not address?

PROBLEM #6:
ELECTRICAL ENERGY AND HEAT

You are working on a team to design the lobby for a new office building. The centerpiece of the design is a large tropical fish tank. A decorative submarine at the bottom of the tank is lit by a light bulb immersed in the water. You suspect that the light bulb will cause the water temperature to rise, killing all the fish! If this is true, you will have to install a mechanism to remove energy from the tank at the same rate that the bulb adds energy. To test your theory, you measure the rate that a light bulb transfers energy to the water.

EQUIPMENT

You will have the same equipment as previous problems. In addition, you will have a light bulb that can be submerged in a liquid, and a battery to supply the energy for the light bulb. You will also have a Digital Multimeter to measure the electrical properties of the light bulb and batteries. You will use an alcohol solution for this problem because the temperature of alcohol will change more than water for the same of change in internal energy.



PREDICTION

Calculate the energy transfer from the light bulb to the liquid surrounding the bulb for a predetermined time interval. This will be in terms of the specific heat of the liquid, its mass, and its temperature change. Based on your experience, make an educated guess of the rate that the energy is transferred and sketch a graph of energy transferred as a function of time for your guess.

WARM-UP

Read Serway & Vuille, Chapter 11, Section 11.5 (or Cutnell & Johnson 12.6 and 12.7)

1. Make two pictures of the situation, one before the submerged light bulb is turned on, and one at some time later. Define your system. Label quantities that designate the energy of each object in the system. Draw and label arrows to represent energy transfers. Write down the quantities you can measure or look up.

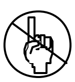
2. Write down the energy conservation equation for this situation, assuming that all the energy from the light bulb is transferred to the internal energy of the liquid.

How is the total energy output from the light bulb during a time interval related to the *rate* of energy transfer (power) from the light bulb? How does this energy output relate to the liquid's change in internal energy, if you assume no energy is transferred between the liquid and the environment? How does the internal energy change of the liquid relate to the liquid's temperature change?

3. Do you think the rate of energy output from the bulb is constant? Increasing with time? Decreasing with time? Sketch a graph of temperature of the liquid as a function of time that represents your guess.

How is the slope of the temperature versus time graph related to the rate of energy transfer (power) from the light bulb to the liquid?

EXPLORATION



WARNING: Denatured alcohol contains a small amount of methanol mixed with the ethanol. Methanol causes blindness and death in very small quantities! **UNDER NO CIRCUMSTANCES SHOULD DENATURED ALCOHOL BE INGESTED!**

Decide how much liquid to use for best results. How can you minimize any energy transfer to the environment that you cannot measure? You may want to review your notes from other problems in this lab so that you do not waste time with a poor measurement plan.

Conduct tests to determine how long your experiment will last. **MAKE SURE YOU DO NOT IMMERSE THE ENTIRE BULB SOCKET!**

Check out how fast the temperature of the liquid changes. How fast does it evaporate? How often do you need to measure the temperature of the liquid? Why?

Outline the measurement procedure you plan to use.

MEASUREMENTS

Using your decisions in the exploration, make the necessary measurements consistent with your prediction that will allow you to determine the power output of the light bulb. Using your experience from other problems in this lab, estimate the energy transfer from your system.

You can check your prediction equation of the power output of the light bulb by determining it in another manner. Looking ahead in your textbook, you will find that the electrical power output of the light bulb is the product of the electrical current and voltage. Use the digital multi-meter (DMM) to measure the electrical current through your light bulb and the voltage across your light bulb.

See *Appendix A* for instructions about how to use the DMM to measure current and voltage. **BE SURE TO CONNECT THE DMM CORRECTLY FOR EACH MEASUREMENT, OR YOU WILL DAMAGE IT!**

ANALYSIS

Graph the temperature of the liquid in the Styrofoam cup-versus-time as you collect the data. What is the value of the slope of this line? What physical quantity does the slope represent? How does this graph compare to your answer to the third method question?

Calculate the electrical power output of the bulb by multiplying the current through the bulb by the voltage across the bulb. Current measured in Amperes (A) times voltage measured in volts (V) gives power in units of J/s.

How do these two values of the power compare? Which of the two results has the greater accuracy for your purpose? Why?

CONCLUSION

What is the rate that energy is transferred from a light bulb to the water in the fish tank? Is the power output of the light bulb constant, rising, or falling? Did your results match your prediction? If not, why not?

Thermal Properties of Pure Metals

Metal	Specific Heat†	Density‡	Latent Heat of Fusion†
	cal / g °C	g / cm^3	cal / g
Aluminum	0.215	2.7	95
Chromium	0.110	7.14	79
Cobalt	0.1	8.71	66
Copper	0.092	8.92	49
Gold	0.031	19.3	15
Iron	0.108	7.86	65
Lead	0.031	11.34	5.5
Magnesium	0.243	1.75	88.0
Manganese	0.114	7.3	64
Mercury	0.033	13.59	2.7
Molybdenum	0.060	10.2	69
Nickel	0.106	8.9	71
Platinum	0.032	21.45	24
Potassium	0.180	.86	14.5
Silicon	0.17	2.33	430
Silver	0.057	10.5	26.5
Sodium	0.293	.97	27
Tin	0.054	5.75	14.1
Titanium	0.125	4.5	100
Zinc	0.093	7.04	27

Thermal Properties of Water and Alcohol

Substance	Specific Heat	Latent Heat of Fusion	Melting Temperature	Latent Heat of Vaporization	Boiling Temperature
	cal / g °C	J / kg	°C	J / kg	°C
Water	1.00	3.35×10^{5}	0.00	2.256×10^{6}	100.00
Ice	0.50	3.35×10^{5}	0.00	N / A	N / A
Alcohol	0.593	10.42×10^{5}	-117.3	0.854×10^{6}	78.5

† From Handbook of Tables for Applied Engineering Science by R. E. Bolz & G. L. Tuve, The Chemical Rubber Co., 1970.

‡ From The Handbook of Chemistry and Physics, R. C. Weast, ed., The Chemical Rubber Co., 1970.

☑ CHECK YOUR UNDERSTANDING

Use the table on page 25 to answer the following questions.

1. Temperature and heat are two different physical quantities. Their difference is confused by the fact that heat transferred into or out of a substance is sometimes proportional to the change in temperature of the substance. This question will attempt to clarify this distinction.

   a. Define what is meant by the temperature of a substance.

   b. Define what is meant by "the heat added" to a substance.

   c. Under what conditions is the heat added to the substance proportional to the change in temperature of the substance?

   d. Under what circumstances can we add heat to a substance, but NOT change its temperature?

   e. Explain why the behavior described in part d proves that heat and temperature are fundamentally different quantities.

2. A block of lead at 100 ^{o}C is put into an equal mass of cold water at 0 ^{o}C in an insulated container. The system is allowed to come to equilibrium.

   a. Which has greater magnitude, the heat energy transferred out of the lead, or the heat energy transferred into the water? Explain your reasoning.

   b. Which undergoes a temperature change of greater magnitude, the lead or the water? Explain your reasoning.

   c. Is the final equilibrium temperature greater than, less than or equal to 50 ^{o}C? Explain.

3. Suppose you heated 1 kg of each of the substances listed below at a constant rate for the same length of time. Rank the order of the substances from the lowest (1) to highest (6) *temperature change*.

____	aluminum	____	iron	____	silver
____	copper	____	lead	____	water

   Explain your reasoning.

4. Suppose you heated 1 kg of each of the substances listed below until they were at their melting temperature, and then continued to heat substance at a constant rate. Rank the order of the substances from the shortest (1) to the longest *time to melt* (6).

____	aluminum	____	iron	____	silver
____	copper	____	lead	____	water

   Explain your reasoning.

5. Suppose 1 kg of each of the substances listed below drops 10 ^{o}C. Rank the order of the substances from the smallest (1) to the highest (6) *amount of heat energy transferred to the surroundings*.

____	aluminum	____	iron	____	silver
____	copper	____	lead	____	water

   Explain your reasoning.

6. When you put water at 25 ^{o}C into an ice tray and freeze it in a refrigerator, is more heat energy transferred in bringing the water to the freezing temperature or during the process of freezing? Or are equal amounts of heat transferred? Explain your reasoning.

7. When you stir the hot coffee in a cup, the energy you input with the spoon
   a. moves the cup back and forth.
   b. cancels out if you stir both back and forth.
   c. cools the coffee by decreasing the kinetic energy of its molecules.
   d. increases the kinetic energy of the molecules of the coffee.
   e. You can't input energy to coffee by stirring it.

   Explain your choice.

8. A cook put two large saucepans of potatoes on a gas stove to boil. When they were both boiling, she turned the gas under one down to low so that the water was just kept boiling. She left the other on high. Which will cook more quickly, the potatoes on high, the potatoes on low, or will they cook at the same rate? Explain your reasoning.

TA Name:______________________________

PHYSICS 1102 LABORATORY REPORT

Laboratory I

Name and ID#: ____

Date performed: ______________ Day/Time section meets: ______________________

Lab Partners' Names: ____

____

____

Problem # and Title: ____

Lab Instructor's Initials: __________

Grading Checklist	Points
LABORATORY JOURNAL:	
PREDICTIONS (individual predictions and warm-up completed in journal before each lab session)	
LAB PROCEDURE (measurement plan recorded in journal, tables and graphs made in journal as data is collected, observations written in journal)	
PROBLEM REPORT:*	
ORGANIZATION (clear and readable; logical progression from problem statement through conclusions; pictures provided where necessary; correct grammar and spelling; section headings provided; physics stated correctly)	
DATA AND DATA TABLES (clear and readable; units and assigned uncertainties clearly stated)	
RESULTS (results clearly indicated; correct, logical, and well-organized calculations with uncertainties indicated; scales, labels and uncertainties on graphs; physics stated correctly)	
CONCLUSIONS (comparison to prediction & theory discussed with physics stated correctly ; possible sources of uncertainties identified; attention called to experimental problems)	
TOTAL(incorrect or missing statement of physics will result in a maximum of 60% of the total points achieved; incorrect grammar or spelling will result in a maximum of 70% of the total points achieved)	
BONUS POINTS FOR TEAMWORK (as specified by course policy)	

* An "R" in the points column means to rewrite that section only and return it to your lab instructor within two days of the return of the report to you.