Physics 5BL Lab 1 Manual: Thermal Energy & Temperature
Fall 2024, UCLA Department of Physics & Astronomy

Directions: As you read through the lab manual, follow along and complete the Google Slides lab assignment submission template to submit your responses to prompts on each slide as indicated. Refer to your pre-lab for theoretical background, including key equations and definitions as needed.

Lab Motivation & Background

At the end of Physics 5A, you learned about various forms of energy, and that energy can take different forms beyond mechanical kinetic energy, gravitational potential energy, or spring potential energy. There are also additional nonconservative forms of energy, like friction, that don't easily convert back to usable kinetic or potential energy. You may have learned that friction was a way for energy to be “lost” to the environment, and that it meant that energy was not conserved in your system’s total energy, with the total energy being defined as kinetic plus potential energy. Now, after mechanics, thermodynamics introduces the concept of thermal energy, which is proportional to the temperature of an object. Just as you verified that your cart on your airtrack had a little friction because kinetic plus potential energy was not perfectly conserved in your system, you could also have said that kinetic energy was converted into thermal energy, and this thermal energy left the system and went out into the environment, which lessened the total energy of the cart system.

Now after your mechanics course, you will learn the vocabulary and specific concepts to be able to show that energy is always conserved, when the system and the environment are accounted for together. Even when system energy is converted into friction, this friction takes the form of thermal, light, sound, or electrical energy. Energy cannot be created or destroyed, as it only transfers between system and environment or between two objects that are in physical contact with one another. For practical purposes it is important to clearly define one of the objects as the system, and quantify heat flow (thermal energy transfer) as either into the system, out of the system, or neither (if the two objects are exactly the same temperature).

In this lab, you will investigate the transfer of thermal energy (heat flow) between system and environment (thermal radiation), or between two systems in contact with each other (thermal conduction). In this lab, we will take the human body to be our system, and the classroom as the environment. This means that there are other objects in the room that may not be at environment temperature, but that are not defined as our system. It is important to remember this perspective when we talk about heat flow in/out of the system, depending upon how we set up the system in relation to the environment or other surrounding objects.

Guiding Scientific Questions

During today’s experiments, you’ll investigate answers to the following questions.

A. How is energy transferred to, from, and within the human body, in relation to its surroundings?

B. How does our body maintain a temperature that is different than the environment?

C. How can we demonstrate that energy is always conserved, using the human body as the system and the environment in the “big picture.” In other words, how can we show that if energy is not being conserved in our system perspective, we can expand our perspective to show that it is being conserved on a larger scale?

Lab Procedure

1. As a first step, **measure** the temperature of the environment (ambient temperature), the human body temperature (both forehead and under the tongue), and two other objects in the room. **Record** this information in both Fahrenheit and Celsius units, and group the items into a category of either being in equilibrium with the environment, or not in equilibrium with the environment. Using the human body as the system, **explain** the direction of heat flow between the body and the environment. **Explain** how you know the direction of this heat flow. *(Use the IR (yellow) thermometer for objects that are not a human's face, the head thermometer for a human's forehead, and the under-tongue thermometer to measure a person's core body temperature. There are single use covers for the under-tongue thermometer.)*

2. As an investigation of scientific question A (see above), use the IR temperature gun to **measure** the temperature of your hands both before and after vigorously rubbing them together (note the frictional resistance to the kinetic energy of the hand motion!). **Compare** the temperature difference (if any) before and after, and relate this to how the temperature change is providing information about how energy is changing form through the use of our body's conversion of food to the chemical energy that fuels the motion of our muscles. Roughly how long does it take for your hands to get back to equilibrium, and what process allows that to occur?

3. As an investigation of scientific question B, **choose** an object that is not the human body, but that also has a consistently higher temperature than the environment temperature. **Describe** how thermal energy should be changing in the object as time goes on (given the direction of heat flow). Given this direction of heat flow, how would you expect the temperature of the object to change with time? How is it able to stay at a hotter temperature than the surroundings, even though heat is constantly flowing? Given that energy is always conserved when one takes a large enough perspective, what is the energy flow process that allows the hot object to stay hot? Now, **relate** this to the temperature measurements taken of the human body, and **create** an explanation for how our human body is able to consistently maintain a hotter temperature than the environment.

4. Use either a human body, electronic devices, and/or light bulbs to take two (2) 'FLIR' images. Capture a copy of these with your phone (don't need to upload any photos from the 'FLIR' camera), and add these photos to your assignment for analysis. **Describe** the heat flow information provided by this picture, including information about the flow of thermal energy. **Explain** how the total energy in time is constant, and **describe** how the energy is changing form as the heat flows. Identify the hottest and coolest objects in each of your images. Feel free to **draw** and upload an additional diagram to supplement your explanations, if the IR camera is available at the end of your lab.

You can read more about how thermal imaging works here.