On-line activities for the first law of thermodynamics labs

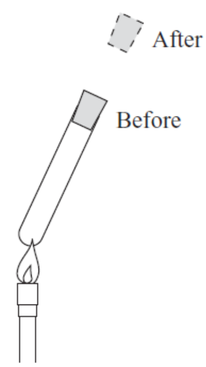
Below is the list of experiments (real, video based and data-based) that students can perform as labs for the first law of thermodynamics. For each experiment we provide goals, equipment and rubrics for self-assessment. Rubrics can be found at https://sites.google.com/site/scientificabilities/rubrics

1. Observational experiments: energy conversions

Goals: Explain a series of experiments using the knowledge of energy
Equipment: none
Rubrics for self-assessment: Ability to conduct an observational experiment B5 and B9.

1a Watch the video [https://youtu.be/u3Y4npFvlO4] Answer the following questions:

a. Construct a microscopic explanation for how the hot gas pushes out the stopper. Remember what you learned about molecules of gas, their motion, and the pressure that they exert.



b. Choose the gas inside the test tube, the stopper, and Earth (not the flame) as the system, and use the concepts of work and energy to explain the experiment. If you need a new physical quantity or quantities for your explanation, define them qualitatively.

c. Draw an energy bar chart to explain the experiment using this new physical quantity. The system is the gas and the cork. The initial state is before we started warming up the gas and the final state is when the cork is flying out.

1b Watch the video of a cup of cold water in an aluminum container being placed in a container with warm water [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-2-2]. The video is taken with a thermal camera and allows you to see the change of temperature of the water.

a. Describe what you observe (choose the initial state to be when the cup is outside the container and the final state when cup is inside and the temperature reaches some intermediate value).

b. Consider the water in the cup as the system and explain this observed process using your knowledge of molecules and their motion. Then use the generalized work–energy principle to explain what happened to the cold water. If you cannot explain this process with this principle, try to modify the principle (for example, introduce a new physical quantity) to account for your observations.

c. Repeat part **b.**, only this time consider the water in the container as the system.

d. Use your knowledge of molecules and their motion to explain the reasoning behind when two liquids of different temperatures mix together, the mixture will eventually reach some intermediate temperature (called the *equilibrium temperature*).

1c Watch the video of a cup of glycerin being stirred by a mixer used to whip cream [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-3-1]. The video is taken with a thermal camera and allows you to follow the temperature of the glycerin at the spot marked by cross hairs.
a. Describe what you observe.

b. Draw a bar chart to represent the process. Indicate any assumptions that you made.

2. Observational experiments: patterns in warming up

Goals: Find mathematical patterns in a series of experiments

Equipment: none

Rubrics for self-assessment: Ability to conduct an observational experiment B7 and B8.

1a You have a small electric heater and water in a calorimeter (an insulated container). The amount of energy provided to the system and the change in water temperature are shown below.

t (s)	ΔU (J)	ΔT (°C) $= T_f - T_i$
0	0	0.0
10	1000	2.4
20	2000	4.8
30	3000	7.2
40	4000	9.6
50	5000	12.0
60	6000	14.4

a. Graph the data in the table to decide whether there is a relationship between the amount of energy provided to the system (the water) and its temperature change ΔT. Think about which physical quantity is the independent variable and which physical quantity is the dependent variable.

b. Write the mathematical relationship.

1b In a second set of experiments, recorded in the table below, the same amount of energy (4000 J) is provided to identical insulated water containers, which contain different masses of water.

***m* (kg)**	**ΔT(°C)**
0.10	9.6
0.20	4.8
0.30	3.2
0.40	2.4

a. Graph the data and decide whether there is a mathematical relationship between the change in temperature and the mass of water (the system) when the amount of energy provided is the same.

b. Write the mathematical relationship.

1c. In a third set of experiments the same amount of energy (4000 J) is provided to four identical-mass (1 kg) systems with different substances. What can you conclude based on the data in the table below? Can we say that the density of the liquid determines how much its temperature changes when a certain amount of energy is provided? If not, then what property of liquids will determine the change in its temperature given a certain amount of energy is provided?

Substance	**ΔT(°C)**
Freshwater	0.95
Seawater	1.03

Alcohol	1.65
Mercury	28.47

3. Application experiment: water heater rating

Goal: determine the power rating of the water heater experimentally

Equipment: immersion heater, thermometer, container for water, measuring cup.

Rubrics for self-assessment: Ability to design and conduct an application experiment D1, D2, D4, D7, D8, and D9.

Examine the water heater and note its stated power rating. Design and conduct an experiment to check whether the manufacturer provided an accurate rating.

a. Brainstorm experiments that you can carry out and then describe an experiment that you agree to perform to test the power rating.

b. Draw a picture of the experimental set-up. Include physical quantities that you will measure and calculations you will make.

c. Complete the calculations to predict the outcome of the experiment.

d. List assumptions and how each will affect the result. List experimental uncertainties and how they will affect the result.

e. Perform the experiment; record the outcome of the experiment, and decide whether the manufacturer's rating is reasonable.

If you do not have an immersion water heater, use the following data for your analysis:

1 liter of water is boiled from 15 C to 100 C in 388s.

The label on the heater states: 990-1100W.

4. Application experiment: mechanical work and internal energy change

Goal: Analyze data collected in an experiment;

Equipment: none

Rubrics for self-assessment: Ability to conduct an application experiment D7, D8 and D9; Ability to collect and analyze experimental data G1 and G2.

Watch the video of a cup of glycerin being stirred by a mixer used to whip cream [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-5-7]. The video is taken with a thermal camera and allows you to follow the temperature of the glycerin at the location of the cross hairs.

a. Use the data provided in the video to estimate how much energy provided by the mixer went into warming up the glycerin.

b. Could this experiment be used to test the equivalence of work and heating as a means for energy transfer? Justify your answer.

5. Application experiment: power of the heater

Goal: solve a practical problem and evaluate assumptions

Equipment: none

Rubrics for self-assessment: Ability to conduct an application experiment D7, D8 and D9.

Watch the video of a 0.3-kg ice-water mixture being put on a constant power stove [https://youtu.be/hLcYCzMgSzc]. The video shows thermal images recorded at consecutive time intervals. Thermal images allow us to determine the surface temperature of the objects. In the video, the temperature is measured at the spot on the metal pot (marked with a cross) and displayed in degrees Celsius.

a. Explain the graph shown at the end of the video.

b. Use the graph and other data to estimate the power of the heater. Indicate any assumptions that you made.

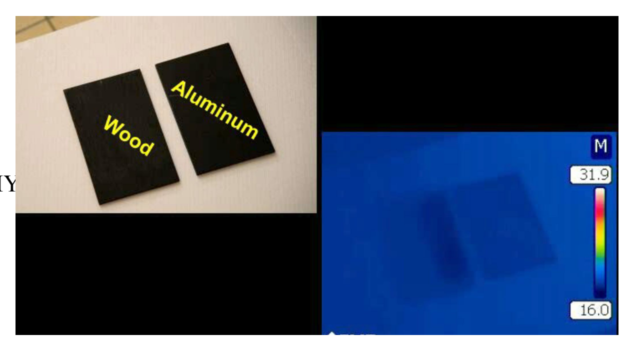
6. Observational experiment: Aluminum vs wood

Goal: to interpret thermal images to explain an observed phenomenon

Equipment: none

Rubrics for self-assessment: Ability to conduct an observational experiment B5 and B9.

Observe the video of an experiment taken with a regular camera and a thermal camera



[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-2]. In the experiment, two identical metal objects (made of brass) are taken from the same hot water bath and placed on two identically-shaped (same height, length, and width) plates. The plates are made of wood and aluminum (colored with the same black paint to reduce the reflective properties of aluminum) and have been sitting on the table for a long time.

a. Describe what you observe.

b. Devise one or more explanations for your observation.

8. Testing experiment: Aluminum vs wood

Goal: To test an explanation

Equipment: none

Rubrics for self-assessment: Ability to conduct a testing experiment C1, C4, C5, C7, and C8.

You use the same plates as in Experiment 1, but this time you place an ice cube on each one.

a. Use the explanations you made in Experiment 7 to predict what you will observe.

b. View the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-3] and compare the outcome to your predictions. Do you need to revise your explanation?

9. Observational experiment: how different materials dry

Goal: To explain why wet papers cool down when drying.

Equipment: none

Rubrics for self-assessment: Ability to conduct an observational experiment B5 and B9.

Observe the video of an experiment taken with a thermal camera [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-4]. In the experiment, you have two identical pieces of paper, one wet with water (on the right) and the other wet with acetone (on the left).

a. Describe what you observe. Make sure you watch the video until the end.

b. Explain your observation. Make sure you use your knowledge from the first section of Chapter 12.

10. Observational experiment: melting an ice cube

Goal: To explain why the location of the heating source matters.

Equipment: none

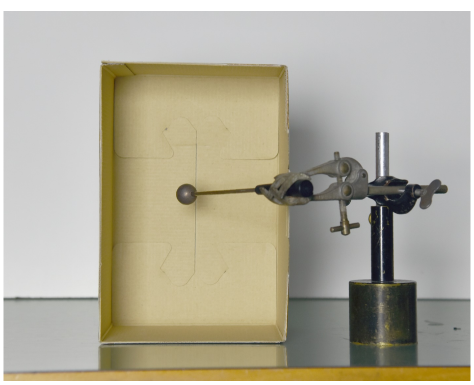
Rubrics for self-assessment: Ability to conduct an observational experiment B5 and B9.

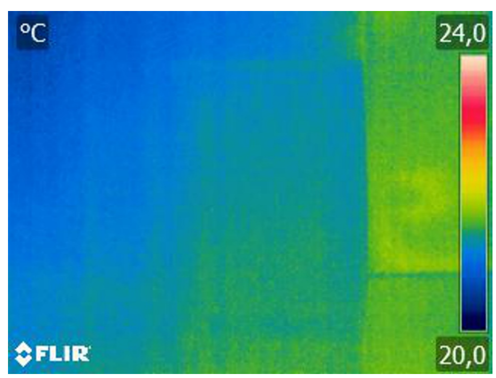
a. Observe the video of the experiment [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-5] and describe what you observe.

b. Explain why the position of the ice cube affects whether or not it melts.

11. Application experiment: hot and cold objects in a box

The figures below show the experimental setup (figure on the left) and the thermal image of the same setup (figure on the right). The setup consists of a cardboard box and a metal sphere on a stand. The thermal image shows the surface temperature of the objects. The temperatures in the thermal images in this activity are represented with colors in the interval from 20 °C (dark blue) to 34 °C (white).





The experimenter performed the following two experiments:

Experiment 1: She heated the metal sphere so that it reached a temperature of 80 ° C, placed the sphere as shown above, waited for about 30 s and took the thermal image.

Experiment 2: She cooled the metal sphere so that it reached the temperature of -5 ° C, placed the sphere as shown above, waited for about 30 s and took the thermal image.

a. Below are the two thermal images. Which was obtained in Experiment 1 and which was obtained in Experiment 2? Explain how you know. Describe and explain any other details that you notice about the images.