Physics Lab 13: Keeping it Cool[1]

> A coffee drinker is faced with the following dilemma. She is not going to drink her hot coffee with cream for ten minutes, but she wants it to still be as hot as possible. Is it better to immediately add the cold cream, stir the coffee, and let it sit for ten minutes, or is it better to let the coffee sit for ten minutes and *then* add and stir in the cream? Which results in a higher temperature after ten minutes?

A container of hot water placed in a room of lower temperature will eventually cool to the same temperature as the room. You observe this cooling process every time you wait for a hot drink to cool. In today's investigation you will examine the cooling of hot water, with the goal of creating a model that describes the process. Related Reading & Problems: Precalculus Ch. 4.6 – Newton's Law of Cooling, Example 7, Try it Now 4; Week 9 Problem Set #29.

Most of the data collection involved in this investigation occurs automatically and leaves you with uninterrupted stretches of time that are 20 minutes long. While the data is being collected, you should complete any parts of Physics Lab 12: Pendulum Periods that you did not complete in that session (note there is a slightly improved version of the set-up at the demonstration station for you to follow-up for setting up at your table). If your group completes all of Physics Lab 12 and still has time available, put your heads together to work on any remaining questions from the Week 8 Problem Set that any of your group members is still struggling with (a number of you indicated in their Reflection that you continue to have some difficulty with this material, so here is a chance to continue to work on it). If your group is satisfied with their progress with the Week 8 Problem Set, put your heads together to seminar on this week's precalculus reading.

Note: For Tuesday's Math Lab 9, bring your Math Lab notes and Physics Lab notes from previous labs this quarter (hopefully neatly arranged in lab notebooks). Also make sure you have access to the associated LoggerPro files.

Getting Started

a) Work in groups of 3; each group will have its own lab table. Gather your equipment: a temperature probe, a 50 mL beaker, a 150 mL beaker, and a 600 mL beaker. **PLEASE USE CARE WHEN HANDLING GLASS BEAKERS.** Your instructor will let you know about the source of hot water and cold water; you won't need those for a while.
b) Plug the temperature probe into Channel 1 of a LabQuest. Note that this is an analog sensor, not a digital sensor, so do not try to plug it into DIG/SONIC 1 or 2.
c) Practice placing the temperature probe in the empty 600 mL beaker and also in the 50 mL beaker placed inside the 600 mL beaker; your goal is to have the temperature probe stably placed in each so that they won't fall over (especially not with water in them!).
d) Launch LoggerPro, which should automatically detect the sensor, displaying a temperature meter and a temperature vs. time graph. If the temperature probe is not automatically detected, check with an instructor.
e) Right click on the graph, and select Graph Options. Under the Graph Options tab, select Point Symbols and unselect Connect Points, and click Done. Right click on the graph, and choose Column Options. Under the Options tab, choose Display every 1 points (using the drop down menu).
f) You will use 2 different data collection settings:
   i) Setting A: When you are collecting data to determine the temperature of the environment, adjust the data collection settings so that the duration is 1 minute and the sampling rate is 10 samples/minute.
   ii) Setting B: When you are collecting data for the cooling rate of water, adjust the data collection settings so that the duration is 20 minutes and the sampling rate is 2 samples/minute.

---

[1] modified from Experiment 33: Newton's Law of Cooling, from Vernier *Physics with Computers*.

Investigation 1: Hot Water in Room Temperature Environment

a) Use Setting A. Place the temperature probe in the empty 600 mL beaker. Collect data. If the readings are steadily increasing or steadily decreasing, collect data again and repeat until the temperature is fairly stable. Save the stable temperature data run as Environment 1.
b) Use Setting B. Use the hot water source indicated by your instructor. Move quickly but safely. Obtain approximately 25 mL of hot water in the 50 mL beaker. Place the 50 mL beaker in the 600 mL beaker. Place the temperature probe in the 50 mL beaker. After approximately 15 seconds, start collecting data. Data should be collected automatically for 20 minutes.
c) On the other side of the lab table, begin to set up for Period Pendulums. Carry out as much as you can, but…
d) Watch the clock. After 20 minutes, if your data is good, save the run as Cooling 1.

Investigation 2: More Hot Water in Room Temperature Environment

a) In Investigation 1, you used 25 mL of hot water. In your group, briefly (no more than 5 minutes) discuss what you think might happen to the cooling curve if you used 50 mL of hot water (discuss before trying!). Use Cooling 1 for comparison in your discussion. Will the cooling curve for 50 mL of hot water be more steep, less steep, or roughly the same as for 25 mL of hot water?
b) Repeat using the same procedure as in Investigation 1, but this time with approximately 50 mL of hot water in the 50 mL beaker. Save the runs as Environment 2, Cooling 2.
c) While the cooling curve is collecting, continue to work on Pendulum Periods or with the Week 8 Problem Set or with seminaring on this week's reading.

Investigation 3: Hot Water in Cold Temperature Environment

a) In the previous investigations, you had hot water cool in a room temperature environment. In your group, briefly discuss what you think might happen to the cooling curve if you used 25 mL of hot water in a beaker that was surrounded by cold water (discuss before trying, and read the protocol below before trying as well!). Will the cooling curve for 25 mL of hot water placed in cold water be more steep, less steep, or roughly the same as for 25 mL of hot water cooling in room temperature?
b) You will need to do some preliminary work before trying this out. The most important thing to discover is how much cold water to place in the 600 mL beaker that will surround the 50 mL beaker but not cause the 50 mL beaker to fall over when the 50 mL beaker with hot water is placed into the 600 mL beaker. Use the cold water source indicated by your instructor.
c) Repeat using the same procedure as in Investigation 1, but this time with cold water in the 600 mL beaker. Save the runs as Environment 3, Cooling 3. Each group member will need to have access to all of this data for Tuesday's Math Lab, so save it in an appropriately named folder in the program Workspace.
d) This time, while the cooling curve is collecting, read ahead about Investigation Alpha and Omega.

Investigation α and Ω: Coffee Drinker's Dilemma

a) Re-read the coffee drinker's dilemma.
b) Based on your observations of the various cooling curves from Investigations 1 – 3, discuss in your group which of the two options (adding and stirring in cold cream right away and waiting for ten minutes or waiting ten minutes and then adding and stirring in cold cream) will result in the hottest coffee after 10 minutes.
c) In your group, use your experiences with the available equipment to design investigations that will help you to resolve this dilemma. Carefully record your experimental protocol.
d) Carry out your investigations. While you are collecting data (and if you can tear yourself away from watching the computer screen update once every 30 seconds…), continue with Pendulum Periods or with the Week 8 Problem Set or with seminaring on this week's reading.
e) Record your results, and report your conclusions, supported by evidence and reasoning.

Continue with Pendulum Periods as needed, or on Week 8 Problems, or seminar on this week's reading… When time is up, clean up your station. Return equipment to original location, except for beakers which should be placed in the dish drainers by the sinks.