

TECHNICAL PUBLICATION 41.

NEWTON'S LAW OF COOLING

PART 1. AN EXPERIMENT.

Suppose you are served hot coffee in a restaurant. You wish to drink the coffee about 15 minutes after it is brought from the coffee pot. You like to add cream to your coffee, but you still want the coffee to be as hot as possible after those fifteen minutes. Therefore, should you add the cream when the waitress brings the coffee or after about 12 minutes?

Newton's law of cooling, which states that the rate at which a substance cools off depends on the instantaneous temperature difference between the substance and the surroundings, and an infrared camera can help you find the solution!

Let's do an experiment!

1. Measure 150 ml of water with instant coffee into a 250 ml beaker and heat it on a hot plate until the temperature reaches 80°C (176°F) degrees.
2. Put 40 ml of milk in a 150 ml beaker.
3. When the coffee has reached 80°C (176°F) degrees, carefully remove it from the hot plate using a paper towel as a pot holder.
4. The temperature of the water may continue to increase a few degrees after it is removed from the heat. When the temperature returns to 80°C (176°F) degrees start taking the temperature.

Case A - Add the milk early

5. At the two minute mark, add the milk and continue taking the temperatures.
6. Record the temperatures in a chart and keep taking temperatures until the time reaches 15 minutes.
7. Make a graph of temperature versus time.

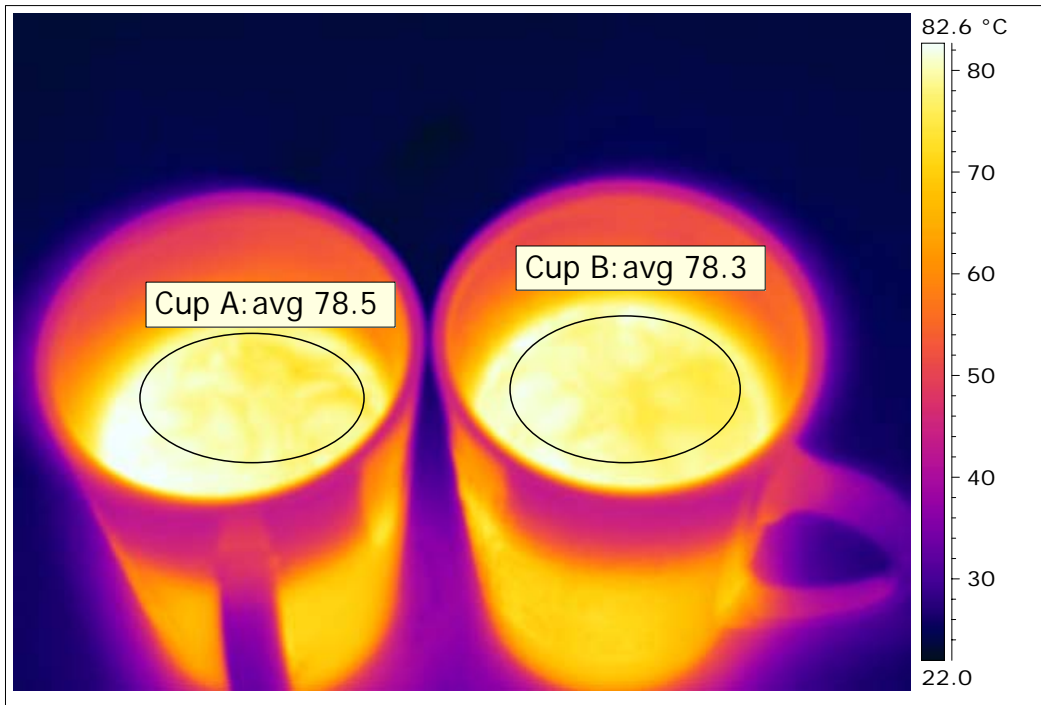
Case B - Add the milk later

5. At the 12 minute mark, add the milk and continue taking the temperature.
6. Record the temperatures in a chart and keep taking temperatures until the time had reached 15 minutes. Make both graphs on the same kind of paper with the same numbers on the axes so that they can easily be compared.
7. Make a graph of temperature versus time

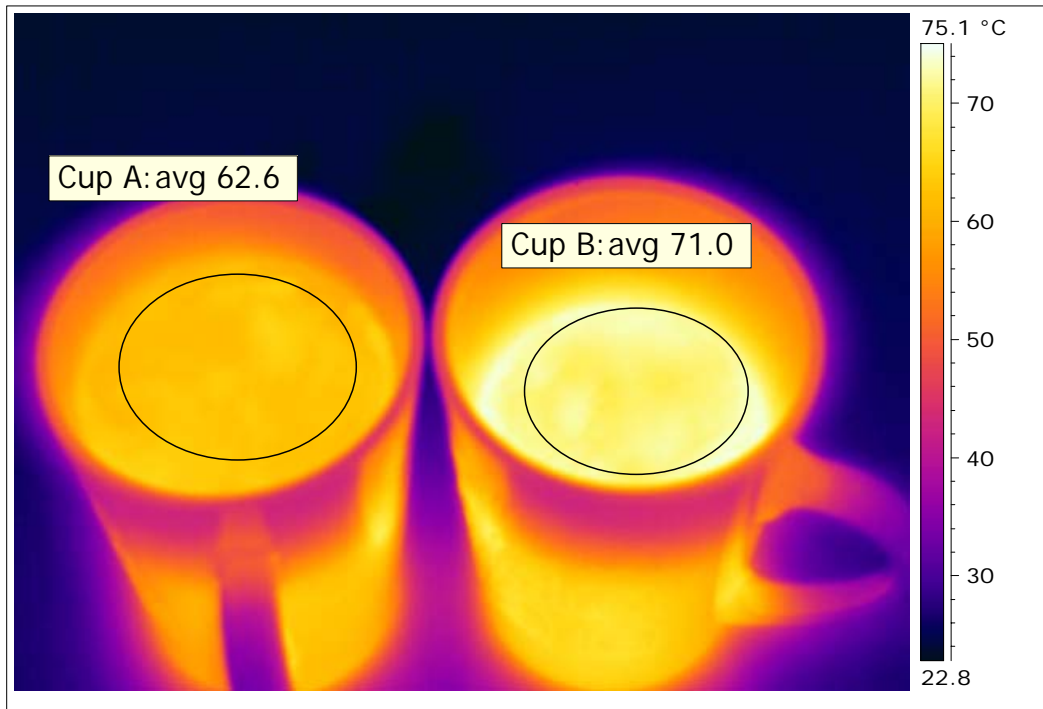
Our materials: 2 cups, instant coffee, and milk.



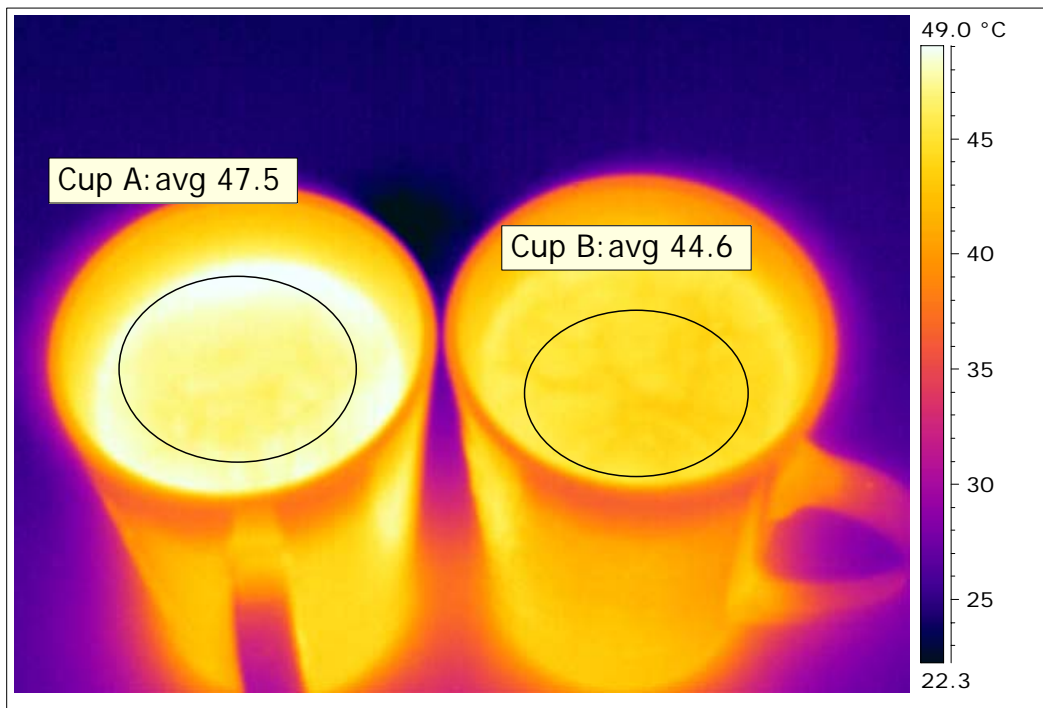
Below is the thermogram grabbed at the beginning of the experiment. Temperature is close to 80°C (176°F) in both cups, not exactly the same but the difference is acceptable.



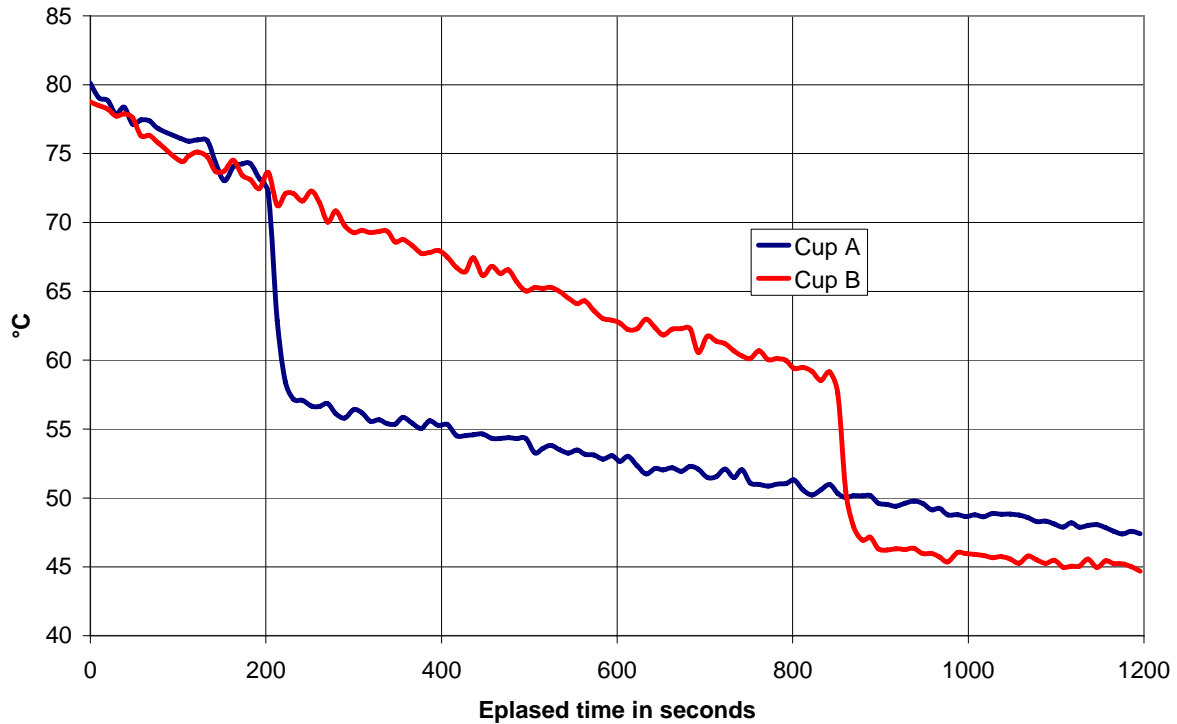
As soon as milk is added to cup A, temperature drops down. Here, we note a difference of 8.4°C (difference of 15.1 °F), cup A is cooler than cup B.



Such a difference remains positive (Temp B > Temp A) until milk is added to cup B. From this instant, cooling rate is much more important for cup B. Cup B therefore cools down more rapidly than cup A. Difference is more than 4°C (difference of more than 7.2°F) after 15 minutes, and still 3 °C (difference of 5.1°F) after 20 minutes!



Full temperature vs. time plot is as follows.



Conclusion: add the cream immediately to enjoy you coffee as hot as possible after 15 minutes!

Initial idea for the experiment is from Knight Foundation Summer Institute, Elizabeth Chesick, Haverford College. Thermography, as a temperature measurement method, was added later.