

## Newton's Law of Cooling

**Newton's law of cooling states that the rate of heat flow by conduction is proportional to the difference in temperature. When the difference is large, the rate of heat flow is fast, and when the difference is small, heat flows more slowly. The solution for the temperature mathematically is an exponential decay.**

1. We will measure the temperature using the computer for a small beaker of boiling water as it loses heat to a well-stirred ice bath that should be at 0°C
2. The software will gather a data point every second for about 20 minutes, and we will use the analyze feature to gather data points.
3. Our hypothesis is that the temperature drops off in an exponential curve given by:

$$T = T_0 e^{-kt}$$

Where

T = Temperature at a time in Celsius

T<sub>0</sub> = the initial temperature (°C)

k = is some constant (s<sup>-1</sup>)

t = elapsed time (s)

If the surrounding temperature is 0°C, and the drop off is immediate.

Your goal is to find k, and show how well this equation does or doesn't work

4. Make a graph of your temperatures, and draw a nice curved line through the points.
5. To find what k has to be, look at the real data by using the examine feature in the data acquisition program. You will need the original temperature T<sub>0</sub>, and then six points of data (T and t), and math skills. Show these calculations. With your six data points, you should calculate k six different times.
6. Answer these questions:
  - A. Why does the temperature drop off as it does? (i.e. why is it an exponential decay or nearly so?) Explain the shape of the curve. (Why is it steep at the beginning, and more gradual near the end? – use Newton's Law of Cooling at the top of this page to explain)
  - B. What effect would insulating the beaker have on the graph, (i.e. would the temperature drop more quickly, or more slowly) and how would this affect the value of k? (Would k be bigger or smaller?)
  - C. You like your coffee hot, but you like cream in it. The phone rings just as you finish pouring yourself a cup of coffee. You know you will be on the phone for five minutes. It would be gauche to pour the coffee back into the thermos, so the question is this: Should you a) take the cream from the refrigerator and pour it into the coffee now before taking the call (The cream is cold.) or b) wait until you have finished the call and then take the cream out of the refrigerator and add it to your coffee to have the hottest cup of coffee to drink. Base your selection of one of these two options on Newton's law of cooling and give examples. Think about the time that you are on the phone, and what the temperature is of the coffee in both scenarios.
  - D. Evaluate the lab. (Discuss the validity of the model, sources of error and ways to mitigate the errors)