# Determining the Speed of Light with a Chocolate Bar

Mark Lattery and Greta Voit
*University of Wisconsin Oshkosh*
October 30, 2006

---

At a recent meeting of undergraduate physics students at the University of Wisconsin Oshkosh, we made a chocolaty mess! We also determined the speed of light (*c*) to within 5% of its accepted value ($3.0 \times 10^8$ m/s)! Here is how you and your students can do the same.

First, purchase a box of chocolate bars. (We used Nestle® Crunch® bars.) Next, place one unwrapped chocolate bar on a paper plate, and set the plate in the microwave. If your microwave has a built-in rotating plate, it is important to remove it. For this experiment, the chocolate bar must be on a stationary plate. Position the paper plate such that the shorts sides of the bar are parallel to the sides of the microwave. Set the microwave to five minutes and turn the microwave on. At the strong smell of burning chocolate, remove the bar.

When we performed this experiment, we discovered two black burn marks on the chocolate bar about 6 cm apart (Figure 1a). This result was reproduced many times. We then rotated the chocolate bar several degrees to the left (Figure 1b) and repeated the experiment. Again, the burn marks were about 6 cm apart. Repeated experiments reveal that the burn marks (or partially melted areas) form *strips* parallel to the sides of the microwave.

To understand the burn marks, it is helpful to view the microwave as a resonating cavity of electromagnetic waves. In Figure 1c, we model this wave as a simple standing wave. The red and blue lines represent one possible standing mode of microwave radiation. To satisfy boundary conditions, an integral number of half-wavelengths must fit between the microwave walls. Hence, the nodes of wave are at the walls of microwave, and at several (evenly spaced) points in between. The energy content of a standing wave is greatest at the antinodes. Evidently, this is where the black marks develop on the chocolate bar. The distance between black marks is equal to half the wavelength of the standing wave. If the frequency of the radiation is known, then the speed of light, c, can be easily determined using the formula: $c=\lambda f$.

Experimental results are given in Table 1 (below). For Trials 1 and 2, the short ends of the bar were parallel to the interior walls of the microwave, and for Trial 3 the chocolate bar was placed at an angle relative to the sides of the microwave.

*Table 1.* Chocolate bar measurements.

| *Trial* | *½λ (cm)* | *Bar Placement* |
|---|---|---|
| 1 | 5.9 | Sides parallel to microwave walls |
| 2 | 5.8 | Sides parallel to microwave walls |
| 3 | 5.8 | Sides at an angle to the microwave walls |

Based on these measurements, the *full* wavelength of the microwave radiation is about 11.7 cm. The frequency of a typical microwave oven is 2.45 GHz.[1] Therefore, the estimated speed of light is $2.87 \times 10^8$ m/s (a deviation from the accepted value of 4%.)[2]

To reproduce this result, you may want to disable nearby fire alarms. This experiment can also be performed with chocolate chips, cheese bars, and marshmallows.[3] More rigorous studies can be performed with thermograms and CoCl-soaked paper towels.[4-5]

**References**


1. *The World Book Encyclopedia of Science: Physics Today.* World Book, 95 (1989).

2. Strictly speaking, this experiment measures the wavelength of light ($\lambda$) and then *calculates* the speed of light ($c$). The frequency of radiation ($f$) can be determined independently with an antenna and frequency counter.

3. R.H. Stauffer, *Phys. Teach.* 35, 231 (1997).

4. A. Steyn-Ross and A. Riddell, *Phys. Teach*. 28, 474 (1990).

5. J. Viiri, *Phys. Teach*. 36, 48 (1998).

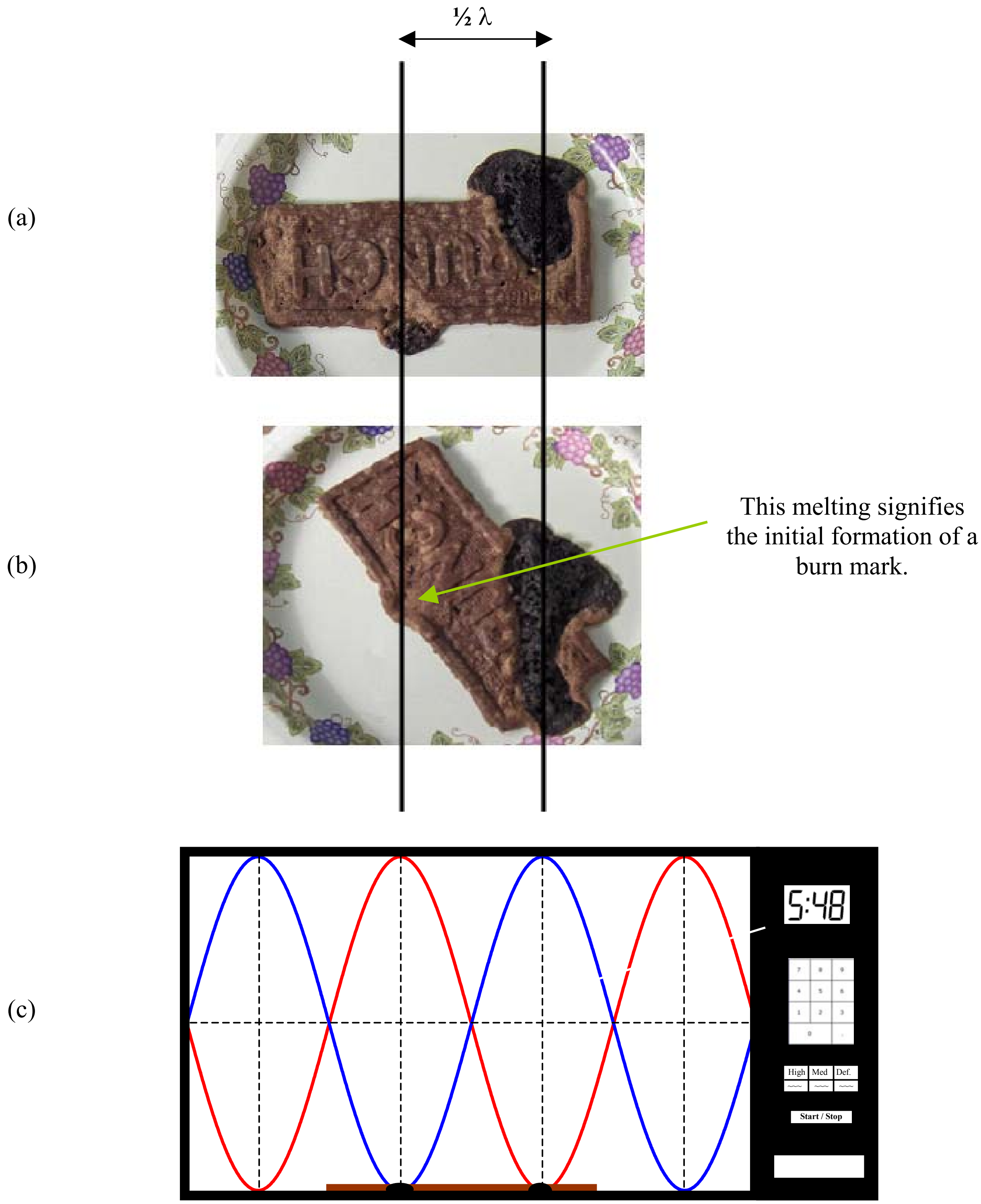


*Figure 1.* Burn marks in the chocolate bar develop due to the non-uniform heating of the microwave. (a) Burn marks after the bar is heated with the short sides of the bar *parallel* to the sides of the microwave. (b) Burn marks after the bar is heated at an angle to the sides of the microwave. (c) Standing waves in a microwave. The red and blue lines represent one possible mode of vibration. To satisfy boundary conditions, an integral number of half-wavelengths must fit between the microwave walls. (The microwave is not drawn to scale.)