POTATO CHIP PHYSICS
A Warped Approach to Sound

Start this activity by giving each student a couple of **rippled** Pringles potato chips (or some equivalent brand with the same shape). These chips have the virtue of being very uniform, and usually most of them remain unbroken in the can. Next, point out that the contour across the saddle of a Pringle (perpendicular to the ripples) is essentially the fundamental mode of vibration of a wave, i.e., one-half wavelength. (Put two Pringles together, one after the other -- with the first oriented as a crest and the second as a trough -- and you get a whole wavelength.) **While keeping a straight face**, tell the students that the overall contour of the Pringle is obtained by dropping a potato slice into hot oil, and sending a sound wave through the oil. This forms the fundamental contour of the chip! Just before the chip hardens all the way, the tone is shifted to a much higher frequency, producing the ripples! Some students will likely scoff at this, and others won't quite know what to believe. But my experience with my high school physics classes was that if I played it straight enough and just kept on talking and plowing ahead, most students would actually begin to accept this! For about two out of three classes I could usually pull it off, but some classes did absolutely refuse to swallow it. They might note that one side of the Pringle is flat; I responded that the side tilted away from the sound source doesn't ripple; etc. In fact the more things you can think of to say, the better.* But even if the hoax part fails, finishing the activity is still worthwhile in helping students to visualize wave behavior, and they still enjoy it.

To further legitimize the story and keep things going you can show them a printout or an actual live search result for speeds of sound in various materials, including oil. By discussing variations in speed with different temperatures, and lamenting the fact that the value from the search is probably a little different than the value for the actual cooking oil used in the Pringle process, you can further legitimize your patter. Using this value (approximately 1500 m/s) and the wavelength (twice the distance across the saddle of the Pringle, since the fundamental is one-half of the wavelength), you can then have students calculate the frequency of the sound in oil, using the equation $f = v/\lambda$. Using the wavelength of the ripples, they can also calculate the frequency necessary to produce the ripples.

If desired, the wavelengths of these frequencies in air can also be calculated, using the known speed of sound in air. The frequencies can then be compared to the response of the human ear, and the size of the wavelengths in air can be visualized.

Finally, if you have succeeded in keeping your kids on the hook, you can admit that this is just a bunch of baloney; or, you can let students go away without tipping things off, and see what kinds of reactions they get from parents at the dinner table that night. I once had a student whose father worked for the Potato Board of America (or something like that), and he quickly dispelled her belief that Pringles were made this way. She ended up phoning an authority in Ohio recommended by her father to check it out! It actually makes a great lesson in credibility and authority; you will likely find your students questioning you more often, and less willing to swallow whatever you dish out without thinking about it. This is an activity that some students will remember for a long time!

*****One year, right in the middle of the Pringles patter, I happened to notice a newspaper article that I had posted in my room about potential damage to whales and other marine life from an experiment, designed by scientists from the Scripps Institute of Oceanography, which would monitor ocean temperatures through the use of sound waves beamed into the ocean from underwater speakers. All this was actually true, but on the spur of the moment I worked it right into the Pringles tale with a radically untrue extension. I read part of the article to the students, but then told them that it was feared that the whales would be bent into a curve by very low frequency waves, whose wavelengths might approximate those of the whales! Just like the Pringles! Even something as bizarre as this carries a glimmer of plausibility, and can act as reinforcement for the Pringles tale, if you can keep a straight face while doing it! At the end of the year, two of my students gave me a card showing a dolphin jumpint out of the warter with its body in an arc. The card said: "Dear Mr. Rathjen, We suppose that this dolphin swam through those waves -- the ones that shape the Pringles?!?"

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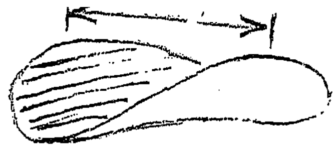
Don Rathjen.....Exploratorium Teacher Institute.....Pier 15, San Francisco, CA…..drathjen@exploratorium.edu

POTATO CHIP PHYSICS
Frequency and Wavelength of Sound for Pringles

1. Measure the length of the Pringle across its "saddle," perpendicular to the ripples. Measure to nearest 0.1 cm. Then convert to meters.



__________ cm

__________ m

2. The measurement made in the preceding step corresponds to the length of the fundamental mode of vibration, which is one-half wavelength. (This is also called the first harmonic.) Double this value to obtain a whole wavelength.

__________ m

3. Look up the speed of sound for cooking oil (or some comparable oil, if you can't find exactly what you're looking for).

v = __________ m/s

4. Calculate the frequency of sound in oil which corresponds to the Pringles wavelength, using the relationship $f = v/\lambda$.

$$f = \frac{v}{\lambda} = \frac{\_\_\_\_\_\_\_\_\_\_ \text{ m/s}}{\text{m/cycle}} = \_\_\_\_\_\_\_\_\_\_ \text{ cycles/s} = \_\_\_\_\_\_\_\_\_\_ \text{Hz}$$

5. Count the number of ripples in one-half wavelength of the Pringle. Multiply this value by 2 to obtain the number of ripples in a whole Pringle wavelength.

__________ ripples

6. Multiply the Pringle frequency in step 4 by the number of ripples to get the frequency used to produce the ripples.

__________ Hz

7. Compare the frequencies for the Pringle and the ripple to the response of the human ear. Would you be able to hear these sounds?

8. Within a given medium, the speed of sound remains constant, and the frequency and wavelength vary inversely, e.g. the ripple wavelength was smaller than the Pringle wavelength, so the ripple frequency was greater than the Pringle frequency. All of this was taking place in oil, so the speed of sound was constant.

As sound passes from one medium to another, however, the frequency remains constant. Therefore if the speed increases in the second medium, the wavelength also increases. This is shown in the following relationships:

$$f_{air} = \frac{v_{air}}{\lambda_{air}} \qquad f_{oil} = \frac{v_{oil}}{\lambda_{oil}} \qquad f_{air} = f_{oil} \qquad \frac{v_{air}}{\lambda_{air}} = \frac{v_{oil}}{\lambda_{oil}} \quad \text{or} \quad \frac{v_{air}}{v_{oil}} = \frac{\lambda_{air}}{\lambda_{oil}}$$

a. An approximate value for the speed of sound in air is 340 m/s. Would the wavelengths of the Pringle and ripple sound waves in air be longer or shorter than in oil?

b. Calculate the wavelengths of the Pringle and ripple sound waves in air.

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