Relative Error and the Speed of Sound

A scientist is asked "Suppose you had a scale that could weigh anything accurately up to one hundredth of a ounce. Would that be accurate enough?"
"It depends," the scientist replies, "on whether my job is to weigh elephants or mosquitoes."

This scientist understands that not all error is the same. The scale's one hundredth of an ounce is an example of *absolute error*. This amount of absolute error might not be important (weighing elephants) or it might completely ruin the measurement (weighing mosquitoes). The notion of comparing the amount of absolute error to the measurement being made leads to the idea of *relative error*.

$$\text{Relative Error} = \frac{\text{absolute error}}{\text{measured amount}}$$

In this activity, you will use the HP StreamSmart 400 to measure the spee d of sound. You will see that there may be ways to set up a measurement to reduce relative error even if the absolute error of measurement stays the same. Just keep in mind that there is error in every measurement, no matter how carefully it is made.

Sound travels pretty fast, but we can get a good measurement of the speed of sound with the StreamSmart 400. We will do this by using two microphones – one close to the source of sound and one farther away from the source of sound. If we know the distance between the microphones and the time it takes for the sound to go from one microphone to the other, we can calculate the speed of sound.

Connect the microphones to the HP StreamSmart 400 and place them as close to 1 meter apart as you can. Make sure that your sound source and the two microphones all form a straight line with the source at one end. Connect the HP StreamSmart 400 to the HP 39gs.

Turn on the HP 39gs, press the APLET key and choose the **StreamSmart** aplet. The system will immediately begin taking d ata so be quiet! Make a sudden, brief sound by striking the tuning fork, or playing a note on the piano (or other musical instrument). Press the STOP menu key on the HP39gs.

First, you need to find the time when the sound first reaches each of the two microphones. Press the menu key labeled either PAN or ZOOM (the labels changes) until the key reads PAN with a little square after it. Now press the left arrow key until you see both microphones begin to react to the sound.

We also need to see more detail; we want to stretch out the time scale (zoom in horizontally) to the maximum amount. To do this, press the PAN/ZOOM menu key again until the key reads ZOOM with a little square after it. Hold down the right arrow key until the **Win:** value at the top of the screen stops changing. The time interval displayed

is now as short as possible. You can also zoom or pan vertically (depending on the status of the ZOOM/PAN menu key) by pressin g the up or down arrows. Notice that vertical zooming and panning works on each data stream independently.

This shows a plot with the data panned and zoomed nicely.
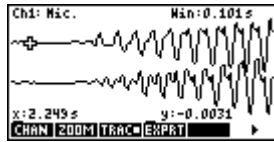
Now press the TRACE menu key. Notice that pr essing the up or down arrow switches the cursor from one data channel to the other.

Exercises
1) In the figure above, which graph (the top one or the bottom one) represents the microphone that was farther away from the source of sound? Your own data might be reversed depending on how you plugged in your microphones.

On your own data, make sure you are tracing on the plot representing the closer microphone, then press the left or right arrow keys to move the cursor to the first crest (mountain peak) caused by the sound. You know you are at the crest when the y-value is the bigger than its neighbors on either side.
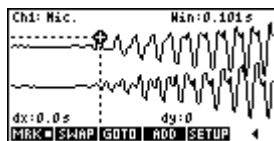
2) Write down the x-value of the first crest on the first plot. What does this number represent? Call this number T1.
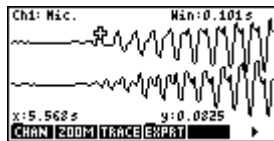

Press the down arrow key and then trace to the first crest on the other plot. Again, once you are near the first crest look for the y-value that is bigger than its neighbors.

3) Write down the x-value of the first crest on the second plot. What does this number represent? Call this number T2.

4) How do we find the time it takes the sound to go from one microphone to the other?

5) Use the formula $d = rt$, which can be rewritten $r = \dfrac{d}{t}$, to find the speed of sound in meters per second. Show your work.

Another way to measure the difference between the times in the plots is to use the mark feature. First, trace to the first crest on the plot representing the microphone closer to the source. Now press the menu key furthest to the right to bring up a second set of menu options. One of those options is MRK which stands for mark. Press the MRK menu key and you may see something like this:


Now press the up or down arrow key to switch to the other plot and trace to the first crest on the plot representing the microphone farther from the source. The difference in time is given by the value of **dx** on the screen.
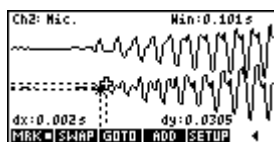
Your *dx* value may be slightly different from your T2 – T1 because of the way the calculator rounds.

6) If *dx* is different from T2 – T1, recompute the speed of sound using *dx*. Show your work!

Now redo the experiment, but this time place the microph ones 2 meters apart. Here is a series of plots from a sample experiment.
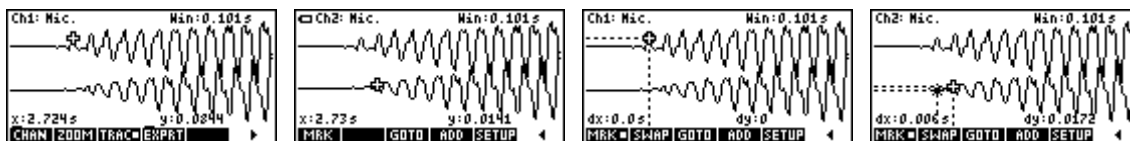
7) What speed of sound did you measure with the microphones 2 meters apart? Do both calculations if *dx* is different from T2 – T1. Show your work.

8) Which experiment (with microphone distance 1 meter apart or 2 meters apart) should have the smaller relative err or? Explain your reasoning.