How can we use sound to "see" inside ourselves?

Exploration

A common clinical situation concerns a woman in early pregnancy. She needs to have an accurate dating of the pregnancy so as to estimate reliably the birth date and to help assess proper growth during the pregnancy. Several length measurements can be made on the fetus to help determine its gestational age, including the crown-rump length, the bi-parietal diameter (ear to ear distance), and the femur length.

GE 1.

1. Imagine every possible way you can of making these length measurements on the fetus. Describe or list the ways below.

2. Obviously, mom, dad, and baby would prefer the least invasive means possible. Are any of the measurement methods you listed preferable over others? Describe why you think so.

3. You have probably had a physical at the doctor's office. One examination method used in a routine physical is "percussing". The doctor listens to the echoes to identify different density regions in the body. If you don't mind you can give it a try here. (If you do mind that's okay, continue reading to question 4.) Stand up. Place two fingers of one hand on the side of your abdomen, preferably where there is a cavity. Tap these fingers with two fingers from your other hand. (Physicians use one finger from each hand, but they are better at this procedure than most of us). Move your fingers to a higher position that is more filled. Is there a difference in what you hear?

4. An easier exercise is to do what some doctors do to practice percussing. Go to the wall and find a stud (a vertical support in the wall) by tapping as described above. Did you find the stud? What was different about the sound? Why do you think so?

Physicians can gain significant information from small changes in the percussive sounds from different body regions, but this method is too qualitative to measure lengths in a fetus. Can we still use sound as a fairly non-invasive technique for making such measurements?

Invention

Activity Guide
© 2010 The Humanized Physics Project
Supported in part by NSF-CCLI Program under grants DUE #00-88712 and DUE #00-88780
You probably know the answer is yes. Ultrasound (high frequency sound) has been an important diagnostic tool in obstetrics and other areas of medicine since the 1940's. How do we get position data from sound? It is as simple as listening for echoes.

You might recall from your study of sound, that the speed of a sound wave depends on the medium. As long as the medium does not change, the sound speed is a constant.

**GE 2.**

1. You are standing in front of a high building. You clap your hands once and listen for the echo. With a stopwatch you can time the interval between clap and echo. How can you use this information to find the distance to the building? Do you need any other data? If so, what?

**Application**

Obtain the video clip echo.mov. It shows an enterprising physics student standing in a parking lot near two buildings and a car. Take a quick look at the video. Notice that the second frame shows the geometry of the situation. The camcorder is very close to the physics student. The frame rate of the camcorder was 30 fps. The window at the bottom of the video shows the microphone output of the camcorder. While the multiple echoes may be difficult to hear in the video (they are high pitched clicks), you can identify them by the spikes in the microphone output.

Your challenge now is to find the distance to the Communications Building and to the cars near the physics student.

**GE 3.**

1. Identify the most likely echo from the Perry Campus Center. Measure the time between sound production and this echo.

2. What is the distance traveled by this sound pulse in this time?

3. Calculate the speed of sound in the air of this parking lot?

4. Identify the likely echoes to the Communications Building and the cars. Measure the time between sound production and recording of each echo.
5. Calculate the distance from the physics student to the Communications Building using your answer to question 3. Show your calculation!

6. What is the distance from the physics student to the cars? Again, show your calculation.

7. What evidence did you use to decide which echo corresponded with each object above? How was that evidence useful?

8. Using only the information on the second frame of the video, estimate the distances to the Communications Building and the cars. Be as precise as reasonably possible. Hint: The schematic is an accurate scale drawing! Explain how you made your estimates.

9. Compare your distance measurements using the sound recorded by the camcorder (questions 5 and 6) to the measurements you made in question 8. How well do they agree? Discuss the accuracy of the two methods.

10. Based on this activity, can sound be used to measure distances? How might the accuracy be improved?

11. You might have used an ultrasonic motion detector in your studies of motion. Knowing that a computer can measure time very accurately, what property of sound does the computer need to determine distances with such a detector?