Experiments with Sound

Damian Smith, 2008
Group Size: <30
Age: High School – although younger students could make use of <fixme>
Equipment needed:

Per group of 6 students: one bucket, one A4 sheet of paper, some sand/grit.

Two hose pipes (one short, one long) (optional)

Several stop-watches. Two pieces of wood (optional). String/tape measure or something similar to measure the distances. Some means of recording results.

A buzzer and battery, tennis ball and string.

Note: The Zambian high-school syllabus does not seem to mention the Doppler effect, but does expect familiarity with the idea that sound is a wave.

Initial Discussion (3 minutes):

Ask the students what they know about sound. Try to draw out words like speed, wave, frequency, wavelength, pitch, volume, amplitude. Ask the students for definitions of these words – watch out for rehearsed answers – try to get an alternative explanation to ensure the meaning is understood.

In this module, we are going to “see sound”, measure its speed, and understand the Doppler effect.

Sound as a vibration (5 minutes).

Equipment: Per group of 6 students: one bucket, one A4 sheet of paper, some sand/grit.

Two hosepipes (one short, one long) (optional)

How do we know that sound is a vibration? We can do an experiment to see this.
Give each group of students a bucket and a piece of paper.
One person should hold the bucket (open end up).
Ask someone else to sprinkle some grit on the paper, and hold it above the bucket (not touching the plastic).
Another student may tap the bottom of the bucket like a drum.
Ask the students what they saw – help them to explain that the air is vibrating the paper, which causes the grit to bounce.
If available, try blowing the hosepipe bugle (make a raspberry noise down it) next to the grit (be careful not to point the end at the grit – it should be clear that the vibrating air, not flowing air, causes the movement.

Speed of Sound (10 minutes)

Equipment: Several stop-watches. Two pieces of wood. String/tape measure or something similar to measure the distances. Something to record results on.

Does sound travel instantly? How do we know? How fast does it go?
We will now measure the speed of sound!
Students stand a measured distance from a building that has a large, flat unobstructed outside wall. The distance can be measured using a roll along device used in athletics to lay out football fields. If one of these is unavailable, a measuring tape can be extended to a fixed length and shifted repeatedly to find the distance.. The group of students stands together, and one of them is nominated to clap. Shortly after the clap, an echo is heard as the sound travels to the wall and is reflected back

toward the students. If the distance to the wall is sufficiently large, the student doing the clapping can try to synchronize her clapping with the echoes so that she is clapping at a regular frequency. The period between each clap is the time for the sound to make a round trip between the clapping hands and the wall. Another student measures the time for, say, eleven claps.
The speed of sound is then calculated by dividing twice the distance to the wall by 1/10th the time for the ten claps.
If it is too difficult to synchronize the clapping with the echos, try to find the right rhythm such that the echo is heard exactly between two claps. The speed would then be calculated by dividing 4 times the distance to the wall by 1/10th the time for ten claps.
If no wall, it may be possible to stand one student a good distance from the rest, and measure the time between seeing the blocks meet, and hearing the clap. This will require multiple measurements to get anywhere close.
(Expected value is 343 m/s at 20 deg C, 0% humidity. C prop to sqrt T. C prop 1/sqrt density.)
Alternative is to use Kundt's Tube – a transparent tube dusted with talc inside. Requires a plunger to be moved in one end, and a tuning fork held at the other (known frequency). Adjust the plunger until volume increases, and clear node/antinodes are visible. The separation will give half the wavelength. I have not tried this – and need to think about what to use for a tube. Maybe a water bottle, or more than one (taped together/slipped inside one another.)
Recap the formula $c=f\lambda$ if doing Kundt's Tube.

Doppler Effect (10 minutes)

Equipment: A constant-pitch buzzer and battery. A tennis ball. Some plastic rulers and a hard edge. String, Clothes Pegs

First, demonstrate the Doppler effect in case anyone is unfamiliar with it. To do this, swing a tennis ball with the buzzer inside it attached to the string. (A Tennis ball can be attached by piercing a small hole and pushing the string through with a pen/screwdriver, and then cutting a slot on the other side so that pliers can be used to pull the string through. Tie a big knot.)
What do the students understand about why the pitch changes?
Relate pitch to frequency – Use rulers of different lengths and ping them to get different notes. It can be seen that the frequency rises with pitch.
Recap the formula $c=f\lambda$
Explain that we are going o perform a play:
Have a student (Simon) representing a sound source, and one representing the wave front (Wayne). Introduce them both to the group.
Wayne has a long piece of string tied around his middle. The string is loosely held by Simon. With the other students clapping a slow pace, Wayne takes one step on each clap. (I.e. he is moving at a constant velocity – this is the speed of sound.) On every other clap, Simon marks the string using clothes pegs. This can be made easier by threading the string through a pen-barrel and attaching several clothes pegs to the pen barrel.
The marks are being made at a fixed frequency. Once Wayne has gone 30 paces, the experiment is stopped and the students are invited to note the separation of the marks. (If a board is present, hold the string to the board and draw a wave such that the peaks match the positions of the pegs.)
Then the experiment starts again, but this time, Simon moves in the direction of the wave front, at half the speed of sound. I.e. one step every two claps. He produces the same "tone" by continuing to mark the string on every other clap (probably the one where he doesn't move.). At the end of this part of the experiment, the marks will be closer together. (Use the board again to highlight this)
Think: This means that in the first example, anyone standing along Wayne's path would see a mark come past every two claps. Now, with the source (Simon) moving towards them, the marks will come past closer together.
Think: What happens at speed of sound? (I.e. when Simon follows Wayne at the same speed.)
Think: What happens when Simon moves away from Wayne?

What use is this?

Link to astronomy – light – hubble
also – gas temperatures – given by spectral broadening.
Speed cameras.
Must be considered for radio communications – e.g. cell-phone in a moving car, TV signal through a satellite.

Credits to:

http://www.west.net/~science/sound.htm

http://homepage.eircom.net/~kogrange/sound_experiments2.html#hydrophone

http://en.wikipedia.org/wiki/Doppler_effect