The Doppler Effect with Sound – Teacher Notes

1. A common way to introduce the concepts of wavelength and frequency visually is with a slinky With different "energies" students can create waves, comparing frequencies, wavelengths and amplitudes.

2. Another suggestion is to have students listen to different frequencies from audio sources, electronics, or musical instruments and compare what they *hear* to the frequency they *measure* with Phyphox (using the Audio autocorrelation function), to understand the relationship between pitch (what they hear) and frequency (what they measure).

3. Making sense of the Doppler effect is predicated on students prior understanding of the nature of waves, wavelength and frequency. The video that accompanies the lesson uses a slinky to demonstrate the inverse proportionality between wavelength and frequency, relative to the motion between source and observer.

   Depending on the grade level, it may be appropriate to distinguish the difference between electromagnetic (transverse) waves and compression or longitudinal (sound) waves. With sound, changes in wavelength are synonymous with changes in pitch (frequency). With light, changes in wavelength are synonymous with changes in color.

4. If you want to try to use a keyboard or musical instrument as an audio source for the experiment, students (or you) will have to determine the base frequency using the Audio autocorrelation function. Keep in mind that the microphone of the phone on which you are running the Phyphox app is optimized for voice, in the range of 300 Hz – 5000 Hz. However, the best results will be obtained with frequencies close to 1000 Hz, since this is range at which Phyphox seems to work most effectively.

5. If you want to do this experiment in the classroom, lab groups obviously could not do the experiment at the same time, since it is essential that the surroundings be quiet, except for the audio source. One option would be to have a single loud speaker at one point in the room, sounding a chosen base frequency, with all students simultaneously collecting data.

   Another option would be to introduce the concepts, demonstrate using the Phyphox app, and have students do their data collection at home. They can then report back and compare results with the rest of the class on their approach and findings.

6. Students often confuse changes in pitch with the speed of the wave. It is important to emphasize that the speed of the wave does not change relative to the motion of either the source or observer. If the student remains stationary and only moves the phone, the pitch they hear does not change. The moving phone intercepts the waves more or less frequently, depending on the direction of motion, causing the change in pitch recorded.

7. Frequency range and time step – The Phyphox Doppler effect app will autofill the values for the frequency range, time step, and speed of sound in air (340 m/s). The **frequency range** gives the parameters of frequency for the algorithm to include as data. If the frequency range is smaller than the largest frequency change (drift) from the source, some of the result may be cut off; larger values will be more difficult to resolve, especially on some phones. **Time step** refers to the sampling time resolution, serving to effectively average the data collected. Learn more about these parameters here; https://phyphox.org/wiki/index.php/Experiment:_Doppler_Effect

You will need to optimize the frequency range and time step for your own situation, specifically the base frequency you use, and most importantly, how fast you plan to have students move their phone. **Faster is not better**. In fact, the app tends to work best with slower velocities. For linear motion, 1 m /s works well; for circular motion, 1 revolution every 2-3 seconds.

We have had good success with a frequency range of 10-15 Hz, and time step of 50ms. **Keep the frequency range significantly smaller than the reciprocal of the time step**. Try this yourself, of course, before you have students do it, so that you are familiar with the possible outcomes.

8. An everyday example of the Doppler effect is the radar detector used by law enforcement to detect how fast a vehicle is traveling. GPS tracking algorithms and locating devices are other examples. Of course in astronomy, the Doppler effect is the standard for determining distances and relative velocities between Earth and luminous objects around the cosmos.

If you have questions about this, or any of the other instructional materials from Saturday Morning Astrophysics at Purdue, please contact Dr. David Sederberg at dsederbe@purdue.edu.