ExploreLearning

Name: ______________________________

Exploration Guide: Doppler Shift

Have you ever heard a train whistle suddenly change pitch as the train rushes by? The same effect can be heard when cars zoom by on the highway, or when a fire truck with sirens blaring passes you. This change in pitch is known as the Doppler shift, first described in 1842 by the Austrian physicist Christian Doppler. Later, experiments confirmed that the Doppler shift applies to light waves as well as sound waves.

Because the magnitude of the Doppler shift depends on the velocity of the source, the Doppler shift can be used to measure the velocity of objects. Police officers and baseball scouts use a Doppler "radar gun" to measure the speeds of cars and fastballs, and astronomers use the Doppler effect to study the motions of distant stars and galaxies.
Observing the Doppler Effect

In this activity, you will observe how the Doppler effect is created. In the simulation, a car or plane emits sound waves at steady intervals as it passes by an observer.

PROCEDURE:

1. Click the Play sample button. (Make sure the speakers of your computer are connected and turned on.) The recording is a siren that passes by an observer. What do you notice about the pitch of the sound as the sample plays? The change in pitch is called the Doppler shift. The Doppler shift only refers to the changes in pitch. The changes in volume you hear are due to the fact that the ambulance is approaching at first and then moving farther away.

2. The Gizmo™ shows an overhead view of a car and observer. Check that the speed of the car (v_{source}) is 100 m/s, and the speed of sound (v_{sound}) is 340 m/s, which is the speed of sound in normal atmospheric conditions. Click **Play**, and then **Pause** when the car is about halfway across the screen.

   a. How is the pattern of sound waves in front of the car different from the pattern of sound waves behind the car?

   b. Click on and drag the ruler tool from the bottom of the Gizmo onto the simulation. What is the distance between sound waves in front of the car? What is the distance between sound waves behind the car?

   c. Based on what you see, why are sound waves compressed a bit in front of the moving car, and expanded behind the car?

3. The frequency of a sound is the number of sound waves per second, measured in Hertz (Hz). The greater the frequency, the higher the pitch that you hear. Place the ruler back into its original position, and click **Reset**. Click **Play**, and then **Pause** when the first sound wave hits the observer. (The observer will flash red.)

   a. The Time is displayed in the upper left corner. Make a note of this time on your page.

b. Click **Play**, and then hit **Pause** when the next sound wave hits the observer. Note the time now. How much elapsed time was there between waves?

c. In this simulation, each red ring represents 1,000 sound waves. To calculate the frequency, divide 1,000 by the elapsed time between waves. What was the frequency of the perceived sound as the car moves towards the observer?

d. Compare the value you calculated to the frequency of the sound emitted from the source, shown next to the f_{source}(Hz) slider. Is the observed sound frequency higher or lower than the source frequency?

e. How would this altered frequency affect the pitch of the sound?

4. Click **Play**, wait for the car to pass the observer, and then click **Pause** when the next sound wave hits the observer. Note the time. Click **Play** again, and note the time when the next sound wave hits the observer.

a. How much time elapsed between waves behind the moving car?

b. As before, the frequency of the perceived sound is 1,000 divided by the elapsed time. What is the frequency perceived by an observer behind the car?

c. How does this compare to the frequency of the source? How does it compare to the sound frequency perceived by an observer in front of the car?

d. How much did the observed frequency change as the car passed by at 100 m/s? This change in frequency is called the Doppler shift.

e. Based on what you have observed, how will the pitch of the sound change as the car passes the observer? Does this match your own experience? Explain.

5. Increase v_{source} to 250 m/s. The sound source is now a jet. Click **Play**.

   a. How does this affect the spacing of sound waves in front of and behind the jet?

   b. Click **Reset**, select the Observed frequency checkbox, and click **Play**. Note the frequency observed from in front of and behind the jet. Is the amount of Doppler shift greater than or less than the Doppler shift for the 100 m/s car?

   c. How much of a Doppler shift would you expect when the vehicle is moving very slowly? Use the Gizmo to test your prediction.

6. Some jets can fly faster than the speed of sound. Click **Reset**, set v_{source} to 400 m/s, and click **Play**.

   a. What do you notice about the sound waves? Because the jet is moving faster than its own sound waves, the sound waves are left behind!

   b. Select Display additional waves. Notice that a cone of sound waves is formed, spreading out behind the plane. The edge of the cone consists of many sound waves, piled together in the same place. When the edge of the cone hits an observer, the result is a very loud, thunderous sound, called a sonic boom. The sonic boom generated by supersonic aircraft can be powerful enough to rattle doors and break windows.

   c. Click **Reset**, **Play**, and then **Pause** when the sonic boom has hit the observer (and the observer first hears the jet). Relative to the observer, where is the jet at this time? If you were a fighter pilot in the jet, how might this be an advantage?

7. To summarize what you have learned, answer the following questions.

   a. What causes the Doppler effect?

   b. How can the Doppler effect be used to measure the speed of a sound source?