Gizmos

Name: _____ Date: _____

Student Exploration: Doppler Shift

Vocabulary: Doppler shift, frequency, pitch, sonic boom, sound waves, wavelength

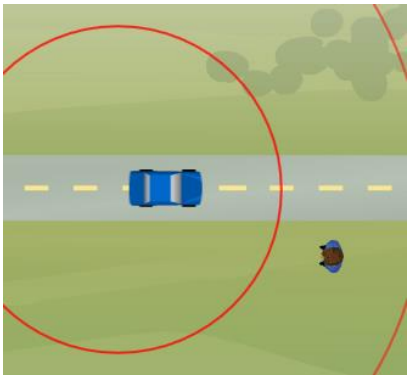
Prior Knowledge Questions (Do these BEFORE using the Gizmo.)
Have you ever heard a siren on a moving ambulance, fire truck, or police car? If so, what happens to the sound as the vehicle passes by?

_____

_____

The change in the sound that you hear is called the **Doppler shift**.

Gizmo Warm-up
The *Doppler Shift* Gizmo illustrates why the Doppler shift occurs. The Gizmo shows a vehicle that emits **sound waves** and an observer who will hear the sounds.



1. Click the **PLAY SAMPLE** button ( ). (Check that the Gizmo's sound and your computer's speakers are on.)

   What do you hear? _____

   _____

2. Click **Play** ( ) and observe the sound waves emitted from the moving car. Click **Pause** ( ) and compare the sound waves in front of and behind the car. What do you notice?

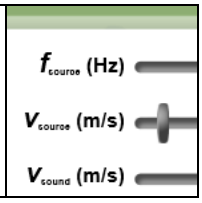
   _____

3. Use the **Ruler** to measure the **wavelength**, or the distance between the lines, of the waves in front of and behind the car. (Note: The red circles represent every thousandth wave.)

   Wavelength in front of car: _____ Wavelength behind car: _____

4. Why do you think the waves in front of the car have a shorter wavelength than the waves behind the car? _____

   _____

Activity A: **The Doppler shift**	Get the Gizmo ready: • Click **Reset** ( ). • Check that f_{source} is set to 500 Hz and v_{sound} is set to 340 m/s, close to the actual speed of sound. • Set v_{source} to 0 m/s.	

Introduction: The **pitch** of a sound, or how shrill or deep it is, is related to the **frequency** of the sound waves. The greater the number of sound waves passing by a point each second is, the higher the frequency and the pitch will be. The unit of frequency is the *hertz* (Hz).

Question: What causes the Doppler shift?

1. Observe: With the car's velocity (v_{source}) set to 0 m/s, click **Play**. Notice the sound waves moving away from the car in all directions.

   A. Increase the frequency of the sound waves by moving the f_{source} slider to the right.

   How does this affect the spacing of the waves? _____

   When the wavelength of the waves is short, the sound will be high in pitch.

   B. Now decrease the frequency by moving the f_{source} slider all the way to the left.

   How does this affect the spacing of the waves? _____

   Sound waves that are spaced far apart will produce a lower, deeper pitch.

2. Measure: Click **Reset**. Set the frequency (f_{source}) to 1000 Hz. Change the velocity of the sound source (v_{source}) to 200 m/s. (The car is now an airplane.) At upper right, turn on the **Observed frequency (Hz)** checkbox.

   Drag the observer onto the road. Click **Play**, and then click **Pause** when the sound waves first reach the observer.

   A. What is the frequency of sound waves in front of the plane? _____

   B. Click **Play**, and then click **Pause** just after the plane has passed the observer. What is the frequency of sound waves behind the plane? _____

3. Summarize: Based on what you have learned, how will the sound that the observer hears change as the airplane passes by? Explain your answer.

   _____

   _____

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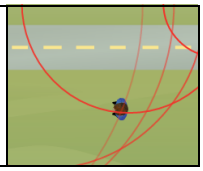
Activity B: **Faster than the speed of sound**	Get the Gizmo ready: • Click **Reset** ( ). • Set f_{source} to 300 Hz. • Check that v_{sound} is set to 340 m/s.	

Introduction: On October 14, 1947, the Air Force test pilot Chuck Yeager became the first man to officially travel faster than the speed of sound in level flight. Modern fighter jets can fly nearly three times the speed of sound.

Question: What happens when objects travel faster than the speed of sound?

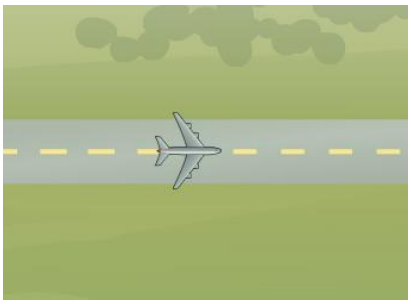
1. Observe: Some jet planes can travel faster than the speed of sound. Place the observer below the road, and set the velocity of the plane (v_{source}) to 500 m/s. Click **Play**.

   Observe for a while, and then click **Pause**. What do you notice? _____

   _____

2. Make a sketch: Click **Reset**. The red circles represent every thousandth sound wave. To see more waves, turn on **Display additional waves**. Click **Play** and observe.

   Sketch the sound waves in the diagram at right.



3. Infer: Think about what the observer would experience as the jet flew by.

   A. Describe what the observer would see and hear as the plane flew by. _____

   _____

   _____

   B. Supersonic aircraft produce a loud noise called a **sonic boom**. Look at the waves hitting the observer. Based on what you see, what causes a sonic boom?

   _____

   _____

   C. At major sporting events in America, a flight squadron such as the Blue Angels often flies over the stadium in a tight formation at supersonic speeds. Would spectators in the stands hear the jet planes first or see them first? Explain your reasoning.

   _____

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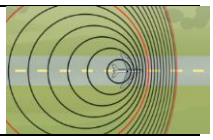
Activity C: **Measuring the frequency change**	Get the Gizmo ready: • Click **Reset**.	

Question: What factors affect the magnitude of the Doppler shift?

1. Observe: Using the Gizmo, try to determine how each factor (f_{source}, v_{source}, and v_{sound}) affects the observed Doppler shift. Based on what you have observed, how will each of these actions affect the magnitude of the Doppler shift?

   A. Increasing the frequency of the sound (f_{source}): _____

   _____

   B. Increasing the velocity of the source (v_{source}): _____

   _____

   C. Increasing the speed of sound (v_{sound}): _____

   _____

2. Measure: Set f_{source} to 500 Hz, v_{source} to 200 m/s, and v_{sound} to 340 m/s. Turn on **Observed frequency**, and drag the observer into the middle of the road.

   A. Click **Play**, and then click **Pause** just before the airplane reaches the observer. What is the frequency observed by a person in front of the airplane? _____

   B. Click **Play**, and then click **Pause** just after the airplane has passed the observer. What is the frequency observed by a person behind the airplane? _____

   C. To measure the magnitude of the Doppler shift, divide the frequency of sound waves in front of the plane by the frequency behind the plane. What do you get? _____

3. Gather data: For each combination, measure the frequencies of the sound waves in front of and behind the moving sound source. Then divide the first number by the second number to calculate the Doppler shift magnitude. In the first experiment, find the effect of frequency.

f_{source} (Hz)	v_{source} (m/s)	v_{sound} (m/s)	Frequency in front of source (Hz)	Frequency behind source (Hz)	Doppler shift magnitude
300	200	340			
1000	200	340			

(Activity C continued on next page)

Activity C (continued from previous page)

Now gather data to determine the effect of the sound source velocity.

f_{source} (Hz)	v_{source} (m/s)	v_{sound} (m/s)	Frequency in front of source (Hz)	Frequency behind source (Hz)	Doppler shift magnitude
500	100	340			
500	300	340			

Finally, gather data to see the effect of the speed of sound. (Note: The speed of sound in Earth's atmosphere ranges from about 274 m/s to 355 m/s.)

f_{source} (Hz)	v_{source} (m/s)	v_{sound} (m/s)	Frequency in front of source (Hz)	Frequency behind source (Hz)	Doppler shift
500	200	300			
500	200	500			

4. Analyze: Look carefully at the Doppler shifts for each experiment.

   A. What effect did increasing the frequency of the sound (f_{source}) have on the magnitude of the Doppler shift? _____

   B. What effect did increasing the velocity of the sound source (v_{source}) have on the magnitude of the Doppler shift? _____

   C. What effect did increasing the velocity of sound (v_{sound}) have on the magnitude of the Doppler shift? _____

5. Think and discuss: Why did the magnitude of the Doppler shift increase as the velocity of the sound source increased, but decreased as the velocity of sound increased? If possible, discuss your answers with your classmates and teacher.

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