OBJECTIVES
1. Investigate the relationship between frequency and wavelength and the Doppler effect.
2. Calculate speed and pitch using algebraic equations.

BACKGROUND INFORMATION
Most people have heard the variation in frequency of sound from an ambulance as it speeds past. As the vehicle is approaching, the frequency of the sound of the siren is higher and at the moment it passes the frequency drops. This apparent change in frequency is due to the objects motion and is known as the Doppler effect.

When a sound source approaches a listener, the waves in front of the source are crowded together so the listener receives more waves per unit time and thus detects a higher pitch than when there is no movement. When the sound source moves away from the listener, the reverse is true and the pitch is lower.

Figure (a) shows the wave pattern produced by a stationary source. The waves are equally spaced and will arrive at points A and B at regular intervals. Figure (b) demonstrates a moving sound source in relation to a stationary observer. These waves are closer together in front of the moving sound and further apart behind the moving sound.
WHAT YOU NEED

- Electronic buzzer (frequency in the range of 500 to 1500 Hz)
- 9 volt battery
- Rubber band
- Jar lid
- 3 metres of string
- Electrical tape
- Nail
- Hammer
- Stopwatch

For visual demonstration
- Laptop computer
- WASP software free download at http://www.speechandhearing.net/laboratory/tools.html
- Microphone

WHAT TO DO

1. Use the hammer and nail to make two holes in the jar lid. The holes should be opposite each other and close to the edges.
2. Tie the 3m string through the holes on the jar lid so that the string comes out through the top end of the lid.
3. Prior to plugging the battery in, attach the buzzer to the 9 volt battery using a rubber band.
4. Tape the electronic buzzer and battery to the bottom of the jar lid.
5. If using the computer set up the computer and microphone at one spot to record the frequency and amplitude of the sound.
6. Have the observer stand a safe distance in front of the person swinging the string and buzzer.
7. Connect the battery to the buzzer and carefully swing it in a circle over your head. Try to keep the velocity of your swing consistent.
8. Your partner should listen for any differences in pitch accompanying the buzzer’s orbit.

CALCULATIONS

1. Calculate the speed of the buzzer
2. The speed of the buzzer can be determined by dividing the circumference of a swing $2\pi r$ by the time required per revolution. To determine the time required for one revolution, measure the time required for 10 revolutions and divide by 10.

3. Calculate the pitch

$$f_0 = f_b \left\frac{V}{V - v_b}\right$$

Where $f_0$ is the frequency observed, $f_b =$ frequency of the buzzer, $v =$ Velocity of sound (340m/s at 20C) and $v_b$ is the velocity of the buzzer.
QUESTIONS
1. At what point in the swing was the pitch of the buzzer highest? Why? The pitch of the buzzer is highest when it is approaching the observer because the sound waves are being received at closer intervals.
2. Is the Doppler effect more noticeable at slow speeds or high speeds? Students answers will vary.
3. What is the speed of the buzzer? Answer will vary depending on the speed the buzzer is being swung at.
4. What is the pitch of the buzzer? Answer will vary depending on the frequency of the buzzer and the speed it is being swung.

REAL WORLD APPLICATIONS OF THE DOPPLER EFFECT

The Doppler Radar is used to forecast the weather. It measures the changes in the frequency of the signal it receives to determine the wind. The radar detects precipitation intensity, wind direction and speed, and provides estimates of hail size and rainfall amounts. Doppler radar gives forecasters the capability of providing early detection of severe thunderstorms and tornadoes.

Doppler-shift Burglar Alarms. By analysing the frequency of reflected ultrasound, such alarms detect motion.

Police radar uses the Doppler effect to measure the speed of cars.

CURRICULUM

Physics Senior Syllabus
-E1: Energy may take different forms originating from forces between, or relative motion of, particles or objects.
-E1.4 Colour, pitch and temperature are measurable quantities that can be used to distinguish between energy levels for observable physical phenomena.

RESOURCES