SCIENCE 1204
INTRODUCTION TO WAVES

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III. SOUND WAVES

One of the most important methods of communication is by sound. An infant quickly learns that crying evokes a response of comfort; birds use sound as signals of fear, attack, or approach; dolphins and whales have developed a rudimentary language using a combination of simple sounds: but only man developed sound into abstract meanings of much complexity But what is sound? Sound waves are pressure (longitudinal) waves in a medium such as air, water, or metal. You will be using tuning forks, speed of sound apparatus, ripple tank, and a guitar to investigate **beats, resonance,** the **Doppler effect, shock waves,** and the speed of sound.

SECTION OBJECTIVES

Read these objectives. When you have completed this section, you should be able:

8. To calculate problems involving **beats.**
9. To describe **resonance.**
10. To describe and explain the Doppler **effect.**
11. To describe and explain shock **waves.**
12. To calculate speed of sound problems.

VOCABULARY

Study these words to enhance your learning success in this section.

beats
Doppler effect
resonance
shock wave

BEATS

The interference of two sound waves of slightly different frequencies produces a series of alternating constructive and destructive interferences that yield a fluctation in sound called **beats.** The difference in frequencies is equal to the number of beats per second. Striking two tuning forks of almost the same frequency produces beats, as does striking two piano keys or plucking two guitar strings that have almost the same frequencies.

Complete these activities.

3.1 Two tuning forks, 254 H and 260 H, are struck simultaneously. How many beats will be heard?

3.2 When a 480 H tuning fork and a piano key are struck together, four beats per second are heard. When a 470 H tuning fork and the same piano key are struck, six beats per second are heard.
What is the frequency of the piano key?

RESONANCE

When a vibrating tuning fork is held near a second identical tuning fork, the second tuning fork starts vibrating. **Resonance** is the setting up of vibrations at an object's natural vibrational frequency. If the sixth string, called the E string (the one with the lowest frequency), on a correctly tuned guitar is held down at the fifth fret and plucked, the string next to it (the fifth string, or A string) will begin to vibrate, demonstrating resonance. Holding the E string down at the fifth fret makes it an A string also.

Enrico Caruso is said to have shattered crystal glass with his voice. He was able to cause the crystal to resonate by singing a note of the correct frequency.

In Ancient Rome, commanders were instructed not to march their armies across bridges; nor do modern armies march across bridges. Instead, the troops break step to avoid resonance that could destroy the bridge. In 1967 a partially-built overpass in Boston came crashing down, killing three people, because of resonance established by construction equipment. In 1940 the Tacoma Narrows Bridge in Washington state collapsed because of resonance generated by winds.

Resonance is not to be confused with forced vibrations. Heavy equipment in operation causing walls and floors to vibrate is a case of forced vibration because when the machinery is turned off the walls and floors stop vibrating. The Boston overpass continued to vibrate and finally collapsed thirty minutes after equipment was removed.

Complete this activity.

3.3 Give at least one example, other than those already mentioned, that demonstrates either resonance or forced vibrations, and state which phenomenon is being illustrated.

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DOPPLER EFFECT

If you have heard a moving fire truck with siren of constant pitch, you have observed that the pitch (frequency) of the siren drops as the truck passes. The same is true of the whistle of a passing train. This phenomenon is observed not only as the source passes you, but also when the source is stationary and you pass it. This relative motion produces a change in frequency called the **Doppler effect.**

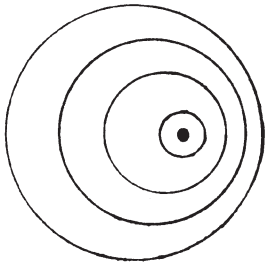
Try this investigation. In this investigation you will observe the Doppler effect with water waves.

These supplies are needed:

ripple tank	white paper
light source	wave generator

Follow these directions and answer the questions. Put a check in the box when each step is completed.

- ☐ 1. Set up the ripple tank and the generator with one bobber on it.
- ☐ 2. Generate waves at low frequency from a point near one side of the tank. Move the generator slowly toward the opposite side of the tank, but do not overshoot the lead wave.



3.4 What happens to wavelengths ahead of the generator? _____

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3.5 What happens to wavelengths behind the generator? _____

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SHOCK WAVES

When a boat races across the water, a bow wave is produced. This bow wave occurs when the boat travels faster than the speed of the water wave. When a plane travels faster than the speed of sound, it produces a bow wave also, called a **shock wave.** A shock wave is a cone-shaped wave made by an object moving faster than the speed of waves in that medium. When electrons travel faster than the speed of light in a particular medium, a beautiful deep blue light occurs, called *Cerenkov radiation.*

Try this investigation. You will produce shock waves in a ripple tank by causing the wave source to move faster than the speed of waves in water.

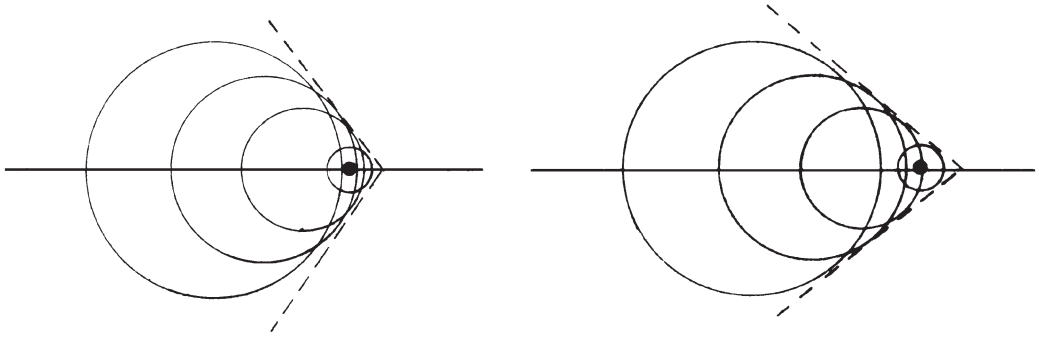
These supplies are needed:

ripple tank	white paper
light source	wave generator

Follow these directions and complete the activity. Place a check in the box when each step is completed.

- ☐ 1. Set up the ripple tank and generator as in the previous investigation.
- ☐ 2. Move the generator forward faster than the speed of the water wave and observe the bow wave, or shock wave, formed.

As the generator is moved faster, the cone-shaped shock wave becomes narrower.



The bow wave (indicated by the dashed line) is the region of reinforcement (constructive interference) where crest meets crest to produce a wave of larger amplitude. At high frequency this region appears as a smooth line.

3.6 Make a general statement concerning the angular measure of the cone-shaped shock wave and the speed of the wave source.

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THE SPEED OF SOUND

Sound travels through air at approximately 330 $\frac{\text{meters}}{\text{second}}$. To be precise, the velocity of sound in air is given by the equation

$$v = 330\ _{\text{sec.}} + \left(0.6\ \frac{m}{\text{sec.} \cdot °C}\right)(T)$$

The speed of sound depends on the temperature of air and not on the object producing the sound.

Try this investigation. In this investigation you will measure the wavelength and speed of a wave and determine that its speed is temperature-dependent and is not affected by the source producing the sound.

These supplies are needed:

speed of sound apparatus
tuning fork (400 H - 550 H)
thermometer

Follow these directions and answer the questions. Place a check in the box when each step is completed.

☐ 1. Set up the speed of sound apparatus as shown. (See the teacher's manual for alternative equipment if this apparatus is not available). The water level can be changed by raising or lowering the reservoir.