Workshop Tutorials for Introductory Physics

Solutions to WI4: **Sound**

A. Review of Basic Ideas:

Sound

Sound waves are **longitudinal** waves. They require a **medium** to propagate through, and the **velocity** at which they propagate depends on the **elastic** and inertial properties of the medium. Sound travels faster in more **rigid** mediums such as **water** and rock than it does in air.

A sound wave can be characterised by its pitch, which depends on the wave's **frequency**, and its volume, which depends on the **amplitude** of the wave.

When a guitar string is plucked or a violin string is bowed, **travelling** waves on the string reflect from the fixed ends and set up standing waves. These **vibrations** of the string cause the air to vibrate, which is transmitted to our ears as sound waves. Travelling sound waves can also produce **standing** waves in air columns, this is how woodwind instruments work.

Humans can hear frequencies in the range 20 Hz – 20 kHz, although this range usually **decreases** with age. Sound waves with frequencies above 20 kHz are called **ultrasound**, and are used for medical imaging. Many animals also hear and use ultrasound. Sound waves with frequencies below 20Hz are called **infrasound.** While we can't hear infrasound, it can cause headaches. Earthquakes produce waves of infrasound, and **elephants** use infrasound to communicate over long distances.

When a police car with its sirens blaring overtakes you on the road, you hear a range of **frequencies.** When it is coming towards you it sounds **higher** in pitch than it does after it has overtaken you. This is called the **Doppler** effect. This effect is used to measure **velocities** of moving objects, for example a police radar detector uses the Doppler effect to tell if you are speeding, and bats use it to catch insects.

Discussion Question

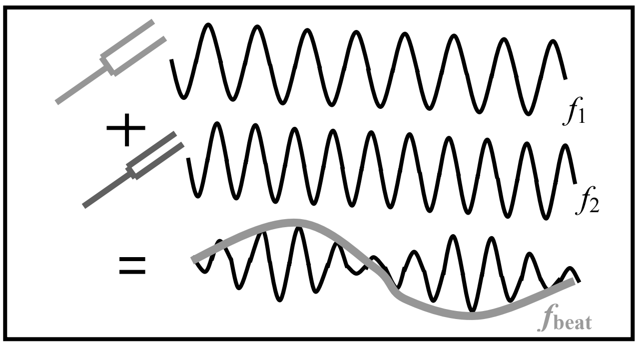
In some science fiction movies, for example the Star Wars series, the explosion of a spaceship can apparently be heard in another spaceship, while both are in the vacuum of space. This is not possible, as sound needs a medium to travel through. However you would still be able to see the explosion.

The only way the explosion could produce sound inside a second ship is if bits of the exploded ship collided with the second ship. However this rarely seems to happen in movies.

B. Activity Questions:

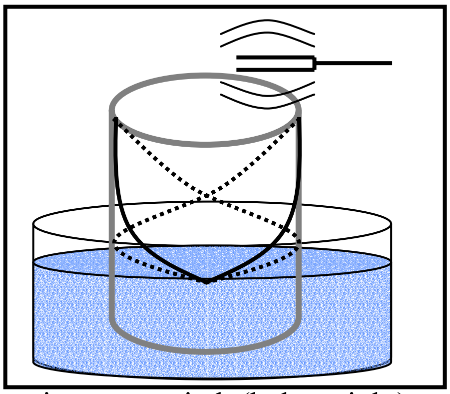
1. Tuning forks and beats.

The beat frequency you hear from two notes is the difference between the frequencies of the two notes, $f_{beat} = f_1 - f_2$. The closer the frequencies and hence the notes, the slower the beats.

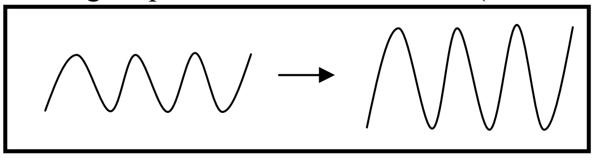


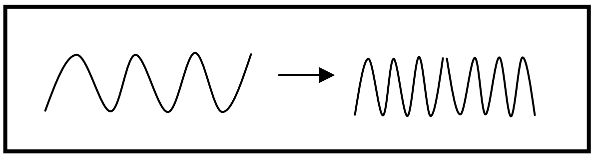
Musicians tune their instruments by sounding a known note, for example with a tuning fork, then adjusting the tuning of their instrument so the beat frequency decreases until the beats stop. When the beats stop, the note from their instrument is the same as the tuning fork.

2. Resonance in a tube.
When the tube is the right length, the air column inside it will resonate with the tuning fork, producing a louder sound. See diagram opposite. A trombone produces different notes by varying the length of the air column inside it.



3. Look and listen
Increasing amplitude increases volume (below left), increasing frequency increases pitch (below right).



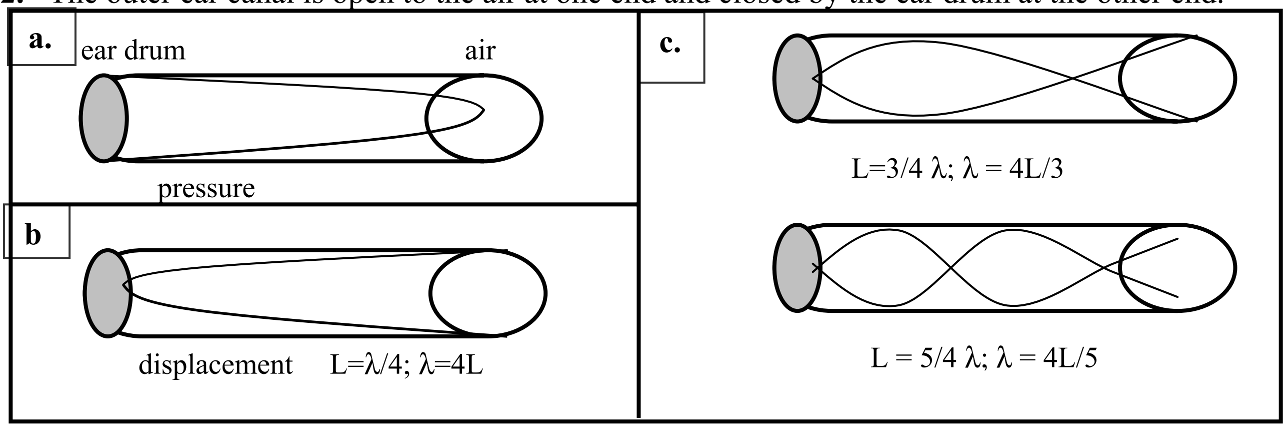


4. Visualising Speech
The microphone has a diaphragm (transducer) that converts vibrations in the air (sound) into an electrical signal. If this diaphragm is vibrated by other means it still produces an electrical signal.
You should see a complicated wave-form, because when you speak you produce many frequencies simultaneously. A whistle gives an approximately sinusoidal signal.

C. Qualitative Questions:

1. Resonance is a remarkably useful phenomenon, but can also be quite destructive.
a. A wine glass may shatter if the frequency is right because the sound waves set up standing waves in the glass at the resonant frequency, which causes it to dramatically shake apart. The frequency needs to be just right, but the intensity (volume) can be quite low.
b. When an explosion shatters a window, the window is shattered by a shock wave, which transmits a large amount of energy in a very short time. This is not due to resonance.

2. The outer ear canal is open to the air at one end and closed by the ear drum at the other end.



D. Quantitative Question:

Your local council is considering a proposal to locate a new airport near your house. A representative of the company has claimed that it will only increase ambient day time noise by 3dB, and night time noise levels by 6dB. An increase of 3 dB is equivalent to doubling the sound intensity, so it is a substantial increase. However the way we are sensitive to sound is not linear, but logarithmic, so 3 dB would generally not make much difference. An increase of 6 dB is equivalent to doubling intensity and then doubling it again, a four fold increase. Normal night time levels are around 10 dB, so this is quite a large increase, and would definitely be noticeable.