Workshop Tutorials for Introductory Physics

Solutions to WI3: **Interacting Waves**

A. Review of Basic Ideas:

Interacting Waves

Have you ever called out to someone and heard your voice come back to you? Maybe you were in the bush and there was a cliff nearby. The **sound** waves that left your mouth were reflected off the cliff and came back to you as an **echo**. In the same way, when you pluck a guitar string you start the string vibrating and waves move down the string. The waves are **reflected** from the fixed end of the string and return along the string. In both cases the incoming and reflected waves occupy the same space and we say the two waves are **superimposed** on each other.

This superposition of the waves results in interference. At any given point in space the resultant disturbance is the **sum** of the individual disturbances of the two waves in question. At some places the two disturbances will add to give zero displacement - a point of **destructive** interference. At some places the waves will add to a maximum disturbance, a point of **constructive** interference. This superposition of waves and the resulting interference occurs for any type of waves – think what happens to your car radio when you pass under a transmission line. In this case there is interference between the electromagnetic radio waves from the station and electromagnetic waves from the transmission lines. Mobile phones have to be turned off in aeroplanes so they don't interfere with navigation signals.

In some cases when waves superimpose there is a regular interference pattern set up which has points of destructive and constructive interference that are constant in time. These are called **standing** waves. Standing waves on violin strings and in the air columns of flutes and clarinets give notes of fixed frequency that are the bases of musical sounds.

Another strange property of waves, called **diffraction**, occurs when they bend around obstacles and move through narrow spaces. This diffraction is most noticeable when the obstacle or narrow space has a size of the order of the **wavelength** of the wave. Hold two fingers very close together and up to the light. The light will diffract around your fingers and interfere. Can you see some fine lines between your fingers? This is an **interference** pattern.

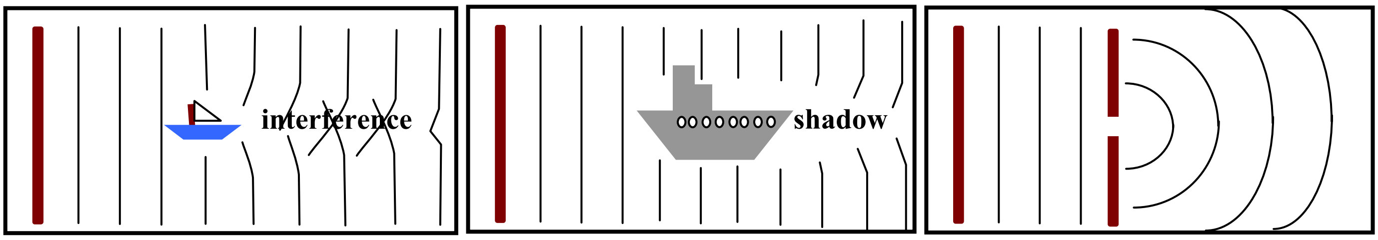
Discussion Question

You are sitting with your friends in a cafe which is very noisy. Often this is because the sounds people make are reflected off the walls and floors – particularly when the walls are hard surfaces. Rooms with tiles or floor baords are usually noisier than rooms with carpet. To make a room quiet, other than by getting everyone to stop talking, you would have sound absorbing surfaces, like carpet on the floor and walls.

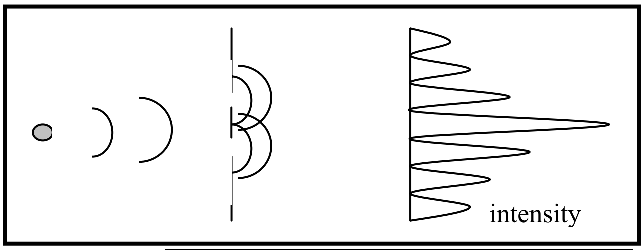
B. Activity Questions:

1. Ripple tank

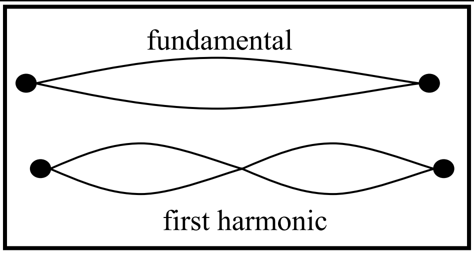
The waves will difract around a small object forming an inteference pattern where the waves from either side meet. Waves will be blocked by large objects, leaving a shadow or wake behind the object.
When plane waves pass through a narrow slit the slit acts as a point source, and semi-circular wave fronts are produced. You may also see an inteference pattern, due to diffraction effects at the edges of the slit. This is most commonly seen with light, for example try looking looking through at a light source through a pinhole in a piece of paper – you will be able to see maxima and minima.



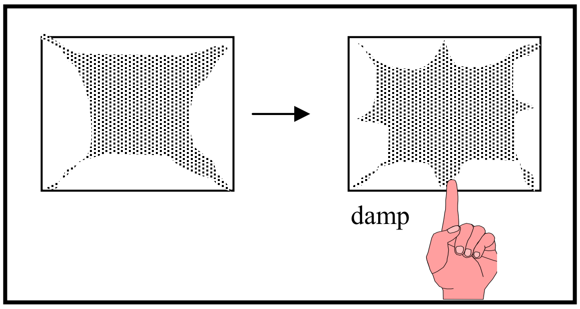
2. Interference
The waves from the two slits interfere to give light and dark fringes, as shown opposite
The greater the slit separation, the closer together the fringes are.



3. Standing waves on a string.
You should see nodes and antinodes when at the fundamental frequency, and multiples of the fundamental. Changing the tension changes the wave speed which changes the frequencies at which standing waves occur, as $v = f\lambda$, and the values of λ are fixed by the string length.



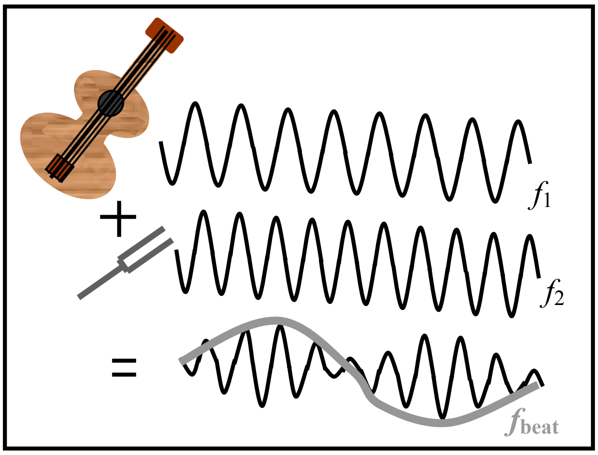
4. Chladni's plates.
When you bow on the plate it will vibrate. The sand gathers in the nodes as it is shaken from the antinodes. The pattern depends on where you bow, and on the shape and size of the plate. Damping forces a node where you put your finger and the pattern changes.



C. Qualitative Questions:

1. If you hide behind something, such as a large tree, you cannot be seen, but if you make a noise you can still be heard. This is because sound waves have wavelengths of a few centimetres to a few metres, so they diffract around objects likes trees. Visible light has a wavelength of around 500 nm, much much smaller than a tree trunk, so while the light can still diffract around the tree, it forms a shadow behind it. The light that reflects off you, that allows you to be seen by other people, cannot diffract enough to allow someone on the other side of the tree to see you. If visible light had wavelengths similar to the wavelength of sound, you wouldn't be able to hide behind trees.

2. Musicians often using tuning forks or electronic sound generators which produce a pure tone.
a. 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 further apart the notes, the slower the beats.
b. Musicians tune their instruments by sounding a known note, for example with a tuning fork, then adjusting their tuning until the frequency from their instrument is the same and no beats can be heard.



D. Quantitative Question:

In air, sound waves travel at around 340ms^{-1}. An insect is a few millimetres long or less. Estimating the insect size to be 1mm long, the wavelength needs to be this or less, so the bat needs a frequency of
$f = v/\lambda \sim 340 \text{ ms}^{-1} / 0.001\text{m} \sim 340{,}000$ Hz.
This is well beyond the frequency threshold of human hearing, which is around 20 Hz to 20 kHz .