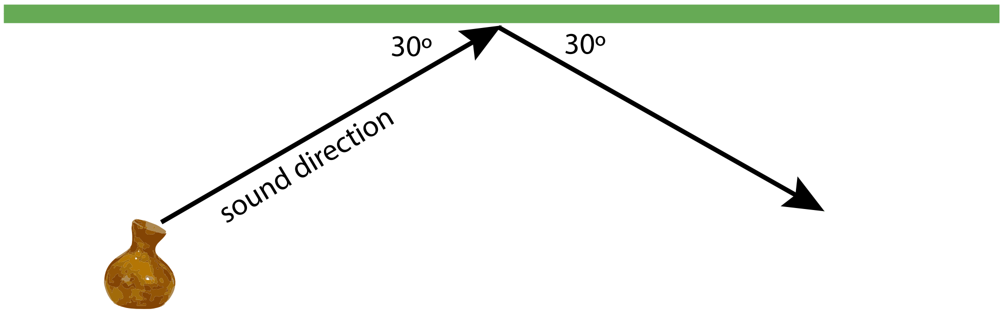
Unit 5: Measurement Geometry

Activity 5.1 - Sound reflections I

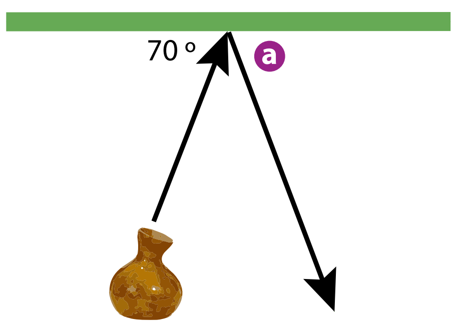
Sound reflects off of hard surfaces. The angle that sound approaches a surface is the same as the angle that it leaves the surface when it is reflected. For example, if you play a ipu and the sound wave hits a wall at 30°, then it will reflect away at a 30° angle and continue on its way. This is called the Law of Reflection.



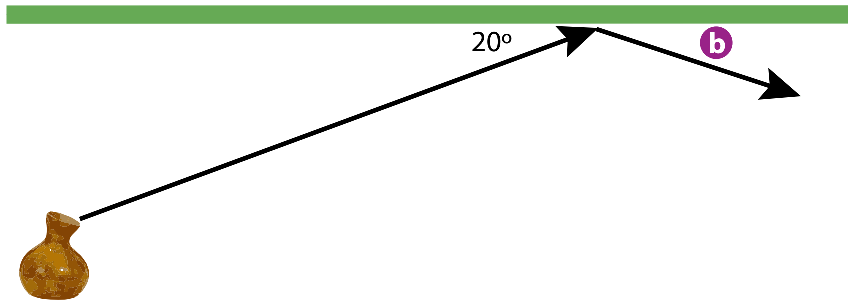
Side note: This is a simplification of how waves move. Remember that waves actually spread out in many directions instead of staying together and moving in one line. Let's just keep it simple for now. Later, we'll look at sound waves moving in different directions.

1. What are the measures of the following angles?

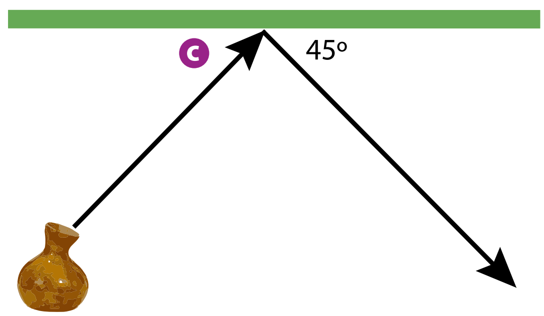
a. Angle a.



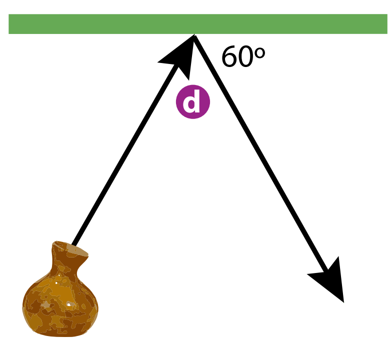
b. Angle b.



c. Angle c.



d. Angle d.



2. This is related to another law called Snell’s Law. Look on the internet to see what Snell’s Law is about.

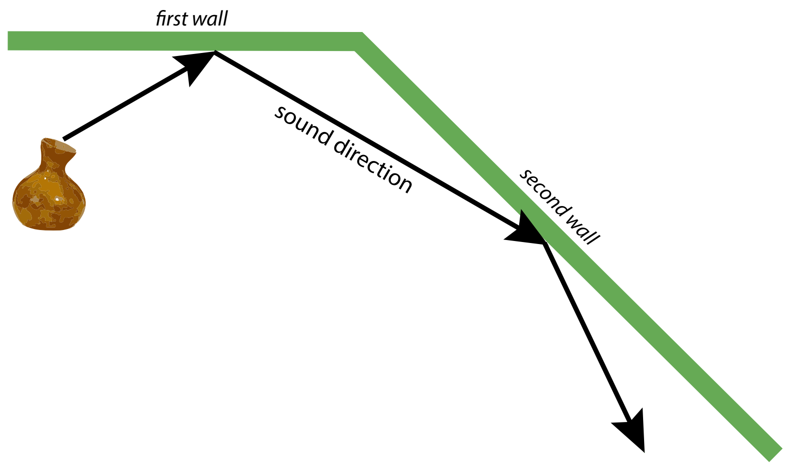
a. What are some of the many things that Snell’s Law talks about? It can get complicated so be sure to work together and share your ideas with your classmates.

b. Where do you see Snell’s Law in real life? Share your ideas in your classroom or on the online comment section .

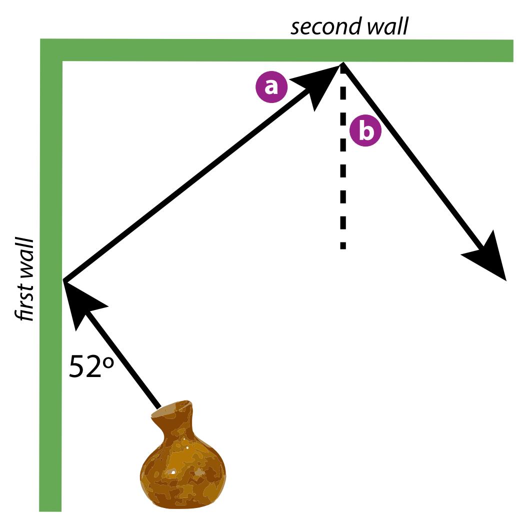
Activity 5.2 - Sound reflections II

Recall that the Law of Reflection says that when sound approaches a hard surface and is reflected away, the angle that it approaches the surface is equal to the angle that it leaves.

1. When sound wave moves toward a corner with two walls, the sound usually reflects off of both walls before going off in some direction in the room.



Let's take a look at what happens when the two walls are perpendicular to each other.



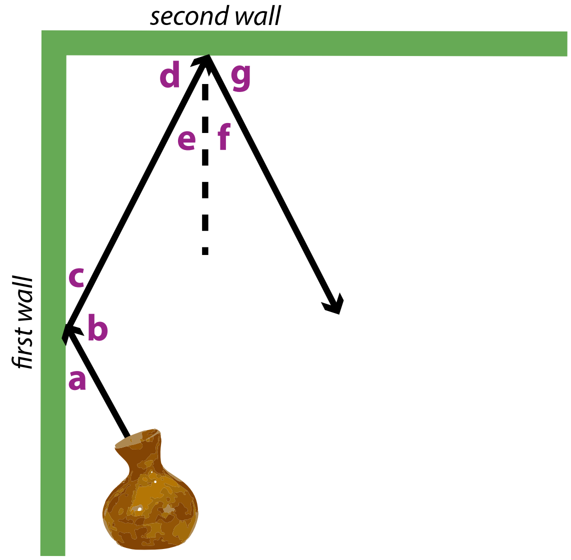
a. Find the measure of angle a. Explain your work, including when you needed to use the Law of Reflection or a math theorem.

b. The dashed line is parallel to first wall. Find the measure of angle b. Explain your work.

c. What can you say about the *direction of the sound wave approaching the first wall* compared to the *direction of the sound wave leaving the second wall*?

d. When designing a *hale* (house or building) for listening to music, architects usually avoid having perpendicular walls in their designs. Why do you think that is?

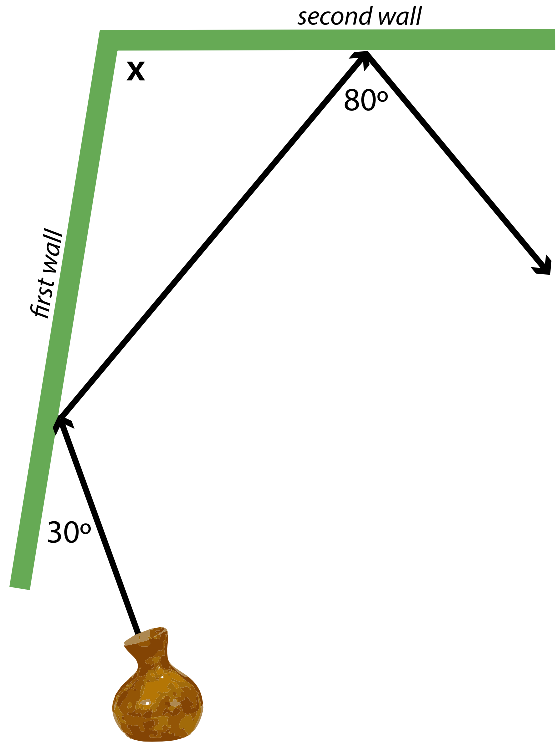
2. Here's another 90° corner. The dashed line is parallel to the first wall. Angles a and c are congruent. Angles d and e are complementary.



a. What are four other pairs of congruent angles? Write as pairs, for example a & c.

b. What are four other pairs of complementary angles? Write as pairs, for example d & e.

3. Here's a corner that is *not* at a right angle.



a. What is the measure of the angle of the corner, x?

b. Think about the *direction of the sound wave approaching the first wall* compared to the *direction of the sound wave leaving the second wall*. How does this compare to the perpendicular walls in parts 1 and 2?

Activity 5.3 - Reverberations

For this activity, use 340 m/s for the speed of sound. You may also need to use the Law of Reflection at some point.

Sound waves spread out in many directions. Sometimes we need to understand the distances of things around us and how that distance affects sound.

Imagine that your hula class takes place in a valley. When kumu plays an ipu, some of the sound will go straight to you so you hear it right away. Some of the sound will actually go away from you toward mauka (the mountains). Then the sound waves will reflect off the mountains and come back to you. You might hear the reflected sound right away if the mountains are close or you might hear the sound a couple of seconds later in an echo if the mountains are far away.

1. Suppose that you're at the coordinates (0 m, 0 m), your kumu is at (40.8 m, 54.4 m), and a mountain is at (224.4 m, 299.2 m). You may use a calculator for parts a-g.

a. How far away is your kumu from you?

b. If kumu plays the *pū* (conch shell), how many seconds later will you first hear the sound of the pū? Round to three decimal places if needed.

c. How far away are the mountains from the kumu?

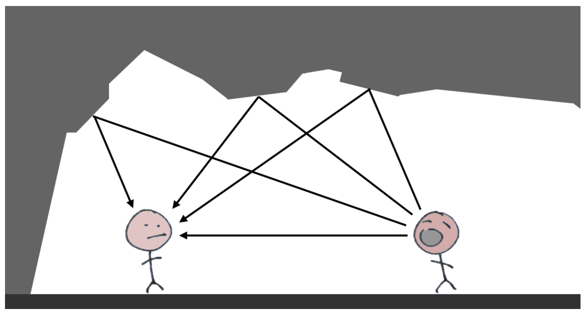
d. How far away are the mountains from you?

e. How far must the sound of the pū travel from the kumu to the mountains and then to you?

f. How how many seconds after the kumu plays the pū, will you hear its sound after it reflects off of the mountains? Round to three decimal places if needed.

g. How much time passes between when you first hear the sound and when you hear its echo from the mountains?

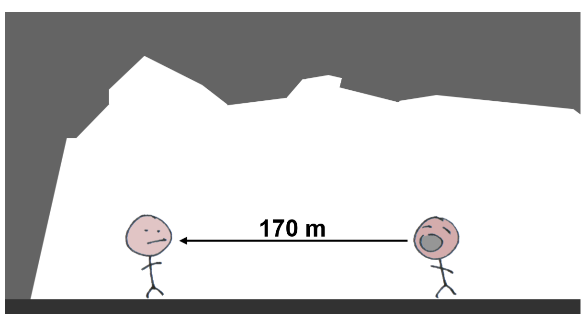
2. If you hear a sound once, then it travels far away, reflects, and you hear it a second time, this is called an *echo*. Since sound spreads in many directions, it is more common to have sounds bouncing all over the place before reaching your ears. So we don't just hear a clear sound twice. Instead we hear a sound many times stretched out over a short duration. This is called *reverberation*. Here's a picture of sound bouncing all over the *ana* (cave) before reaching the listener.



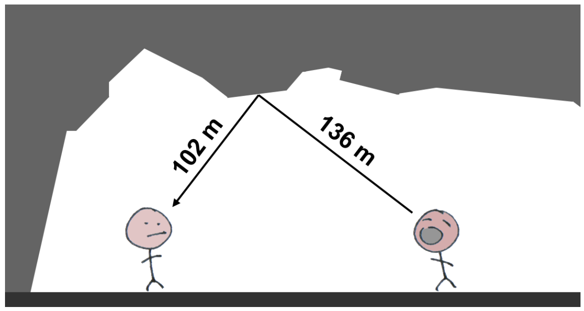
The first sound this listener hears is the sound that went straight to him/her. The last sound is the sound that bounced around the *ana* the furthest before reaching the listener. Roughly speaking, *reverberation time* is the time between when you hear the first sound and when most of the sound goes away.

Suppose that someone is singing 170 m away.

a. How long after the singer sings, does it take for the sound to first reach you? Round to three decimal places.

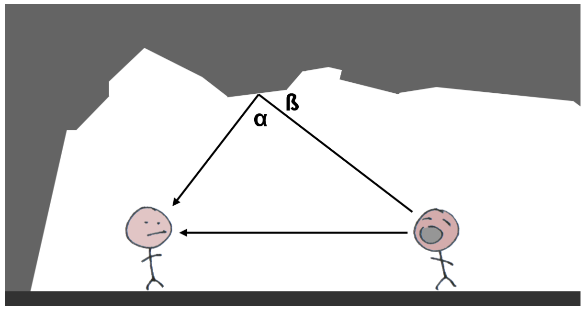


b. Some of the sound does not go straight towards you, but instead bounces around first. If the slowest and last sound traveled 136 m to the ceiling before reflecting another 102 m to you, how long did it take for this sound to reach you? Round to three decimal places.



c. Suppose that it's silent after the last sound wave in Part 2b reaches you. What is the reverberation time?

d. To control reverberation, we have to carefully design the angles and shape of the *ana* or where ever you like to listen to music. What is the measure of angle α? Hint: look at how the lines form a triangle. On each side of the triangle, write down how long it took sound to travel that distance.



e. Use your answer to Part d and the Law of Reflection to figure out the measure of angle β.

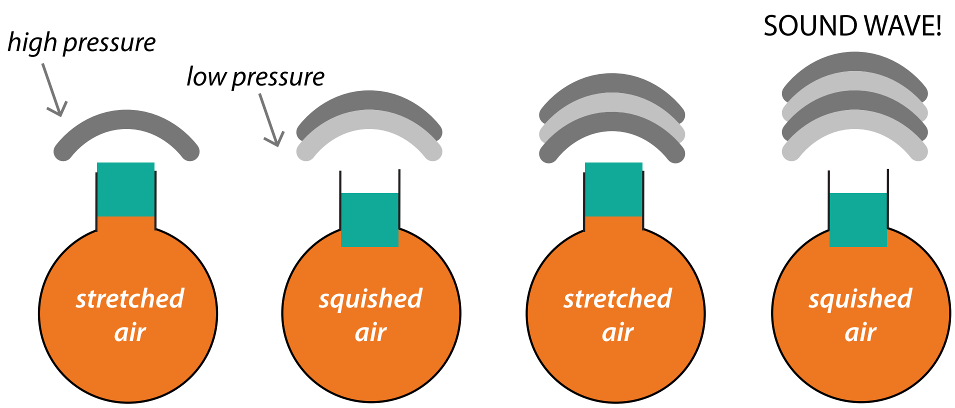
3. Think about times where you've been in a place with a lot or very little reverberation or echo. Describe the environment. What do you think it is about those environments that give it a lot or little reverberation and echo? Share your ideas in your classroom on the online comment section.

Activity 5.4 - Helmholtz Resonator

We know how the strings of a 'ukulele make sound waves. What about an ipu? A ipu works like a Helmholtz resonator, which is any instrument that is made up of a narrow tube connected to a larger hollow body. For example, a milk jug would make a great Helmholtz resonator.

ipu **Helmholtz resonator**

When you hit or blow across a Helmholtz resonator, the air in the neck lightly bounces in and out of the instrument. The air in the neck bounces because the air in the body can be squished and stretched. As the air in the neck bounces, it creates sound waves outside of the instrument.



**The air in the NECK moves up and down,
while air in the BODY stretches and squishes.
The moving air in the NECK makes a sound wave outside!**

1. Suppose that you're playing several ipu in a room. They all have the same neck, but the volume of their body is V. Then the frequency that the ipu make is $f = k\sqrt{1/V}$, where k is a constant positive number.

a. If you increase the volume of the ipu body, will you get a higher or lower sound? How can you tell by looking at the formula for frequency?

b. Rank the following ipu from *lowest* sound to *highest*. Everything expect the volumes of their bodies are the same. Assume that the body is a perfect sphere.
Ipu 1 has body radius 5 in.
Ipu 2 has body volume 900 in^3.
Ipu 3 has body diameter 13 in.
Ipu 4 has circumference of 8π inches at the widest part of the body.

c. What other objects (musical instruments or not), can be a Helmholtz resonator? Explain why and share your ideas with your classmates or on the online comment section.