Drexel-SDP GK-12 ACTIVITY

Activity Template

Subject Area(s): Sound

Associated Unit: None

Associated Lesson: None

Activity Title: Sound Wave Reflections in a Room

Grade Level: 8 (7-9)

Activity Dependency: None

Time Required: 90 minutes

Group Size: 3-4 students

Expendable Cost per Group: US $0.00

Summary:
In this activity, students will determine the path traveled by sound waves in an acoustic room environment as the waves reflect from room surfaces and calculate the time taken for the sound to travel each path. As a result, students will learn about how sound travels through air, reflects from surfaces, and travels at a known speed. This experiment will give students an overview of sound that involves rate calculations, working with number systems, and a bit of geometry.

Engineering Connection:
Engineers concerned with the acoustics of rooms focus on the paths traveled by sound waves, such as the direct path and the paths of the reflections of sound waves. Room acoustics are important for various applications that include the development of audio equipment, acoustic simulators, and determining where a sound originates. Students most likely experience acoustic simulators on a daily basis as they are a large component of making video games realistic. Audio engineers for video games attempt to create a simulated listening experience that is very similar

to the real world. To do so, the engineer must be able to model sound waves as they travel throughout the game environment, reflect from surfaces, and combine to form the sound received by the ears of the player in the game. Modeling a sound is based on an understanding of the paths traveled by each sound wave as it propagates throughout the room, reflecting from surfaces until it reaches the position where the player is located in the game. Therefore, a general knowledge of geometry and the physics of the sound waves is required.

Keywords: sound, acoustics, sound reflection, angles, geometry, rate

Educational Standards

Science: 3.4 – Physical Science, Chemistry and Physics
Math: 2.9 – Geometry
2.3 – Measurement and Estimation

Learning Objectives

After this lesson, students should be able to:

- Explain what sound is and how it travels
- Explain how sound reflects off of a flat surface
- Trace the direct path of a sound wave
- Calculate the time taken for a sound wave to travel to a location

Materials List

Each group needs:

- ruler
- protractor
- pencil
- calculator
- copy of the lab worksheet

Introduction / Motivation

Many components in this activity are directly related to practical applications used by engineers when dealing with acoustics and audio. For example, when an engineer is attempting to determine where a sound originates, the arrival times of the direct path to each ear play an important role in the localization process. As an example, when sound arrives at the left ear before the right ear then the sound most likely originated to the left of the listener. Therefore, identifying the direct path and calculating the time it takes for the sound to reach the listener is crucial in localizing the sound source. Similarly, in and acoustic environment simulation, a similar physical model has to be developed to create a realistic listening experience. This activity presents the basics of sound reflection and the physics of sound in order to create a direct connection to the sound environments students experience on a daily basis.

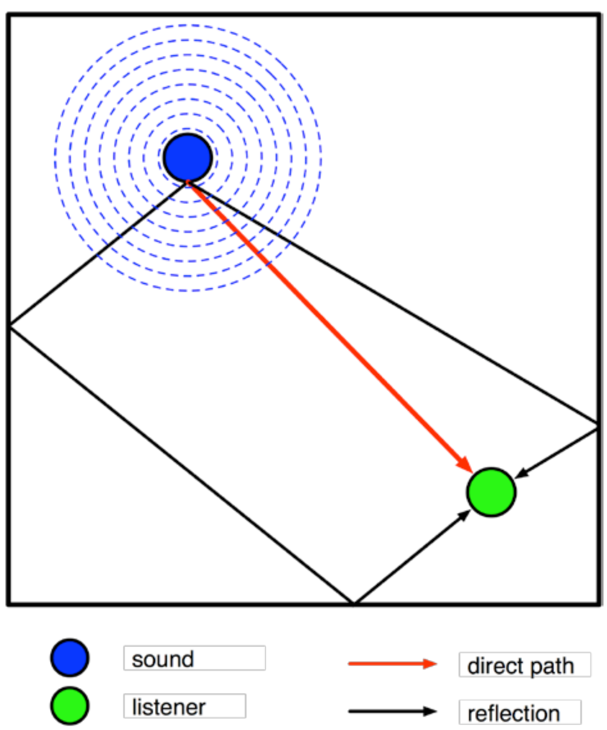
Vocabulary / Definitions

Word	Definition
direct path	the sound from the source that reaches the ears without reflection
reverberation	the reflection or bouncing a sound off of a surface (wall) that reaches the ears after the direct path
angle of incidence	the angle formed by the sound path approaching the surface and a line perpendicular to the surface
angle of reflection	the angle formed by the sound path leaving the surface and a line perpendicular to the surface

Procedure

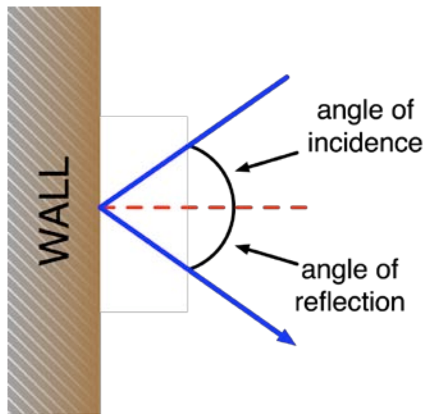
Background

When a sound is generated, sound waves propagate from the source in a spherical manner, which is characteristic of a point source. This is a general assumption that is made when modeling an acoustic environment, and it does not apply completely in cases where the sound is directional. An example of a directional sound would be someone speaking through a large cone, which contains most of the energy pointed in the direction of the cone. In either case the sound generated propagates through the room and is often received by an observer. The shortest, unobstructed path from the sound source to the listener is defined as the direct path. The other sound waves that reflect from surfaces in the room before reaching the ears are considered reverberation, or more simply, echo. The reflected waves are copies of the original sound (in the direct path) that that are modified in some manner. The modification may just be that the sound wave reaches the ear slightly after the sound wave in the direct path or that the sound wave has lost some of its energy as it bounced off a surface in the room. An example of these terms can be seen in the diagram below.



Notice in the diagram above that as the sound waves propagate from the sound source, some of the sound waves bounce off of the walls (NOTE: Only two paths are shown for the reflection waves, but many more exist as the wave propagates in all directions from the sound source as is seen by the blue dashed lines).

The angle at which the sound wave approaches the wall is considered the angle of incidence, which is defined as the angle created by the approaching path and a line perpendicular to the wall. As the wave bounces off of the wall, the exiting path and a line perpendicular to the wall create the angle of reflection. These angles should be exactly the same as long as the surface is flat. The terms are shown in the diagram below.



Before the Activity

- Print out a copy of the lab worksheet for each group
- Prepare a set of supplies for each group in the class (ruler, protractor and calculator)

With the Students

1. Ask the students what they think sound is and how it travels
2. Discuss how sound bounces off surfaces as is described in the background section
3. Explain to the students that their job is to determine the path taken by different types of sound waves propagating from a sound source
4. Come up with your own example and demonstrate what must be done to find the direct path and reflection paths
5. Calculate the distance traveled by each path and calculate the amount of time taken for each sound wave to reach the listener
6. Discuss the effect reflected waves create and relate that to why we hear echoes (Are echoes always present?)
7. Distribute the prepared supplies (ruler, protractor, calculator and lab worksheet without the challenge problem attached) to each group
8. Have the students attempt to complete the worksheet as a group and offer to check answers for each problem to make sure the students are comprehending
9. After the students have completed the worksheet as a group, have the students turn in the worksheet
10. Then have the students work individually on the Challenge Problem to determine if all members of the group understand the concepts
11. Have the students then turn in the Challenge Problem

12. Hand the group worksheets back to the students and discuss the answers to clear up any misunderstandings

Attachments

- Sound Wave Reflection in a Room Worksheet
- Challenge Problem Worksheet
- Sound Wave Reflection Worksheet Answers

Safety Issues

- None

Troubleshooting Tips

None

Investigating Questions

- In what types of rooms do you hear echoes when you speak (i.e., large, small, church, classroom)?
- What rooms in your house do you tend to hear echoes best?
- Why does the sound not continue to reflect off surfaces in a room?

Assessment

Pre-Activity Assessment

Class Discussion:

- Talk with the students about how sound travels and mention that it needs a medium in which to travel, such as air (Can you hear sound waves in space?)
- Explain how sound waves decay as they bounce off surfaces

Activity Embedded Assessment

Lab handout/worksheet: Have the students fill out the lab worksheet and review their answers as a measure of comprehension

Post-Activity Assessment

Challenge Problem: As a final assessment, give the students the Challenge Problem, which is the last page of the worksheet. This problem ties in all components of the activity to determine if they truly understand the concepts.

Activity Extensions

- The students could experiment with non-traditionally shaped rooms, such as a triangular or pentagonal shaped room
- Have students explore how sound amplitude decays as it reflects from different surfaces, such as carpet, wood, and tile

Activity Scaling

- For lower grades, the angle of reflection can be presented by just folding the piece of paper perpendicular to the reflection surface and tracing the line
- For upper grades, the complexity of calculations should include oddly shaped rooms with more precise calculations necessary to obtain correct results

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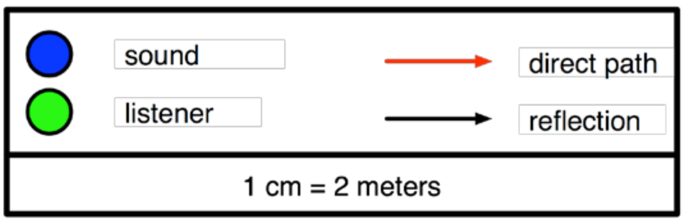
Sound Wave Reflection in a Room Worksheet

Names: ____

Materials

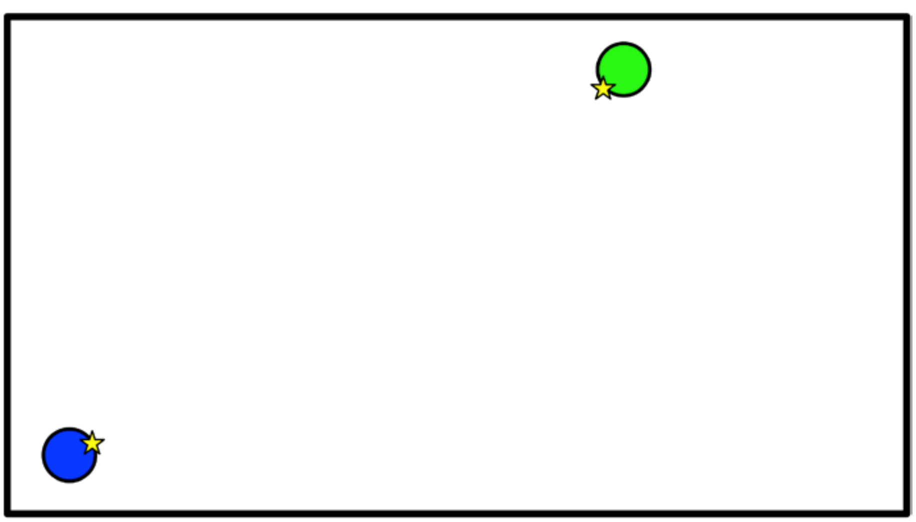
- ruler
- protractor
- pencil
- calculator

Legend



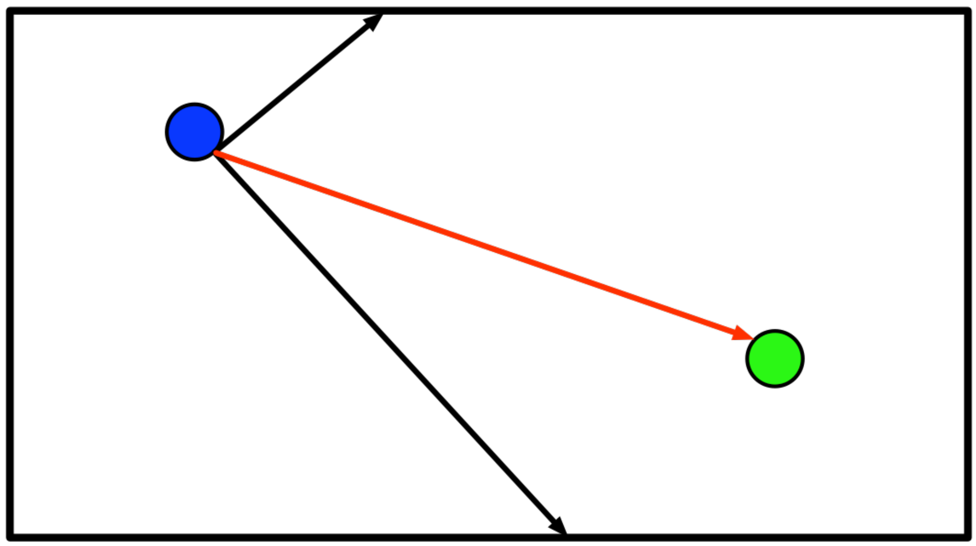
Problems

Problem 1: Draw the direct path between the sound source and the listener, which connects the stars on each circle. In this type of room there are no reflecting sound waves because the walls absorb all of the sound energy during reflections.



Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener (speed of sound = 343 m/s).

Problem 2: Draw the paths of the reflection waves until they reach the listener. All the waves should intersect at the same point on the listener. Remember that the angle of incidence and reflection are equal.

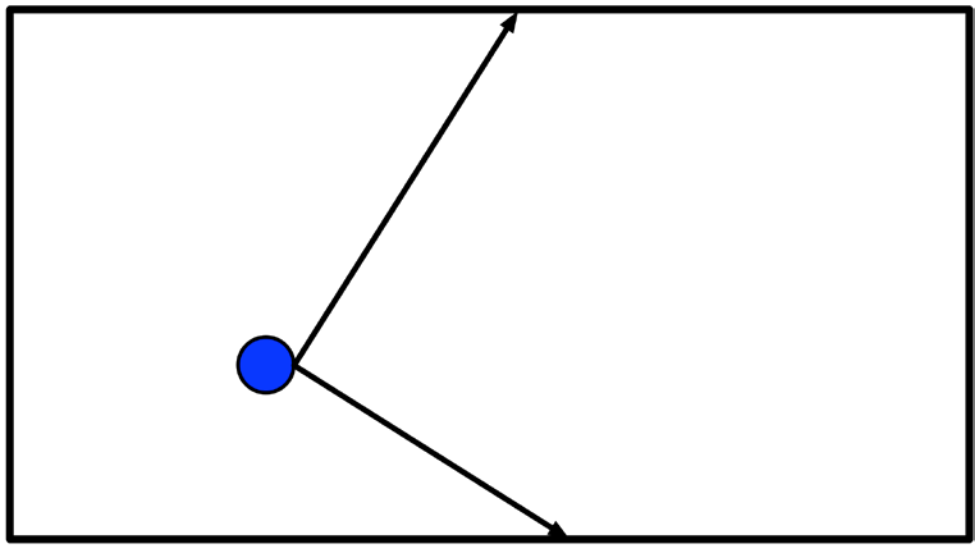


Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener for the direct path.

Calculate the total distance the top reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Calculate the total distance the bottom reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Problem 3: First draw the path of the top reflected sound wave until it reaches the next wall. Next draw the bottom reflected sound wave until it reaches the next wall. The point where the lines cross is the front edge of the listener circle, as was the case in the previous problems. Once you have the listener drawn, draw the direct path from the sound source to the listener. Remember that the lines should all intersect at the same point!



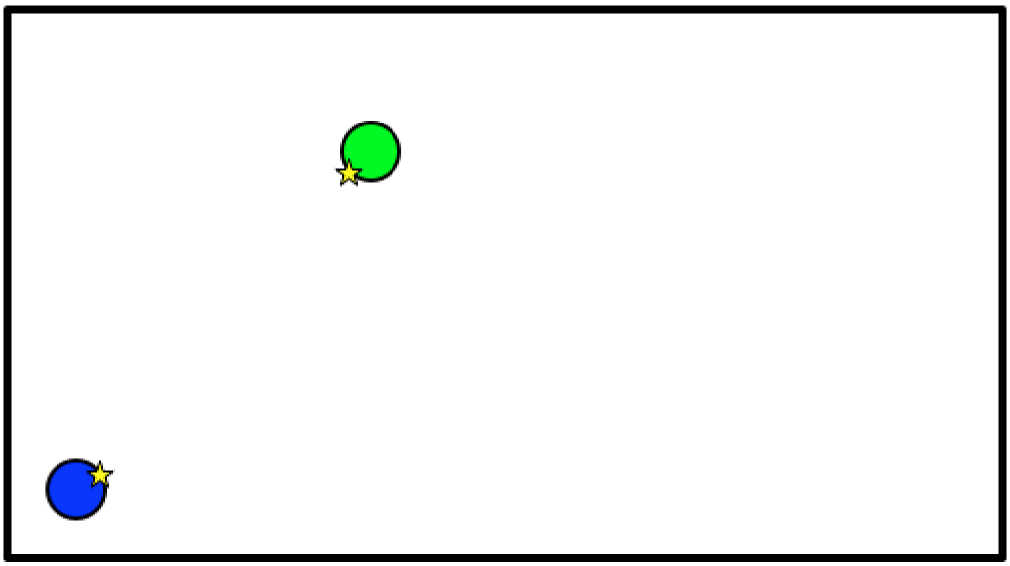
Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener for the direct path.

Calculate the total distance the top reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Calculate the total distance the bottom reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Challenge Problem

This problem tests your comprehension of the topics from the previous problems. In this problem you are to draw the direct path connecting the stars on the sound source and the listener and draw two reflection paths that bounce off at least one wall. This problem is very similar to the previous problems requiring the same type of logic. Good luck!



Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener for the direct path.

Calculate the total distance the top reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Calculate the total distance the bottom reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

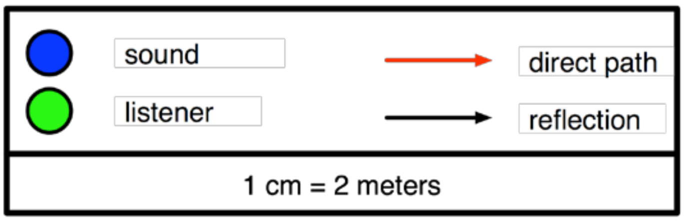
Sound Wave Reflection in a Room Worksheet Answers

NOTE: ALL ANSWERS ARE APPROXIMATES.
STUDENT ANSWERS SHOULD BE SIMILAR, BUT NOT EXACT

Formulas for time calculations

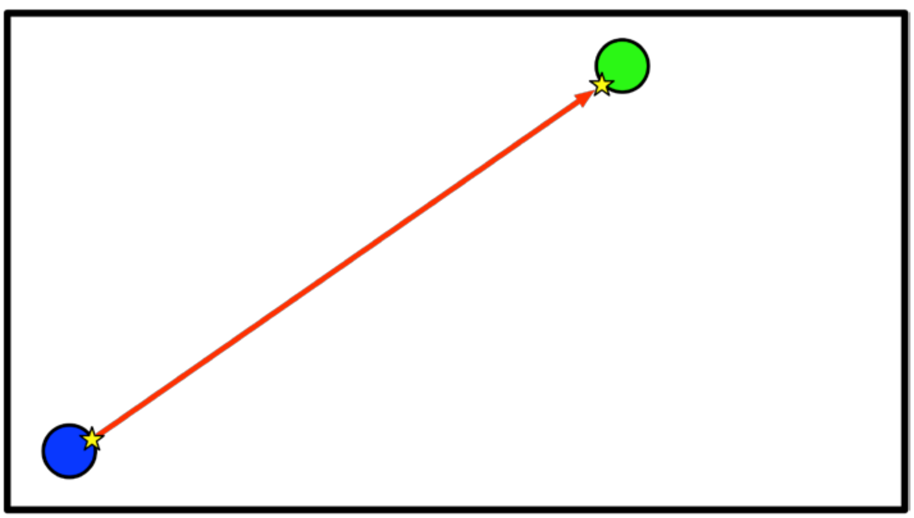
rate = distance / time
OR
time = distance / rate

Legend



Problems

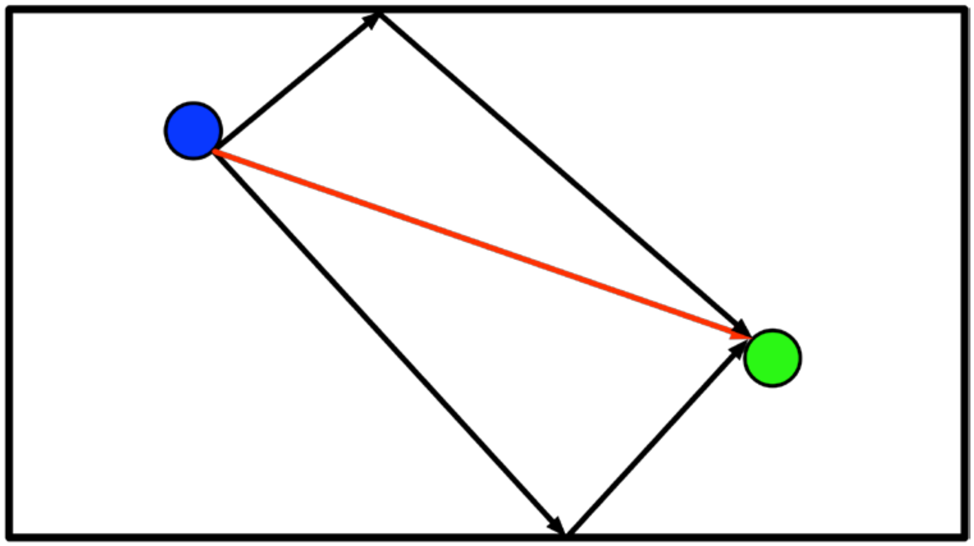
Problem 1: Draw the direct path between the sound source and the listener, which just connects the stars on each circle. In this type of room there are no reflecting sound waves because the walls absorb all of the sound energy during reflections.



Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener (speed of sound = 343 m/s).

Red line: 8 cm = 16 m
Time: 0.0466472303 s

Problem 2: Draw the paths of the reflection waves until they reach the listener. All the waves should intersect at the same point on the listener. Remember that the angle of incidence and reflection are equal.



Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener for the direct path.

Red line: 7.5 cm = 15 m

Time: 0.0437317784 s

Calculate the total distance the top reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Top black line: 2.75 cm + 6.5 cm = 5.5 m + 13 m = 18.5 m (9.25 cm)

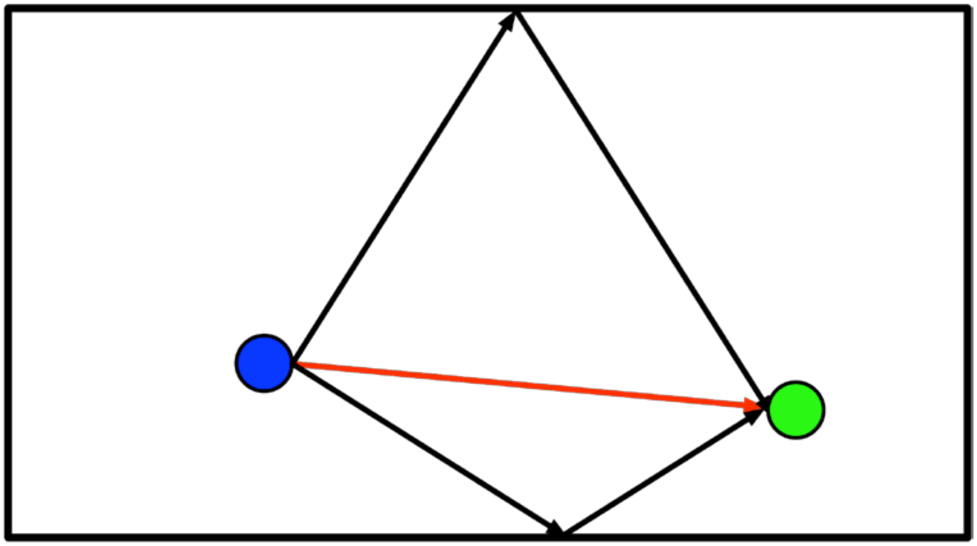
Time: 0.0539358601 s

Calculate the total distance the bottom reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Top black line: 6.75 cm + 3.5 cm = 13.5 m + 7 m = 20.5 m (10.25 cm)

Time: 0.0597667638 s

Problem 3: First draw the path of the top reflected sound wave until it reaches the next wall. Next draw the bottom reflected sound wave until it reaches the next wall. The point where the lines cross is the front edge of the listener circle, as was the case in the previous problems. Once you have the listener drawn, draw the direct path from the sound source to the listener. Remember that the lines should all intersect at the same point!



Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener for the direct path.

Red line: 6 cm = 12 m

Time: 0.0349854227 s

Calculate the total distance the top reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Top black line: 5.5 cm + 6 cm = 11 m + 12 m = 23 m (11.5 cm)

Time: 0.0670553936 s

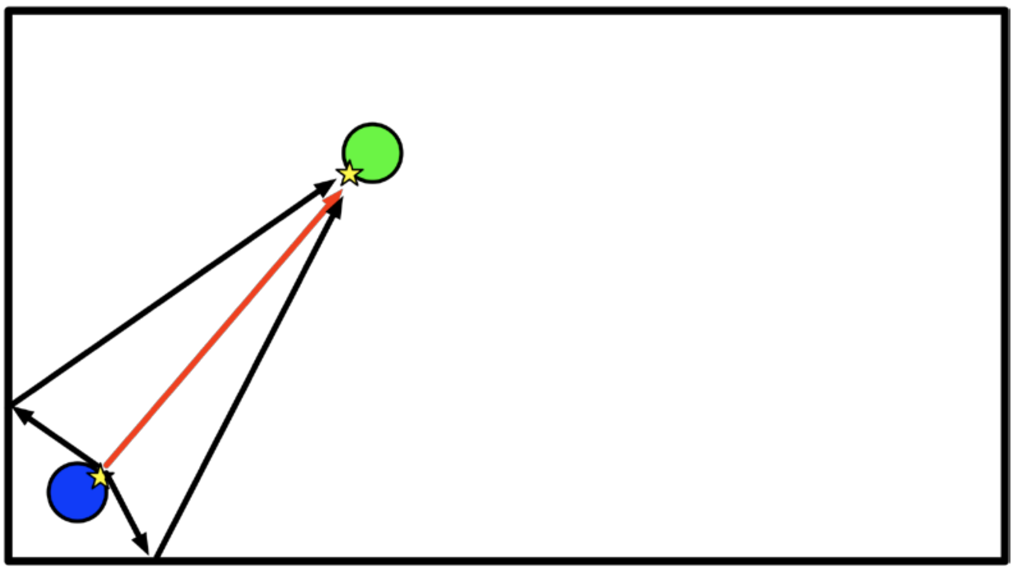
Calculate the total distance the bottom reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Top black line: 4.25 cm + 3 cm = 8.5 m + 6 m = 14.5 m (7.25 cm)

Time: 0.0422740525 s

Challenge Problem

This problem tests your comprehension of the topics from the previous problems. In this problem you are to draw the direct path connecting the stars on the sound source and the listener and draw two reflection paths that bounce off at least one wall. This problem is very similar to the previous problems requiring the same type of logic. Good luck!



Calculate the distance the sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener for the direct path.

Red line: 5 cm = 10 m

Time: 0.029154519 s

Calculate the total distance the top reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Top black line: 1.5 cm + 5.5 cm = 3 m + 11 m = 14 m (7 cm)

Time: 0.0408163265 s

Calculate the total distance the bottom reflected sound wave travels from the sound source to the listener in meters and determine how long it will take the sound to reach the listener. Make sure to include the full path the sound wave travels!

Top black line: 1.25 cm + 5.75 cm = 2.5 m + 11.5 m = 14 m (7 cm)

Time: 0.0408163265 s